MONTANA WEIGH-IN-MOTION AND AUTOMATIC TRAFFIC RECORDER STRATEGY

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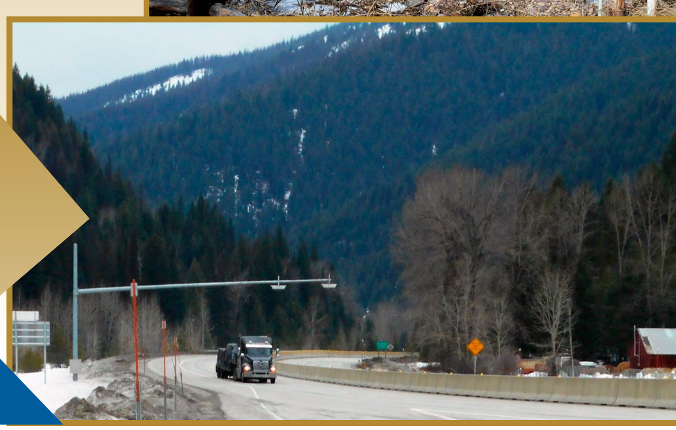

RESEARCH PROGRAMS

MDT

Montana Weigh-in-Motion (WIM) and Automatic Traffic Recorder (ATR) Strategy

Final Report

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16. Abstract **The objective of this project was to review the Montana Department of Transportation's (MDT's) permanent Weigh-in-Motion (WIM) and Automated Traffic Recorder (ATR) data collection programs to ensure they are efficiently providing the best possible traffic information to meet data user needs. Primary project tasks included a) review of the state-of-the-practice, from the hardware being used to the operating procedures being employed, b) compilation of a comprehensive description of MDT's current traffic data collection program with a focus on WIM/ATR data, from field data collection to data dissemination, c) survey of traffic data users to determine if their needs are being met, d) review of current traffic factor groups, including alternatives to these groups, and e) development of a methodology to prioritize new WIM/ATR deployments. MDT currently has 106 permanent count sites statewide (42 WIM and 64 ATR sites), and 5,800 short-term count locations. The data collected are processed to generate multiple reports and maps that are available on the internet. Overall, MDT's WIM/ATR program was determined to be efficiently and effectively meeting traffic data needs. MDT's traffic data collection and analysis effort was found to be consistent in size/extent with that of similar states, and traffic data users were found to be very satisfied with the data being provided. As MDT's data collection efforts continue to move forward, recommendations were made to further increase their efficacy.**		
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Executive Summary

A critical element in achieving the Montana Department of Transportation's (MDT) fundamental goal of providing safe, efficient and sustainable transportation services is the collection of accurate data on how the state's highways are being used. Such data are necessary to support numerous agency activities including pavement design, infrastructure planning, weight enforcement, and traffic monitoring. Due to limited resources, it is essential that such data are efficiently collected and then put to the best possible uses. The Traffic Data Collection and Analysis Section (TDCA) of MDT initiated this project through the Western Transportation Institute (WTI) at Montana State University (MSU) to review their Automatic Traffic Recorder (ATR) and Weigh-in-Motion (WIM) data collection programs to ensure they are providing the best possible traffic information in the most cost effective manner to meet current and future data user needs.

Multiple tasks were completed to achieve the project's goals, including a review of the state-of-the-practice; preparation of a detailed description of current equipment, facilities, and practices; examination of current data collection, analysis, and dissemination practices, with preliminary work on identifying areal/seasonal traffic patterns and the associated economic activities that drive them; a survey of traffic data users and their needs; a review of current traffic factor groupings and development of potential alternative grouping; and the development of a methodology for the prioritization and planning of new permanent count sites. This work concluded with an overall assessment of the adequacy of MDT's data collection effort, and recommendations for areas/activities of possible improvement.

The state-of-the-practice review included a comprehensive examination of the literature related to traffic data collection technologies, data transmission and processing methodologies, data users and uses, and data collection site selection and prioritization processes. The review also included a survey of practice for peer states. The review found that many technologies are available to collect traffic data, with typically more-established technologies consisting of pneumatic tubes used for short-term traffic counts; inductance loops for ATRs; and piezoelectric sensors, bending plates, and single load cells for WIMs. Many communication technologies are used to transmit traffic data including landline, cellular, and high-speed wireless and network systems. Many software packages exist for processing data and performing checks on its quality. Some states are using WIMs in Virtual Weigh Stations and real time weight enforcement. Montana has a similar number of ATR sites and conducts a similar number of short-term counts annually as many states, but Montana has considerably more WIM sites than peer states.

A description of MDT's current traffic data collection program was generated detailing the data collection equipment used and its deployment, and the operations and management of the department's data collection, processing and dissemination efforts. There are currently 106 permanent count sites (64 ATR and 42 WIM sites) spread across the state with an additional 5,800 short-term count locations, with approximately 3,000 of these counts performed annually. Overall the TDCA Section consists of fourteen permanent employees, a supervisor, a unit supervisor, and three seasonal staff positions. The TDCA Section is responsible for short-term and permanent traffic data collection, traffic data processing, and data QA/QC and analysis, as well as data presentation/display. Total annual program cost (labor, equipment, supplies, travel, contracted services, personnel training, etc.) is approximately 1.9 million dollars.

The state's ATR and WIM systems collect volume, classification, weight, and other raw traffic data. These data support various and diverse Department activities. Quality control checks of "reasonableness" are done based on physical limits and historic values of the parameters being measured, as tested both automatically and by experienced TDCA Section personnel. The screened data are used to determine various characteristics of the traffic operating on the state's highways, such as average annual daily traffic (AADT), vehicle miles of travel (VMT), equivalent single axle loads (ESALs), etc. These data ultimately determine traffic factors that are used to expand the results of short term traffic counts to AADTs. Traffic data dissemination is realized through a variety of publications, interactive maps and software applications, all available on the internet. Notably, MDT is ahead of peer agencies in providing valuable information via interactive geographic information systems (GIS) maps.

In Montana, large local/regional fluctuations in traffic volumes and in the composition of the traffic stream may be encountered both temporally and spatially, as the state's economy is agriculture, natural resource extraction and tourism intensive. Efforts were made to begin documenting various temporal and areal traffic flows related to these activities. Specifically, seasonal/regional commodity flows for wheat, barley, sugar beets, beef cattle, talc, and timber were characterized at the network level in terms of the annual trips they generate on the highway system. Of these commodities, wheat generates significantly more trips than other commodities considered (234,000 trips per year), although the list of commodities considered was not exhaustive. An innovative technique to further estimate traffic impacts of such commodity flows at the route level using GIS databases and analysis methodologies was investigated, with a trial application to wheat and barley movements. This analysis methodology appears promising, and may benefit from further modification/refinement in the future. This methodology could, among other things, help identify potential locations with significant traffic flows that merit direct monitoring by WIM or ATR.

Unanimously positive responses were received in a survey of traffic data users conducted as part of this project to determine if current traffic data needs are being met. Thirty three responses were received, from data users both within and outside MDT. Primary data uses reported by the respondents were for planning, design and safety analysis purposes. The most frequently used traffic data were AADT, ESAL, and percentage of trucks. The data was described as vitally important, supporting for example, numerous federal reporting requirements, which are directly tied to the funding that a state department of transportation receives. Feedback that highlighted opportunities for improvement included that 1) some data are not currently provided at an optimal time for submission in certain federal reports, 2) some types of data that are needed by some users are not collected, such as ATV, pedestrian and transit data, 3) the provided data need to be as current as possible, and 4) users are interested in being shown how traffic data can be used to better support their various activities. The majority of MDT data users reported having the data they needed; it was typically responses received from individuals outside of MDT that identified additional data needs, and it may not be feasible for MDT to satisfy all these needs. Additionally, around sixty percent of respondents currently made use of the traffic data website, and those that used it, found it valuable.

Relative to systematically charactering/describing highway system use, the current traffic factor groupings used by MDT were reviewed. Notably, traffic factor groups are employed in generating traffic factors for use in extrapolating annual traffic volumes based on short term traffic counts often conducted for just a 48 hour period during the year. Each short term count location is assigned to a "traffic factor group", with this group embodying annual traffic characteristics consistent with those at the short term count location. MDT's current traffic factor groupings are based primarily on the nature of a route's use, as categorized by highway functional classification with effectively a total of eight groups (i.e. Interstate – Rural, Interstate - Urban, Principal Arterial – Rural, Principal Arterial – Urban, Minor Arterial – Rural, Minor Arterial and Collector - Urban, Major Collector – Rural, Recreational). Three alternative groupings were investigated, based on 1) vehicle type, i.e., commercial versus non-commercial and functional classification, 2) area of the state and its socio-economic characteristics and functional classification, and 3) simplified functional classification scheme, consisting of just four groups, interstate versus non-interstate with subcategories of rural and urban. Analysis of these grouping schemes found that:

1. Within each group, commercial vehicles showed different patterns in average daily traffic over the year compared with all vehicles, particularly during weekend days. Using separate adjustment factors for commercial traffic may be beneficial, especially for use in those activities that are affected by and/or concerned with commercial vehicle operations (e.g. pavement design, weight enforcement, etc.).
2. The second grouping scheme, i.e., by area/economic activity, while generating reasonably accurate adjustment factors, may be somewhat impractical to implement. Notably, the assignment of permanent data collection stations to groups based on dominant economic activity in an area can be subjective in nature.
3. The third grouping scheme, i.e., the abridged functional classification scheme, has merit in that it simplifies the estimation and use of adjustment factors while not compromising

accuracy. This scheme may prove appealing, should it result in notable savings in data analysis time and resources.

Based on these findings, it is recommended that a traffic factor grouping scheme be considered which consists of two main groups urban and rural. These groups would be further divided by interstate and non-interstate routes, with factors generated for all vehicles and for commercial vehicles. The recreational grouping currently used by MDT would be retained.

A critical data collection activity is the selection of locations for future WIM/ATR deployments. In a resource constrained environment, every effort must be made to select sites that optimally support the collective needs of traffic data users. Use of a weighted sum model (WSM) was investigated as a method to provide for systematic and relatively objective input to the WIM/ATR site selection/planning process. The proposed WSM approach includes the same criteria used in the current MDT prioritization process. Each criterion is assigned a weight which reflects its relative importance to the agency. In evaluating a potential WIM/ATR deployment, a numerical score is assigned indicating the degree to which the site meets each criterion. The criteria considered in the WSM were grouped into the categories of data quality/comprehensiveness, specific data user needs, and opportunistic/situational factors. Two WSM models were developed, one that considers ATR and WIM sites together in the prioritization process, and one that considers them separately.

To demonstrate WSM operation, sample weights were assigned to the various criteria and sample scales were used to evaluate the degree to which sites meet these criteria. When this approach is implemented, both these weights and scales should be reviewed and modified by MDT personnel, as necessary, based on their expert knowledge of MDT's needs. In practice, the users of these WSM will be MDT personnel intimately familiar with the sites and data needs of the program, and thus their assumptions will be well founded and will support the generation of accurate and useful results. The expectation is that the results of the WSM will not be the sole input used in the decision-making process for WIM/ATR site prioritization, as the problem is complicated, but the WSM will provide a quantitative input to this process based on a systematic and uniform consideration of many of the important factors involved.

Overall, MDT's traffic data collection efforts effectively meet their basic data needs, as well as the needs of other data users (i.e., state highway patrol, metropolitan planning districts, and tribes), and does so in a manner consistent with the level of facilities and resources of other state programs. The TDCA Section has and should continue to consider various improvements, notably as technologies improve and data user needs continue to evolve and become more sophisticated.

The current WIM/ATR sites are adequate in number and distribution across most of the elements of Montana's highway network to meet general Highway Performance Monitoring Systems (HPMS) and Traffic Monitoring Guide (TMG) guidelines, and are generally similar in number to those found in other states. Data collection coverage is sparse in Montana's limited urban environments, with this urban coverage being one potential area for improvement. Nonetheless, work should continue to identify local areas with increased vehicle activity that merit increased data collection coverage to adequately characterize both volume and weight related traffic demands. Additionally, assessment should continue of the basic structure of the traffic factor and weight factor groups used by MDT, to ensure these groups reasonably represent operations across the highway network. Prioritization of future WIM/ATR deployments is critical, and the prioritization method developed in this project should help improve this process.

MDT continues to employ advanced technologies with a high level of automation in its data collection effort, but one area of needed improvement is in data collection in urban environments. This problem is not unique to MDT, and cost effective technologies to reliably collect traffic data under stop-and-go conditions are less established. Nonetheless, MDT should continue to be alert for the development and validation of any such technologies.

MDT's vertical integration of data collection activities within a single administrative section should result in ongoing positive technical and fiscal performance of the overall program. Additional staff and/or seasonal staff may benefit the TDCA, ensuring seasonal field work is not delayed and to improve certain activities like database preparation for planning, because while extensive inventory information and maintenance and repair histories are available for all permanent sites, this information is not in a readily accessible form that could best be used to proactively plan/manage equipment maintenance and replacement activities. Pavement conditions are also critical to system performance, and the current pavement condition at sites needs to be better evaluated and routinely documented. If compiled, this information could be a valuable input in establishing the condition and level of performance of permanent data collection sites.

Looking toward the future, interest in freight transportation and overall performance monitoring continues to be strong at the federal level, and associated traffic data needs related to freight initiatives and other performance data should be considered. Interest in bicycle and pedestrian traffic data is also increasing, and collection of this data should be given some consideration. Interest in travel time data and related performance measures is increasing in general across the motoring public and commercial vehicle operators, and MDT might begin investigating how this data can be collected and disseminated.

1) INTRODUCTION

Traffic data collection provides the underpinning for all transportation-engineering activities such as pavement design, infrastructure planning, weight enforcement, and traffic monitoring. Moreover, the Federal Highway Administration (FHWA) has established guidance on the development, implementation, and continued operation of a traffic monitoring system for highways and public transportation facilities and equipment in each state. As such, states record traffic data as part of their traffic monitoring system to meet federal traffic data reporting requirements. Traffic data typically collected includes traffic volume, vehicle classification, and vehicle weight data. Data collection techniques and technologies employed range from simple manual devices to ever-evolving sophisticated sensors, detectors, and data recorder and transmission equipment. Two fundamental types of data collection systems are generally employed in continuously monitoring roadway use at permanent (fixed) sites on a highway network, namely, Automatic Traffic Recorder (ATR) and Weigh-in-Motion (WIM) systems.

The ATR and WIM systems that are currently installed across Montana's highway network are the major components of the state's traffic data collection system, augmented by short term traffic counts conducted at numerous additional sites around the state with portable equipment. This project was initiated to comprehensively evaluate the existing traffic data collection program of the Montana Department of Transportation (MDT) and to provide recommendations for potential program improvements.

While both short term counts and permanent data collection programs were considered, the focus in this project was on permanent counter (ATR and WIM) programs, with a further emphasis on the WIM program. Consideration was specifically given to:

- data collection equipment/technologies,
- number and location of traffic data collection sites,
- types of traffic data collected,
- data processing and analysis,
- data presentation and accessibility,
- traffic data users and uses, and
- program management and operations.

The Federal Highway Administration's Traffic Monitoring Guide (TMG) (FHWA 2013) recommends that a comprehensive evaluation of traffic monitoring programs be conducted at a minimum of once every five years and should consider "equipment inventories, site selection procedures, data collection practices, validation, quality control, analyzing data, and data dissemination practices"; this project generally provides such an evaluation.

Seven major project tasks were completed for this project, which began in 2013. This final report consists of nine chapters, one chapter for each of the seven projects tasks, augmented with an introduction and conclusion. The chapters and corresponding tasks are:

1. Introduction (this chapter),
2. Review of the State-of-the-Practice (Task 1),
3. MDT Traffic Data Collection Program Description/Inventory (Task 2),
4. Data Collection, Analysis, and Presentation (Task 3),
5. Survey of MDT Traffic Data Users (Task 4),
6. Review of traffic factor groupings (Task 6),
7. Methodology for Future Planning/Prioritization of WIM/ATR Sites (Task 7),
8. Assessment of Adequacy of Data Collection Effort (Task 5), and
9. Conclusions.

2) REVIEW OF THE STATE-OF-THE-PRACTICE

With advances in wireless detector, sensor, transmission, and communication technologies, ATR/WIM technologies continue to move forward. To provide information for MDT to evaluate its existing traffic data collection program and assist in determining the future direction of this program, a systematic and comprehensive literature review on ATR/WIM systems was conducted (completed in 2013 as the first task of this project). This literature review covered all major components of these systems with an emphasis on WIM systems. Sources searched during the review include the Transport Research International Documentation (TRID) database, transportation organization websites, federal and state agencies websites, vendor websites, etc.

Since the information in the literature often is not current, and some states' practices are not described therein, the research team contacted selected states to directly learn about their traffic data collection programs. The survey focused on states that are similar to Montana with areas of low population density, geographically extensive highway networks, and natural resource based economies. Survey responses were received from North Dakota (ND), South Dakota (SD) and Maine (ME). Information gathered from the survey encompasses all major components of each states traffic data collection program, from basic traffic data collection technologies, unit organization, program costs, to data collected and data uses.

Accordingly, the first part of this chapter presents the results of the comprehensive literature review on traffic data collection programs, while the second part presents the information gathered from the survey of the state-of-the-practice of other comparable states. A brief summary of the major findings from the literature review and survey study are presented at the end of each part, respectively.

2.1. Literature Review

This section presents the findings from the comprehensive literature review on traffic data collection programs. The review focuses on four major components of a comprehensive traffic data collection program, namely:

1. Data collection technologies,
2. Data transmission and processing,
3. Data users and uses, and
4. Traffic data collection site selection and prioritization.

For this review, the research team considered ATR and WIM systems, as these are the two fundamental types of continuous traffic data collection systems. The focus of the overall research project is on WIM programs, and this focus is carried through in this literature review. Findings regarding each of the four major program components are presented in the following sections.

2.1.1. Traffic Data Collection Technologies

This section summarizes the data collection technologies used for ATR and WIM systems. ATR systems are generally less expensive than WIM systems, but they only provide traffic volume and/or vehicle classification data. WIM systems provide traffic volume, vehicle classification, speed, and weight data, but they are more expensive to deploy. Thus, traffic data collection programs typically use both systems, with data from the two sources being used individually and synergistically to support data needs in a cost effective manner.

An ATR is any traffic counting device that can be placed at a specific location to record the distribution and variation of traffic flow by the hour-of-day, day-of-week, and/or month-of-year (FHWA 2014). While the term ATR generally encompasses automated vehicle classifiers, portable traffic recorders, WIM systems, and any other non-manual counting device, frequently it is used more specifically to refer to non-WIM systems, and further to permanent systems engaged in continuous rather than short term traffic data collection (this approach, for example, is used by MDT). In the following material, portable/short term and permanent/continuous volume/classification data collection technologies are grouped together, with WIM systems being discussed in a subsequent section of the report.

2.1.1.1. Automatic Traffic Recorders

ATRs use a variety of sensing technologies, from pneumatic road tubes to piezoelectric sensors. The phenomenon used in each of these technologies varies, thus leading to advantages and disadvantages of each technology, as summarized in Table 1.

Table 1: ATR Technologies

Technology	Advantages	Disadvantages
Pneumatic Road Tubes	• Highly portable. • Well understood and mature technology • Inexpensive	• Susceptible to damage by traffic (therefore, not used in permanent, continuous data collection). • Requires precise setup for accurate classification.
Inductive Loop	• Flexible design to satisfy large variety of applications. • Insensitive to inclement weather. • Provides best accuracy for count data as compared with other commonly used techniques	• Installation requires pavement cut. • Wire loops subject to stresses from traffic and temperature. • Multiple loops usually required to monitor a location
Magnetometer (two-axis fluxgate magnetometer)	• Less susceptible than loops to stresses of traffic. • Insensitive to inclement weather. • Some models transmit data over wireless radio frequency link.	• Installation requires pavement cut. • Installation and maintenance require lane closure. • Models with small detection zones require multiple units for full lane detection.

Technology	Advantages	Disadvantages
Magnetic (induction or search coil magnetometer)	• Can be used where loops are not feasible (e.g., bridge decks). • Some models are installed under roadway without need for pavement cuts. • Less susceptible than loops to stresses of traffic.	• Installation requires pavement cut or boring under roadway. • Cannot detect stopped vehicles unless special sensor layouts and signal processing software are used.
Microwave Radio	• Typically insensitive to inclement weather. • Direct measurement of speed. • Multiple lane operation available. • Non-intrusive, can be used for portable short term counts.	• Continuous wave Doppler sensors cannot detect stopped vehicles.
Active Infrared (Laser Radar)	• Transmits multiple beams for accurate measurement of vehicle position, speed, and class. • Multiple lane operation available. • Non-intrusive, can be used for portable short term counts.	• Operation may be affected by fog when visibility is less than ~20-feet or blowing snow is present. • Installation and maintenance require lane closure.
Passive Infrared	• Multi-zone passive sensors measure speed. • Non-intrusive, can be used for portable short term counts.	• Passive sensor may have reduced vehicle sensitivity in heavy rain, snow, and dense fog. • Some models not recommended for presence detection.
Ultrasonic	• Multiple lane operation available. • Capable of over-height vehicle detection. • Large Japanese experience base. • Non-intrusive, can be used for portable for short term counts.	• Environmental conditions such as temperature change and extreme air turbulence can affect performance. • Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles travelling at moderate to high speeds.
Video Detection System	• Monitors multiple lanes and multiple detection zones/lane. • Easy to add and modify detection zones. • Rich array of data available. • Non-intrusive, can be used for portable short term counts.	• Installation and maintenance require lane closure when camera is mounted over roadway. • Performance affected by inclement weather such as fog, rain, and snow. • Required 30- to 50-ft camera mounting height for optimum presence detection and speed measurement.
Acoustic	• Passive detection. • Insensitive to precipitation. • Multiple lane operation available in some models. • Non-intrusive, can be used for portable short term counts.	• Cold temperature may affect vehicle count accuracy. • Specific models are not recommended with slow-moving vehicles in stop-and-go traffic.
Piezoelectric	• Low cost. • Accurate vehicle classification.	• Installation requires pavement cut.

Table Source: adapted from Klein, Mills and Gibson (2006)

Pneumatic road tubes rely on a flexible tube that is stretched across the road. When a vehicle passes over the tube, the air inside the sealed tube is compressed. The data collection unit attached to the hose then measures the pressure increase as a passing axle. To perform vehicle classification, pneumatic systems require two tubes across the road at a known distance from one another. Installation of pneumatic tubes does not require any modifications to the road bed. They are, however, highly susceptible to damage by traffic and road maintenance operations, and they are not feasible for use during winter months. While generally not appropriate for long term/continuous data collection, pneumatic road tubes are the most common form of short-term ATR (FHWA 2013).

The most common technology used for continuous data collection and traffic management is the inductive loop sensor (AASHTO 2009). Inductive loops consist of a series of wire coils placed in the road surface. These coils are then attached to a control unit. When operational, a current is passed through the loops and the inductance of the system is monitored. When a large magnetic body (i.e. a vehicle) passes over or stops within the loops, a change in the inductance is measured by the control unit. Inductive loops cannot detect individual axles; this makes their use for classification difficult.

Magnetometer sensors, whether wired or wireless, work by measuring the local magnetic field at the installation location. When an aberration in the magnetic field is identified, it can be inferred that a vehicle is present (Bajwa, et al. 2011). Magnetometers can be used in locations that may prohibit the use of inductive loops due to the small size of the magnetometer sensors (Klein, Mills and Gibson 2006).

Microwave radio, infrared (active and passive), and ultrasonic sensors all rely on measuring Doppler shift in the given emission type. Each technology outputs a signal that is then reflected by vehicles. A vehicle is detected when a change in the reflected energy is measured. Capable of detecting presence and speed data directly, these technologies are ideal for locations where in-road placement is problematic as they can be installed at the road side with minimal impact on the traffic flow (Klein, Mills and Gibson 2006).

Passive acoustic sensors rely on the noise generated by a passing vehicle. This noise can be either the vehicle itself or the noise generated by the tires on the roadway. Some acoustic systems are capable of detecting traffic on five lanes simultaneously (Nova Teck 2013). All acoustic sensors utilize a two-dimensional array of microphones to detect vehicle noise (Klein, Mills and Gibson 2006).

Video detection of vehicles is achieved through video processing by an on-site computer. A video feed is given to the computer which in-turn monitors a set location for changes in the video. These systems require a clear view of the traffic stream and can be obscured by weather phenomenon such as fog and snow. Modern processing technologies have made video detection less susceptible to misidentification of shadows and reflections as vehicles (Klein, Mills and Gibson 2006).

Middleton, Parker and Longmire (2007) performed a study of non-intrusive vehicle detection systems including video image vehicle detection, acoustic, magnetic, inductive loop, and microwave radar systems. It was determined that none of the technologies were as accurate as inductive loops, but microwave, radar, and magnetometers were identified as promising technologies especially in urban areas where vehicles travelling with short headways is more common, which can impact the accuracy of in-road technologies.

Piezoelectric cables are also commonly used for axle detection. Further discussion of piezoelectric cables will be given in later sections of this report. For axle detection, lower quality piezoelectric cables that are not suitable for WIM applications are used.

2.1.1.2. Weigh-In-Motion

Koniditsiotis (2000) defines WIM as, "A device that measures the dynamic axle weight of a moving vehicle to estimate the corresponding static axle mass." These devices provide information on vehicle speed and weight (including individual axle weights) in addition to collecting vehicle volume and configuration data. WIM systems are generally more expensive than ATR systems, but they offer a greater depth of data.

One of the first WIM systems was developed in 1952 by the United States Bureau of Public Roads (the predecessor of FHWA) (Norman and Hopkins 1952). This early system was a reinforced concrete platform instrumented with resistance wire strain gauges. All calculations of vehicle weight were done manually by interpreting the output of an oscilloscope attached to the strain gauges. This process was labor intensive and inaccurate making it impractical for long term data collection.

WIM technologies have continued to evolve over the past 60 years with advances in wireless detector, sensor, transmission, and communication technologies. Modern WIM systems typically consist of the following elements:

- A scale or set of sensors on the mainline or installed on a ramp that records the impact of the passing vehicle;
- A roadside cabinet containing a processor that converts the downward force readings of the vehicle on the scale into data estimating the vehicle's gross weight and axle weights; and
- A communication system that transmits the collected data to the computers of enforcement personnel or to an enterprise-level WIM database management system (Krupa and Kearney 2009).

The accuracy of a given WIM system is a direct function of the technology used for weight detection. Systems that are installed on the mainline require sensors that are accurate at high speeds, while systems located on ramps need to be more accurate at lower speeds. Generally, more expensive systems are more accurate (Krupa and Kearney 2009).

ASTM (2009) identifies four types of WIM systems based on the data items collected, vehicle speed accommodated, and purpose served. Typically, WIM systems are capable of producing some or all of the data items shown in Table 2.

Table 2: WIM System Outputs

Item	Description
1	Wheel Load
2	Axle Load
3	Axle-Group Load
4	Gross-Vehicle Weight
5	Speed
6	Center-to-Center Spacing Between Axles
7	Vehicle Class (via axle arrangement)
8	Site Identification Code
9	Lane and Direction of Travel
10	Date and Time of Passage
11	Sequential Vehicle Record Number
12	Wheelbase (front-most to rear-most axle)
13	Equivalent Single-Axle Loads (ESALs)
14	Violation Code

Table Source: ASTM (2009)

Table 3 presents the four types of WIM systems and their characteristics. Referring to Table 3, system types are differentiated by vehicle speed, intended application, specific data collected, and accuracy. Note that MDT uses almost exclusively piezoelectric WIM systems which generally are considered Type I and Type II systems. Type I and Type II systems are used for traffic data collection, and Type III and Type IV can also be used for weight enforcement.

Table 3: WIM Types

Type	Speed Range (mph)	Data Items Produced	Functional Performance Requirements (Tolerance for 95% compliance)			
			Wheel Load	Axle Group	Axle-Group Load	Gross-Vehicle Weight
I	10 to 80	All items	±25%	±20%	±15%	±10%
II	15 to 80	All items except 1		±30%	±20%	±15%
III	10 to 80	All items except 7, 12, and 13	±20%	±15%	±10%	±6%
IV	2 to 90	All items except 7, 9, 12, and 13	≥5000 ±300-lb (2270 ±140-kg)	≥12,000 ±500-lb (5440 ±230-kg)	≥25,000 ±1,200-lb (11340 ±540-kg)	≥60,000 ±2,500-lb (27220 ±1130-kg)

Table Source: ASTM (2009)

The scales and/or sensors are the key component of WIM systems. The following sections present an overview of the most common WIM sensors. Currently the most commonly used WIM technologies in the United States are piezoelectric systems, bending plate scales, and single load cell scales (FHWA 2013, and Cottrell and Kweon 2011). Other WIM technologies include capacitance mats, instrumented bridges, and instrumented culverts. Several transportation agencies have comparatively evaluated WIM system technologies over the past decade (e.g. Han, Bennett and Luk (2010); AASHTO (2009); Zhang, Hass and Tighe (2007); and Connecticut Academy of Science and Engineering (2008)). Table 4 provides a fairly comprehensive summary of the advantages, disadvantages, accuracy, and design life of common WIM system technologies used for weight data collection as reported by Austroads and the American Association of State Highway and Transportation Officials (AASHTO).

Table 4: WIM Technologies

Technology	Advantage	Disadvantage	Accuracy (GVW)	Sensor Life (yrs)
Bending Plate	• Well understood, mature technology. • High accuracy of wheel load due to whole footprint of wheel is on the plate at one time. • Resistant to environmental changes.	• Requires lane closure for installation and maintenance. • Requires other sensors to classify vehicles.	±10% for 95% of vehicles	15
Piezoelectric	• Low cost compared to other WIM systems. • Accurate vehicle classification.	• Low accuracy due to tire bridging over sensor. • Installation requires pavement cut. • Temperature sensitive (except quartz systems)	±10% for 95% of vehicles	6-10
Capacitance Mat	• Highly portable.	• Causes dynamic motion, thus, decreasing accuracy. • Highly visible to passing trucks.	±10% not better than ±660-lb (300-kg)	20
Instrumented Bridge	• Some systems do not require sensors in road surface. • Does not require lane closure for installation or maintenance. • Highly accurate vehicle classification. • Low visibility from the road.	• Requires a bridge at the WIM site.	±10% for 95% of vehicles	10
Instrumented Culvert	• Does not require lane closure for maintenance. • Low visibility from the road.	• Requires other sensors to activate system. • Requires installation of culvert at WIM site.	±10% for 95% of vehicles	10

Table Source: Han, Bennett and Luk (2010), and AASHTO (2009)

Piezoelectric Sensors The basic sensor in piezoelectric systems is a piezoelectric material embedded in the roadway. An electric charge is produced when pressure is applied to the piezoelectric material. By measuring and analyzing the charge produced, the sensor can be used to measure the weight of a passing tire or axle group. Piezoelectric WIM systems, when calibrated and installed properly, can be expected to be accurate within 15 percent of the gross vehicle weight for 95 percent of the vehicles that are measured (Bushman and Pratt 1998).

Based on the piezoelectric material and sensing technology, piezoelectric sensors can be divided into several sub-types, among which piezo-polymer, piezo-ceramic, and piezo-quartz sensors are widely used. There are a number of variations on the shape, size, cost, life, and environmental sensitivity of the sensors produced by various vendors. Jiang, et al (2009) conducted research and evaluated these three types of piezoelectric sensors, specifically polyvinylidene fluoride (PVDF), polarized ceramic, and quartz piezoelectric sensors. PVDF sensors can be installed directly into a slot cut into the road with a relatively small cross section for permanent applications, or taped down for portable applications. The ceramic and quartz piezoelectric sensors are installed in a cut in the road way. These sensors must be installed flush with the surface of any existing or new asphalt or concrete pavement surface with epoxy adhesive. The study verified that the quartz piezoelectric sensor technology has the best weight measurement accuracy, is insensitive to temperature change, and showed the best overall performance among these three sensors. MDT currently utilizes these quartz piezoelectric sensors.

Bending Plate Scale A bending plate scale typically consists of two steel platforms placed adjacent to each other to cover the width of a traffic lane. Strain gauges are installed on the steel plates to determine the bending strain in the steel when a tire passes over the plate. The strain can then be converted to axle load. It is typical to have inductive loops and axle sensors at the same site to allow for the collection of vehicle length and axle spacing data. (Bushman and Pratt 1998).

For all bending plate installations, the roadway is cut and excavated to form a pit. The frame is positioned in place and concrete is placed around the frame to form a secure and durable foundation for the scale. When properly installed and calibrated, bending plate WIM systems are expected to provide gross vehicle weights that are within 10 percent of the actual vehicle weight for 95 percent of the vehicles measured (Bushman and Pratt 1998).

Single Load Cell System Single Load Cell WIM systems utilize a single load cell scale to detect an axle and weigh both the right and left side of the axle simultaneously. The single load cell scale consists of two weighing platforms placed adjacent to each other to fully cover the width of a normal traffic lane. A single hydraulic load cell is installed at the center of each platform to measure the force applied to the scale. As a vehicle passes over the system, the measurements from each load cell are analyzed to determine the tire load on each platform and then summed to obtain the axle weight. When properly installed and calibrated, single load cell WIM systems are expected to provide a gross vehicle weight that is within six percent of the actual vehicle weight for 95 percent of the vehicles measured (Bushman and Pratt 1998). Single load cell scale technology has been developing rapidly over the last decade. Currently, new techniques have been incorporated into single load cell WIM systems. For instance, the International Road Dynamics Inc. (IRD) single load cell WIM weigh pads can be used for medium to high speed WIM and/or vehicle classification applications (IRD undated).

Capacitance Mat Capacitance mat WIM systems are commonly used for portable WIM applications. A typical system consists of a traffic data logger, inductive loops, capacitance weight sensor, and optional piezoelectric axle sensors (Han, Bennett and Luk 2010).

The portability of the system is advantageous in that it allows for short-term WIM counts. Conversely, the portability leads to three primary issues:

- The sensor is placed on the surface of the roadway, thus creating a bump that leads to dynamic motion of the vehicle.
- The sensor is rarely large enough to measure both wheel paths leading to an incomplete weighing of the vehicles.
- The system is highly visible to drivers, leading to avoidance of the sensor (Hans, Bennett and Luk 2010).

Capacitance mat WIM systems are made of layers of steel and dielectric rubber. In the same way an electrical capacitor works, the capacitance of the systems is dependent upon the distance between the steel plates. When a vehicle loads the sensor pad, the distance between the steel plates is decreased, causing the capacitance to increase. The increase in capacitance can be used to calculate the deformation of the steel and thus, the load applied to the steel plate (Hans, Bennett and Luk 2010).

Instrumented Bridge Instrumented bridges use strain gauges or transducers affixed to a bridge structure to measure the deformation of the bridge. Based on the deformation of the bridge and knowledge of the construction of the bridge, it is possible to determine the weight of the vehicles traversing the bridge.

In Slovenia, instrumented bridges are the primary type of WIM installation (Honefanger, et al. 2007). Using strain transducers embedded into the structure of the bridge, it is possible to use a calibrated influence line for the bridge to determine the weight of individual axles without the need for loop detectors or piezoelectric axle sensors (AASHTO 2009).

A primary advantage of instrumented bridges is the ability to install and maintain the systems without lane closures. Another advantage is that it is hard to identify the site from the roadway, thus limiting the practice of avoiding the sensors. A major issue with instrumented bridges is the requirement to have a bridge at the location where the WIM system is needed. Even in the event that a bridge is present, the roadway may not meet the geometric requirements necessary for the accurate use of a WIM system (Honefanger, et al. 2007).

Instrumented Culvert Similar to instrumented bridges, instrumented culverts use strain gauges embedded in culvert installations to determine the weight of passing vehicles. The system also includes axle sensors placed on the road to collect volume, speed, and classification data. The culverts typically span 7.5 to 8.0-ft (2.3 to 2.4-m) with an internal height of 4.0 to 7.0-ft (1.2 to 2.1-m). Often the control box for the WIM system can also be housed within the culvert (Main Roads - Western Australia 2012). As with most WIM installations, instrumented culvert sites require that the road meets certain criteria in regards to geometry, smoothness, and grade. It is recommended that the culvert not be used for drainage; this is to ensure that humidity does not affect the equipment housed in the culvert (Main Roads - Western Australia 2012).

Slow Speed WIM System Slow-speed weigh-in-motion (SWIM) offers an alternative to the traditional methods of vehicle weight enforcement using static weight scales. SWIM systems have been used for enforcement in the United Kingdom, much of Eastern Europe, the Middle East, Asia, and South America (Strathman 1998). ASTM defines a Type IV WIM system as a SWIM to be designed for use at weight enforcement stations to detect weight-limit or load-limit violations (ASTM 2009). According to ASTM (2009), this type of WIM system has not yet been approved for use in the United States, but can be deployed for conceptual development purposes.

SWIM technologies have been developed over the years to increase accuracy and reduce system life cycle costs. Currently, various technologies are available and many vendors provide SWIM products to meet the requirements of their clients. For instance, tire-force sensors are recommended for Type IV WIM systems (ASTM 2009). These sensors should be capable of estimating load and weight regardless of the lateral position of the tires within the traffic lane.

Innovation and Development WIM sensor technologies have been evolving over the last 60 years and new types of sensors continue to emerge. Fiber-optic WIM sensors have been heavily researched since the 1990s. While commercial products are available on the market, fiber-optic sensors are still not widely accepted or used. Usually, a fiber-optical WIM sensor is coupled with a photodiode detector and circuit. When a vehicle passes over the sensor and presses on the fiber, the photodiode detector detects the loss of light intensity. The photodiode circuit triggers a pulse if the loss of light intensity is large enough. The application would match pulse pairs from the two sensors, calculate the vehicle speeds, and determine vehicle weights from the pulses (Mimbela, et al. 2003). Fiber-optic sensors have several advantages over existing sensors. They are not affected by electromagnetic interference including lighting strikes, they can withstand harsh environments, and they have low power requirements.

Future innovations and improvements in WIM sensors and systems are aimed to increase system accuracy, reliability and service life, and to reduce cost, simplify installation and reduce maintenance. Future WIM sensors need to be robust to endure harsh environments, as well as have low power requirements. Another trend in WIM system development is for the WIM sensor to combine/accommodate additional data collection to serve multiple functions. These functions include thermal imaging, radio frequency identification (RFID), and tire profile measurement.

Cost The cost of a WIM installation and its operation can be highly variable due to the differing characteristics of each site. Current WIM system cost information was not found in the literature, but relative cost comparisons can possibly be made based on historic information and information available from other locales. Bushman and Pratt (1998) stated that the cost of piezoelectric systems was less expensive than bending plates, followed by load cell systems being the most expensive. This observation is consistent with cost information published in the WIM successful practices handbook prepared by Iowa State University (Center for Transportation Research and Education 1997) repeated in Table 5. Somewhat more current information available from Canada and Australia is presented in Table 6 and generally indicate that this pattern continues, with costs increasing in moving from piezoelectric, to bending plate, to load cell systems. The initial cost of bending plate systems is reported to be similar to, or substantially higher than that of piezoelectric systems (up to double). When life expectancy and maintenance costs are considered (Table 6), the cost of a bending plate system is only slightly higher than a piezoelectric system (20 percent higher), except possibly in the case of quartz piezoelectric systems. A further factor to consider in assessing costs is system accuracy, with increased system cost generally corresponding to an increase in accuracy. Bergan, Berthelot, and Taylor (1996) argued that in weigh station prescreening applications the incremental cost of a system of improved quality and accuracy was negligible compared to the cost of the weigh station operations. Measurement quality of less accurate systems, notably piezoelectric systems, can be improved by installing multiple rows of sensors and collectively analyzing the data they produce (Zhang, Hass and Tighe 2007).

Table 5: WIM System Performance and Cost

WIM System	Performance (percent error on GVW at highway speeds)	Estimated Initial Cost per Lane (Equipment and Installation)	Estimated Average Cost per Lane (12-year life span including maintenance)
Piezoelectric Sensor	±10%	$9,500	$4,224
Bending Plate Scale	±5%	$18,900	$4,990
Double Bending Plate Scale	±3-5%	$35,700	$7,709
Deep Pit Load Cell	±3%	$52,500	$7,296

Table Source: Center for Transportation Research and Education (1997)

Table 6: WIM System Costs

Cost Per Lane	Piezoelectric Sensor	Bending Plate	Single Load Cell	Quartz Piezoelectric Sensor	Strain Gauge (Instrumented Culvert)	Capacitance Mat
Initial Installation (US$)	Low (around $9,000)	Medium (around $20,000)	High (around $50,000)	Medium (around $20,000)		
Annual Life Cycle Cost (US$)	Low (around $5,000)	Medium (around $6,000)	High (around $8,000)	High		
Estimated Initial Cost (AU$)		$30,000		$20,000	$30,000	$30,000

Table Sources: Zhang, Hass and Tighe (2007), and Hans, Bennett and Luk (2010)

WIM Calibration Calibration of WIM systems is an important step in ensuring that the data being received from the sites are of the highest possible quality. Papagiannakis, Quinley and Brandt (2008) presented three general methods for calibration: test truck, traffic trucks, and traffic data quality control (QC).

ASTM E1318 (2009) provides a test truck method that consists of a six step process:

1. Adjust all WIM settings to vendor's recommendations or to a best estimate of proper setting based upon previous experience.
2. Provide means for calculating the reference-value vehicle speed for each run of each test vehicle over the WIM system sensors.
3. Have each of the two test vehicles make a series of three or more runs over the WIM system sensors at the minimum, legal maximum, and an intermediate speed for a total of nine or more runs per vehicle.
4. Calculate the difference in the WIM system estimate and the respective reference values.
5. Determine the necessary changes, according to the vendor's recommendations, to the WIM system settings.
6. Install settings determined in step 5 and have each test vehicle make two more runs over the WIM system at two different speeds.

Using traffic trucks involves comparing the static weight of trucks in the traffic stream against the weight reported by the WIM equipment. This is often accomplished through comparing the front axle weights of the trucks in the traffic stream to an expected average. This method is advocated by the Traffic Monitoring Guide (FHWA 2013).

The third method for calibration is through traffic data QC. This method can identify and adapt to calibration drift. By monitoring and comparing trends in the traffic stream, it is possible to identify a situation in which the WIM system is out of calibration. Either automatic adjustments or re-calibration can be used to rectify the calibration issue (Papagiannakis, Quinley and Brandt 2008).

All WIM sites will require occasional calibration due to changes in the road surface condition, equipment degradation, road construction over the WIM site, and other environmental variables (ASTM 2009). Many states reported that combinations of the three calibration methods are used and that calibration is required every six to 24 months (Papagiannakis, Quinley and Brandt 2008).

2.1.1.3. Virtual Weigh Station

Virtual Weigh Station (VWS) is the application of WIM mainly used in weight enforcement. Various technologies are required to support different types of VWS. Table 7 presents the minimum components needed for VWS deployments. Table 8 offers additional technologies that can be used to enhance VWS deployments.

Table 7: Primary Technologies for VWS

Technology	Description
WIM Scales or Sensors	Measures the weight of the vehicles.
Camera (Digital Imaging) System	Captures image of vehicle crossing the WIM system.
Screening Software	Integrates data from the WIM and imaging systems.
Communication Infrastructure	Makes the VWS data available to authorized users.

Table Source: Krupa and Kearney (2009)

The cost of a VWS system can range from $300,000 to $1,400,000 depending on the scope of the system and presence of pre-existing infrastructure (Capecci and Krupa 2009). The Indiana Department of Transportation (INDOT) has stated that the cost to retrofit an existing WIM site can be as low as $30,000 (Fernado, et al. 2009). Although this cost is high, a standard weigh station can range in cost from $12,000,000 to $300,000,000 depending upon the need for land acquisition (Capecci and Krupa 2009).

Table 8: Secondary Technologies for VWS

Technology	Description
License Plate Reader	Captures and image of the vehicle’s license plate and uses optical character recognition to determine the license plate number.
Commercial Vehicle Information Exchange Window	Provides real-time access to motor carrier safety and credentials data.
State-issued Permit Compliance	Verifies that the proper permits exist if the vehicle is overweight.
Repository of Past Weight Performance	Provides real-time access to the vehicle’s previous compliance records.
Driver Identification System	Accurately identifies the operator of the vehicle while the vehicle is in motion.
Augmented WIM Scales	Enhance the accuracy of the WIM scales.
Two-way Communication	Provides the ability to share data from the vehicle.

Table Source: Krupa and Kearney (2009)

While VWS is discussed in more detail in a later section of this report on the use of WIM in weight enforcement, several VWS technologies used in prescreening vehicles at weigh stations are introduced below. Currently, several commercial systems are available to be incorporated with WIM or VWS for weight enforcement prescreening to reduce the time truckers spend at weigh stations while also improving highway safety. These technologies have been successfully implemented by several state Departments of Transportation (DOTs) and are promoted by the United States Department of Transportation (USDOT). The following paragraphs describe the commercial systems that have been successfully implemented by various states.

PrePass PrePass makes it simple to pre-screen vehicles that are enrolled in the program. When participating trucks approach a roadside weigh station, in-cab technology communicates information about the driver, the truck, and the trucking company to an above-the-road monitor or to an inspection officer's hand-held device. If no compliance issues are found, the driver is allowed to bypass the inspection facility without stopping (Help undated).

360Smart View 360Smart View is a system that uses high-definition cameras to read a truck's DOT number and license plate as it enters an inspection station. The information (collected from about 90 government databases) provides inspection officers with a compliance snapshot for that carrier. This technology allows law enforcement to work with multiple state and federal agencies and identify non-compliant carriers, which helps enforcement officials get bad trucks and unsafe drivers off the road (Help undated).

NORPASS The North American Preclearance and Safety System (NORPASS) is a partnership of state and provincial agencies and trucking industry representatives who are committed to promoting safe and efficient trucking throughout North America. Each trucker who registers his/her vehicle to participate in NORPASS receives a small transponder to mount on the windshield. As the truck approaches a NORPASS weigh station, a roadside reader detects the transponder and a computer in the scale house checks the credentials. Some stations are also equipped with WIM equipment. If everything passes, a signal is sent back to the truck and the transponder gives a green light indicating that the driver may bypass the weigh station. If a problem is detected with the truck, the transponder returns a red signal, indicating that the driver must pull in. The system also samples randomly so any participating trucker can expect to receive an occasional red light (NORPASS 2013).

Green Light Green Light is a truck weigh station pre-clearance system used only by Oregon. Green Light is a state owned, operated, and administered database. As trucks approach the weigh station, WIM is used to determine the weight of the vehicles at high-speed, while automatic vehicle identification devices look for signals from a palm-size transponder mounted inside the truck windshields. The transponder contains only a 10-digit number that is used to identify the carrier and specific truck. A computer takes in all the information, verifies truck size and weight, checks the carrier´s registration and safety records, and sends a green light signal back to the transponder if the truck is "good to go" past the station (Oregon Department of Transportation 2013).

2.1.2. Traffic Data Transmission and Management

The inherent efficiencies of contemporary digital technologies allow traffic monitoring programs to generate tremendous amounts of data. Consequently, the transmission of the large amount of traffic data from field sites to data control centers is an important aspect of traffic data collection programs. This section presents an overview of some of the data communication and management technologies used by various entities.

2.1.2.1. Data Communication Technologies

Communication between ATR/WIM sites and traffic control centers is an integral part of all traffic monitoring programs. In some cases, end users rely on real-time communications with traffic data collection sites. For instance, weight enforcement activities in Slovenia rely on real-time communication between WIM sites and the enforcement personal (Honefanger, et al. 2007). In Minnesota, the Minnesota State Patrol (MSP) relies on real-time communication as part of their virtual weigh station program (URS 2007).

Data communication technologies for WIM programs were reviewed by the Minnesota Department of Transportation (URS 2007). Table 9 presents the various communication technologies along with their advantages and disadvantages summarized by the Mn/DOT study.

Among those communication technologies listed in Table 9 landline, cellular, and wireless technologies are most commonly employed. For the transmission of real-time data and/or images of vehicles, Krupa and Kearney (2009) states that it is required to have a high-speed wireless or digital subscriber line (DSL) connection to the ATR/WIM site.

Dedicated, short-range communications (DSRC) have been implemented for WIM systems (Carson 2008). DSRC is two-way short- to- medium-range wireless communications capable of very high data transmission rates that are critical for communications-based active applications such as virtual weigh stations (VWS) (further information on VWS can be found in later sections of this report). Currently, the USDOT is committing to the use of the DSRC technologies for active safety for vehicle-to-vehicle and vehicle-to-infrastructure applications, as described in the Intelligent Transportation System (ITS) Strategic Research Plan, 2010-2014 (USDOT 2010). Its applicability to other safety, mobility, and environmental applications has also been explored. The use of DSRC for WIM programs essentially falls into the category of wireless communication technologies.

Table 9: Communication Technologies

Technology	Advantages	Disadvantages
Landline Low Speed/Dial-up	• Coverage is usually very good • Most available form of landline communication. • Low cost of capital	• Inconsistent levels of communication speed and quality. • High recurring costs associated with long distance calling
Landline High Speed/ Digital Subscriber Line (DSL)	• Fast communication speeds. • Low recurring cost	• Excessive costs associated with commercial service. • Inconsistent levels of communication speed and quality. • Availability is limited in rural areas.
Landline High Speed/ Cable	• Fastest landline communication speeds.	• Available only in urban areas.
Wireless LAN	• Low recurring costs. • Provides reliable communication when properly installed.	• Communication is heavily dependent on line of sight between stations. • Communication speeds decrease with increased distances. • High initial costs.
Satellite	• Available anywhere what the southern sky is visible. • Fast communication speeds. • Supports multiple interface options.	• Requires dish antenna which decreases mobility.
Cellular Broadband	• Fast communication speeds.	• Low availability in very remote areas. • Designed to connect to the internet, not private networks.

Table Sources: URS (2007), MDT (2013)

2.1.2.2. Data Management

A typical WIM system meeting the Type I requirements of ASTM E 1318 (2009) has the capability of producing continuous high quality traffic data for a multilane roadway location for the 14 data elements for each vehicle previously listed in Table 2.

Usually, a WIM system's controller stores both summary (binned) data and individual vehicle record (IVR) data for each day. For binned data, all of a day's vehicles are typically binned by count for hour-of-day, lane, classification, and speed range; while the IVR data includes data elements for individual vehicles (Quinley 2010).

After these raw data have been communicated to the data control center, a software application is then utilized to process the raw data, including validation of quality and the generation of reports, ASCII files, and IVRs. Usually, WIM system vendors provide the data processing software for their clients. In other cases, some agencies utilize their own custom software applications or third party software to process the raw data, as well as to automate the raw data transferring and/or performing data validation checks to ensure data completeness and accuracy. Usually quality control rules check for incoming data format, volume minimums/maximums, vehicle classification comparisons, identification of atypical days (holidays), etc. Typical in-house software is capable of generating output reports in the FHWA's Traffic Monitoring Guide card format; generating daily, weekly, monthly, or continuous summary reports in hourly increments based on vehicle speed; classification; ESAL; and weight summaries on a lane by lane or directional basis. The typical in-house software can also generate reports on errors, auto-calibration, site history, calibration history, and overweight vehicles. The following sections, while not exhaustive, present just a few typical examples of successful data processing and presentation software suites.

Travel Monitoring Analysis System The Travel Monitoring Analysis System (TMAS) is a traffic data reporting tool created by FHWA to assist in the submission of data to FHWA. TMAS offers many quality control checks to ensure that data is of adequate quality for use in Federal programs. TMAS also allows for easy data sharing between states, with all data being readily available in one location. TMAS version 1.0 was released in August 2007 with the intent of replacing the Traffic Volume Trends system. The newest version, TMAS 2.0, was released in September 2012 (Jessberger 2012). Many quality control improvements have been made as well as improvements to the usability of the data.

TMAS 2.0 performs numerous quality control checks including volume, classification, and weight checks. Many of the volume checks are performed to ensure that a complete data set has been entered. The classification checks compare historical data to the newly entered data to ensure that the new data are within acceptable variation limits. The weight checks compare expected ranges of various metrics to ensure that the weight data are reasonable.

TMAS 2.0 can output reports on volume and classification. The volume reports can be refined to include information on state traffic volume trends, station by hour, monthly average daily traffic (MADT) by month with average annual daily traffic (AADT) by station/state, and volume data uploaded by state and month. The classification reports can include class by day, hour, and site; class by station with no data on weight; class by station monthly by day; station multi-year by month; and class by Highway Performance Monitoring Systems (TMG) vehicle types by state (Jessberger 2012).

Weigh-in-motion Compliance Analysis Tool Weigh-in-motion Compliance Analysis Tool (WIMCAT) is a software product produced by Purdue University using Visual Basic and is currently used by Mn/DOT and INDOT (Krupa and Kearney 2009). WIMCAT helps with the analysis and tracking of WIM data through a variety of built-in checks and algorithms. Major functions performed by WIMCAT include:

- charting violation rates,
- providing information to assist in optimizing enforcement scheduling,
- automating the production of performance measures,
- facilitating the production of pavement damage estimates,
- flagging potential WIM equipment and raw data problems, and

- serving as a preliminary step in creating a vision for a Central Operating System (URS 2007).

As of 2007, WIMCAT only processed data on Class 9 and 10 vehicles to simplify its use in the earlier development stages. The classifications to be monitored were chosen due to their representation of the majority of heavy vehicles found in the traffic stream (URS 2007).

WIMCAT analyzes the data and flags any abnormal or erroneous data. Some of the checks target unreasonably high vehicle weights, differences between the left and right side of an axle, and confirm the speed based on axle spacing. The error reports from WIMCAT can be used to determine when calibration operations need to be performed at a given WIM site.

WIMCAT also automates the production of reports for performance measures. The following list presents the measures that WIMCAT is able to directly report:

- percent of over-weight vehicles by class and violation type,
- an excessive load ratio (ELR) taking both magnitude and volume into consideration,
- percent over-weight trucks by levels of magnitude (ex. 0 to 10-kip (0 to 44-kN), 10 to 20-kip (44-kN to 88-kN, etc.),
- pavement damage due to over-weight vehicles (in dollars),
- violations listed by hour-of-day, and
- violations listed by day-of-week (URS 2007).

Any of the data can then be used for making policy decisions, scheduling enforcement, and/or special use reports. For scheduling enforcement, WIMCAT reports are able to track trends that can be used to determine where enforcement efforts should be focused.

Survey Processing Software The Survey Processing Software (SPS) package was developed by the Florida Department of Transportation (FDOT) to give the districts of Florida a software package that would assist in traffic data quality control and data submittal. SPS was developed using Microsoft Access and performs four main functions: converting raw data to a uniform format, loading the data to the SPS database, performing quality control checks, and uploading data to the SPS mainframe (FDOT 2007).

SPS was designed to work with a variety of traffic counting devices produced by many different vendors, which allows FDOT to save money by only needing to train technicians on one piece of software instead of many. After data are uploaded to the SPS system the software converts the data to a standard format regardless of the equipment that produced the data. Data are then loaded into a database, where SPS organizes them into 24-hour blocks starting with the first data interval. Next, a check is performed to ensure that 24-hours of data are available. If this is not the case, the data are rejected. Then, SPS performs 14 quality control checks that range from ensuring data integrity by checking the validity of counter-station identification numbers to checking maximum volume per lane. If any checks are not passed the data are flagged, and an operator must manually review the data.

After the data has passed the quality control checks, they are uploaded into a central mainframe. Once the data has been successfully loaded to the mainframe, they are made available for access by FDOT personal. Three reports are automatically made available: annual summary record, daily volume record, and daily vehicle classification record. It is also possible to create other reports if more specific information is required.

Traffic Count Database System The Traffic Count Database System (TCDS) is a subscription based software and database service offered by Midwestern Software Solutions (MS2, Ann Arbor, MI). TCDS performs various traffic data tasks from automatic quality control to data visualization including all the functionalities described in the SPS package. Having been designed to accept input from a wide range of traffic counting devices, TCDS allows for the consolidation of data into one central database. To visualize data, TCDS can output a variety of reports and maps. Using a web-based interface also allows for the use of geographic information systems (GIS) to access and visualize data from any location with internet access. Like the SPS package, TCDS is a single software solution that does not require personnel to learn multiple different software systems.

TCDS is used by over 140 road agencies throughout the United States (MS2 2013). The agencies range from State DOTs to metropolitan planning organizations (MPOs). TCDS offers the following systems modules:

- traffic count database system,
- pedestrian count database system,
- traffic signal management system,
- traffic crash location system,
- travel time database system,
- road sign management system,
- pavement management system,
- project management database system, and
- real time traffic system.

TCDS performs many quality control checks for data as it is being entered into the database. The checks for volume and weight data are as follows (Wood 2013):

- missing local ID,
- count exists in TCDS,
- partial count,
- duplicate unassigned count,
- consecutive identical hours,

- data completeness – short count,
- zero by X or more,
- previous year month/day average,
- MADT – out of tolerance,
- class percentage,
- peak hour percentage of total,
- directional split,
- AADT – out of tolerance,
- hourly volume out of range,
- missing related count,
- error on related count,
- average steering axle weight, and
- number of zero WIM hours.

TCDS will also output the following error codes for WIM data:

- Fatal Error: Vehicle with over 25 axles or fewer than 2 Axles,
- Caution: Total Average weight not equal sum of axle weights,
- Caution: Any axle of vehicle out of 1 to 50-kip (4.4 to 222-kN) range,
- Caution: Any axle spacing of vehicle out of 1 to 50-ft (0.3 to 15.2-m) range,
- Warning: Vehicle with 13 to 25 axles, and
- Overweight: Overweight limit in bold red.

2.1.3. Traffic Data Users and Uses

Traffic data have many uses. State DOTs, MPOs, cities, counties, and other transportation agencies use traffic data mainly to serve their internal needs, with state DOTs in all likelihood being the primary user agency. DOT internal data uses include weight enforcement, pavement design, transportation planning, policy making, freight management, traffic safety, asset management, etc. In addition to serving internal DOT users, traffic data are very useful to other government agencies, such as the Department of Commerce, Department of Energy, and Department of Homeland Security, as transportation is an integral part of almost all social and economic activities in contemporary culture.

With the advancement of information and communication technologies, as well as the increased transparency of public agency operations, traffic data collected by transportation agencies have been made more and more accessible to non-government users, such as universities, research institutes, consulting companies, and even the general public. Many states make historical traffic data available on their websites in a variety of formats, with one such format increasingly being interactive maps with data collection sites marked, which when selected by the user, further show what data is available at the site with an active link to that data. A review of state DOT websites nationwide (performed in 2013) found that 22 states provide various elements of their traffic data through an interactive map format.

Recently, traffic data uses by the general public have become more common with the advent of global positioning system (GPS) enabled smart phones. Some companies have started to collect traffic data to serve their clients. For instance, Google has begun using data collected through contracts with DOTs, and anonymous location and speed data sent from users of its Maps application, to give up-to-the-minute congestion data to the users of their Maps application (Google 2009).

This section focuses on four major state DOT uses of ATR/WIM data, namely weight enforcement, VWS, freight management, and pavement design. New developments in each area are then reviewed and summarized followed by a brief description of other traffic data related needs.

2.1.3.1. Weight Enforcement

AASHTO has identified WIM as a focus technology for enhancing the effectiveness and efficiency of vehicle size and weight enforcement in the United States (Honefanger, et al. 2007). According to a study conducted by Honefanger, et al. (2007), weight enforcement using WIM systems improves the delivery of enforcement services and motor vehicle activities, reduces emissions, and enhances commercial and general motor vehicle safety. One of the common applications of WIM technologies for weight enforcement is for the prescreening of truck traffic (Regan, et al. 2006). The use of WIM data for direct enforcement or automatic issuance of citations has not gained legal clearance in many countries. One of the main hurdles for the use of WIM for direct enforcement is the accuracy of the devices.

Many European countries have a long history of using WIM systems for weight enforcement, among which Slovenia, the Czech Republic, and France have the most advanced programs. Slovenia does not have any fixed weight stations throughout the country but instead relies on mobile static scales and permanent WIM systems. Enforcement personnel utilize the data from WIM sites to identify overweight vehicles. After identification, the overweight vehicles are directed to a safe area for static weight measurements (Honefanger, et al. 2007).

Instead of using calibrated scales in conjunction with WIM pre-selection systems, the Czech Republic has employed the Weigh-In-Motion Enforcement (WIM-E) system manufactured by Traffic Data Systems GmbH to monitor heavy vehicle compliance and in the event of a violation, to provide evidence for further prosecution. The first WIM-E system was installed in December, 2007 and was approved by the Czech Meteorological Institute (CMI) in Brno on August 15th, 2008. The system is equipped with two or three rows of sensors and one double inductive loop per lane. The vehicle, driver, and current traversal are documented by means of an infrared (IR) photographic camera and an IR sequence camera. With a fully automatic process for continuously checking and registering overloaded vehicles, WIM-E requires no subsequent manual weighing (Traffic Data Systems undated).

France has one of the most extensive WIM networks in Europe with over 200 installations throughout the country (Honefanger, et al. 2007). As of 2007, France used low-speed WIM for direct enforcement operations. To address the accuracy required for direct enforcement using high-speed WIM, France has developed an automatic calibration procedure that compares static vehicle weights against the weights calculated by the WIM system. It is expected that fully automatic weight enforcement will be in use within the next 20 years (Honefanger, et al. 2007).

In the United States, use of WIM data and systems assist in weight enforcement is not a new practice. The Montana Motor Carrier Services (MCS) has employed the State Truck Activities Reporting System (STARS) program to improve the efficiency and effectiveness of enforcement activities since 2000. While not used to dispatch enforcement in real-time, the STARS program did monitor the temporal and areal distribution of overweight vehicles with data collected from the WIM sites for a base year. This analysis of the data helped to plan an enforcement deployment for the next year to best cover the locations and times where the most weight violations were occurring. A study sponsored by MDT (Stephens and Carson 2005) evaluated the STARS program and concluded that the STARS program was successfully used to reduce infrastructure damage from overweight vehicles. The STARS analysis methodology is now available to MDT's enforcement customers via MS2's TDCS. This allows enforcement entities access to timely weight data that can be monitored to identify trends and schedule enforcement activities.

In Minnesota, WIM systems are used for screening and selection of vehicles that should be weighed with static scales. Due to pavement and weather conditions, many WIM systems are only 90 percent accurate (Mn/DOT 2013). When using the WIM system to identify over-weight vehicles, the WIM system accuracy is taken into consideration. For instance, Mn/DOT (2013) stated, "With the systems being about 90 percent accurate, Class 9 and 10 vehicles that have a legal weight limit of 80,000-lb (36290-kg) are not pulled over unless the WIM indicates that they weigh more than 88,000-lb (36290-kg)." The WIM systems also have several warnings that indicate if the system is not operating correctly. If any error warning occurs, the WIM data will not be used as a basis for intercepting the possible violator.

According to a study conducted by Krupa and Kearney (2009), Washington State includes WIM technology at 14 of its weigh stations, which weigh over 80 percent of the State's commercial vehicles. The mainline WIM system is linked to a camera that takes a picture of a vehicle as it crosses the WIM sensors; the image is recorded along with the vehicle's weight data. In Washington State, automatic identification of vehicles with transponders is conducted through the Commercial-vehicle Roadside Information Sorting System (CRISS). After a vehicle is identified, a query is made of the Commercial Vehicle Information Exchange Window (CVIEW). The credential information contained in CVIEW is checked to ensure that the vehicle is conforming to the State's screening criteria. Any vehicle that has acceptable credentials is signaled to bypass the weigh station. Any vehicle that is not equipped with a transponder is required to stop at the static weight station. The CRISS software displays a picture and weight information for each vehicle as it approaches the weigh station. An algorithm determines if there are any potential axle weight violations, which are highlighted on the computer screen at the scale house. CRISS was the first system in the U.S. to associate digital photos of trucks with their vehicle data on a weigh station computer to aid in visual identification and enforcement.

Wisconsin DOT has been using WIM technology for data collection but has been reluctant to allow shared use of the data with the Division of State Patrol. The main concern with sharing the weight data is a fear that the data will become distorted if carriers intentionally avoid the locations with WIM installations for fear of enforcement actions (WisDOT undated). The need to protect the integrity of the WIM data is not unique to Wisconsin. Many states are searching for innovative ways to ensure reliable and accurate data are and continue to be collected. Relatively recently, Louisiana passed a state law mandating WIM coupled with an Enforcement Camera System to combat weigh-station bypass and ensure the integrity of the traffic data collected (Louisiana State Code 2012).

In addition to mainline implementation, WIM scales are also installed on the entry ramps of weigh stations to weigh and sort vehicles at low speeds (Krupa and Kearney 2009). As a truck passes over the ramp WIM site, it is prescreened for weight compliance. If the vehicle is within legal limits, it is directed to a bypass lane and is allowed to return to the traffic stream. Conversely, if the truck is above the prescribed threshold, it is required to stop at the static weight station for further inspection. Compared to mainline WIM systems, ramp WIM systems weigh vehicles moving at lower speeds and provide a more accurate measure of a vehicle's weight (Krupa and Kearney 2009). It is reported that Kentucky, Michigan, Mississippi, and Indiana have utilized ramp WIM at some of their weigh stations.

2.1.3.2. Virtual Weigh Stations

Another use of WIM installation for enforcement is VWS. The definition of the term VWS is somewhat ambiguous, with the nature of VWS deployments varying widely across states. Commonly, VWS refers to unstaffed and remotely monitored roadside enforcement facilities. Krupa and Kearney (2009) made the following comparison of VWS to a traditional weight station, "VWSs expand the geographic scope and effectiveness of a state's truck size and weight enforcement program by monitoring and screening commercial vehicles on routes that bypass fixed inspection stations and on secondary roadways, as well as in heavily populated urban or geographically remote locations where it may be difficult to deploy traditional enforcement operations."

As described in previous sections, VWS systems generally consist of:

- WIM scales or sensors,
- camera (digital imaging) systems,
- screening software, and
- communication infrastructure (Krupa and Kearney 2009).

The following types of technology also may be deployed in order to support additional VWS functionality:

- license plate recognition (LPR) and/or USDOT number reader system,
- Commercial Vehicle Information Exchange Window (CVIEW) or an equivalent,
- state-issued permit compliance,
- repository of past weight performance,
- driver identification system,
- augmented WIM scales, and
- two-way communication (Krupa and Kearney 2009).

VWS often include a combination of cameras and sensors to accurately identify trucks that do not need to stop at a static weigh station (Miller and Sharafsaleh 2010). According to a study by Hans, Bennett and Luk (2010), a possible ten-fold reduction in disruption costs can be realized by using VWS as compared to static processes that require total interception of heavy vehicle traffic. The AASHTO Technology Implementation Group launched a program to encourage the deployment of VWSs in the United States and documented the best VWS practice in several lead states (AASHTO 2009).

FDOT employs a Virtual WIM ByPass System to curb avoidance of weigh station facilities by heavy vehicle drivers. By using LPR systems in conjunction with WIM systems on freeway ramps, FDOT is able to determine the compliance of heavy vehicles. If a vehicle is found to be in violation of weight limits, an FDOT Motor Carrier Compliance Office computer determines the penalty (ITS International 2008). At some sites, FDOT also employs Cargoscan3D measuring lasers to capture 3-D image of vehicles with arrows identifying highest and widest points (AASHTO 2009).

California initiated research into VWS in 2004 to address the safety and congestion problems on I-710 due to the high volume of commercial motor vehicle traffic and the number of overweight vehicles (Miller and Sharafsaleh 2010). A year later, Caltrans deployed a prototype virtual weigh station, which was on display at the 12th Intelligent Transport Systems World Congress. The prototype virtual weigh station's in-pavement technical components include a bending plate WIM scale, a vehicle detection system, and a camera triggering system. The VWS prototype was used to collect data that was then utilized by the California Highway Patrol to intercept over weight vehicles and perform static inspections. The data are also used to determine patterns of overweight vehicles and to schedule enforcement activities. In California, the VWS prototype often operates in conjunction with a PrePass transponder reader, which is an automatic vehicle identification (AVI) system that enables participating transponder-equipped commercial vehicles to be pre-screened throughout the nation at designated weigh stations, port-of-entry facilities, and agricultural interdiction facilities.

INDOT, working closely with State Police, Motor Carrier Services, and Purdue University, has researched and deployed VMS since 2002 (AASHTO 2009). The VWSs in Indiana use existing fixed WIM scales along with remote cameras technology and wireless communications to provide real-time weight data for enforcement screening. Moreover, the data collected are analyzed for trend identification and targeting enforcement activities (AASHTO 2009). In North Dakota, all WIM sites are setup for both screening and basic traffic monitoring (Krupa and Kearney 2009). State Troopers screen trucks as they pass by the WIM installation, receiving weight data through radio communication with their laptop computers. North Dakota's activities are reported in more detail in the survey section of this report.

The VWS program in Minnesota was built upon the Minnesota Statewide Commercial Vehicle Weight Compliance Strategic Plan (URS 2005), aimed to preserve Minnesota's infrastructure by minimizing damage from overweight trucks. A primary focus of the program was building a Virtual Weigh Station "starter" system at a reasonable cost and within a short time frame. This was accomplished by using current WIM scales and applications for weight enforcement purposes. Through the VWS program Mn/DOT has been able to outfit all of its WIM sites with basic VWS functionality and has created nine fully functional VWSs. Incorporating digital imaging and dynamic feedback technologies, WIM scale data are processed in new ways to create performance measures for tracking progress and for real time enforcement screening (Starr, et al. 2008).

The real compliance, safety, and operational benefits of VWS will be seen if the United States is able to move towards a direct enforcement regime using advanced technology. The system accuracy and some legal implication issues should be tackled before using weight data for direct enforcement. Research efforts should be directed to developing VWS systems that are capable of determining vehicle and axle weights with sufficient accuracy to enable the issuance of citations for violations. Experiences from jurisdictions in the United States that use direct/photo enforcement for red-light running and driving through an automated toll lane without a transponder could be useful in this regard. Moreover, the institutional and legal implications associated with issuing citations and/or warnings based on an automated system should also be researched.

2.1.3.3. Highway and Pavement Design

Highway and pavement design is another major application of traffic data. The AADT, K-factor, D-factor, and traffic growth factor are all estimated from traffic count data, which are then used to determine the directional design hourly volume (DDHV) for highway design. In addition, the traffic count and weight data provide the main inputs for pavement design. The traditional AASHTO pavement design method acts on the number of ESALs expected across the design life of a section of roadway to produce a pavement design. The relationship between ESALs, which are dependent on vehicle axle weights and configurations – often determined from WIM data, and pavement performance was empirically established based on an extensive test program conducted many years ago. AASHTO has developed a mechanistic-empirical pavement design method, which as the name implies, is the result of an extensive effort to better characterize pavement performance based on engineering principles as well as empirical observations. This design method has been implemented through the Mechanical-Empirical Pavement Design Guide (MEPDG). With the introduction of MEPDG, the future pavement design will rely more on traffic data inputs. The traffic data required by the MEPDG include many metrics relating to the speed, volume, configuration, and weight of the vehicles in the traffic stream. All required input data are obtained from traffic data collection programs. Axle weight data by vehicle configuration typically collected by WIM systems are used to generate axle load spectra, which are an essential and fundamental element in the mechanistic-empirical design method (replacing the use of ESALs).

Currently, many states in the U.S. are calibrating the MEPDG software and preparing for the use of this new approach in their pavement design. To support the new design method, the North Carolina Department of Transportation (NCDOT), for example, sponsored a study to develop the required inputs from WIM data (Stone, et al. 2011). This study developed seasonal vehicle classification and truck axle loading clusters for site specific, regional and statewide traffic inputs to be used in the mechanistic-empirical design approach. In addition, vehicle class forecasting methods were proposed for MEPDG procedures.

Software has been developed to process WIM data in order to create the inputs required by the mechanistic-empirical design approach. For example, PrepME, software developed by Dr. Calvin Wang, University of Arkansas, is capable of inputting raw data into database tables, performing traffic data checks, interpolating traffic data, and preparing 11 files that can be directly imported into MEPDG software (Brogan, et al. 2011). Another example is the Bull Guide software developed by Prof. Taek Kwon, University of Minnesota, Duluth, for visualizing and evaluating WIM data for load spectra and creating input files for MEPDG software (Mn/DOT 2011).

2.1.3.4. Freight and Fleet Management

Commercial motor vehicle carriers can benefit from the data provided by a traffic monitoring program in many ways. Miller and Sharafsaleh (2010) studied the use of WIM data for commercial motor vehicle carriers and summarized some of the benefits as:

- improved reliability of scheduling highway-based freight deliveries,
- improved efficiency of trips,
- increased productivity,
- leveled playing field for safe and legal carriers,
- improved confidence levels in meeting transport contracting requirements,
- enhanced company monitoring of driver performance and compliance, and
- enhanced vehicle fleet tracking and goods tracking capabilities.

Using WIM data for freight and fleet management is not a new practice. Over the last decade, Europe has seen a noticeable acceleration in the development of intelligent freight management, which are systems based on information and communication technologies in the domain of the transportation of goods (Janin 2008). Under these systems, information (e.g., travel information, weight information, access rights, fees and toll collection, safety and emergency services, regulation on transportation of hazardous goods, etc.) is exchanged electronically among those in the supply chain. The messages involved in the processes have been standardized at an international level by the Centre for Trade Facilitation and Electronic Business (CEFACT) organized under the umbrella of the United Nations. Moreover, in the context of aggressive competition between companies, these systems support administrative stakeholders in public policy making and enforcement.

In addition to being incorporated into comprehensive ITS systems, WIM data also serve specific purposes in heavy vehicle transportation management. Pedestrian injuries and fatalities brought about by heavy trucks are a significant issue in urban areas. WIM systems were reported as one of the major ITS technology systems for heavy goods vehicle transport management in the Tokyo urban area, with the purpose of reducing traffic accidents caused by heavy goods vehicles (Taniguchi and Imanishi 2008).

2.1.3.5. Other Needs and Opportunities

In addition to the previously discussed traditional application areas, with the ever-evolving WIM sensor technologies, the use of WIM systems has been expanded to new fields. One new application is to enhance traffic operation and safety through real-time detection of vehicle problems such as unbalanced axles, trucks or trailers, and lurching; tires with insufficient pressure, excessive weight, or unbalanced twin tires; and driving in the wrong direction ("ghost-driver-detection"), and to then inform the appropriate authorities of the problem. Other pavement and traffic management applications include "weigh-based-tolling" with individual fees, monitoring and securing tunnels, detection of upcoming and existing traffic jams, prediction of upcoming road maintenance issues long before they appear, and very detailed statistics and predictions of current and future traffic flow. It can be expected that the uses of WIM data will extend to almost all transportation activities.

Currently, the traffic data collection, highway inventory data collection, and pavement condition surveys are usually conducted by different divisions in state DOTs. With the automation of those data collection activities, large amounts of transportation data are now available. Thus, there is a trend and a need to create a data warehouse to integrate ATR/WIM, Pavement Management System, material, construction/rehabilitation, and inventory data, with the aid of ever-evolving database and GIS software. An integrated data warehouse and a standard data format are easier to manage and understand and better serves policy makers, transportation practitioners, and the general public. These trends and needs have been recognized at the 14th Annual North American Travel Monitoring Exposition and Conference, NATMEC 2010. Researchers reported at NATMEC 2010 that it is challenging to generate a uniform report from systems manufactured by different companies (Brogan, et al 2011). Currently, no solution has been found to this challenge, although commercial management software available from vendors such as MS2 (as previously described) may offer promise in this regard.

2.1.4. Data Collection Site Selection and Prioritization

As with most devices, ATR/WIM performance is affected by a number of factors. Those factors include not only the characteristics of the vehicles being counted, classified, and/or weighed but also the type, condition, and geometry of the road section where it is installed. To make certain that the ATR/WIM system operates at its maximum potential, it is important to give full consideration to site selection. In addition, every ATR/WIM deployment is a long-term investment that requires resources for installation, maintenance, and data reduction. In a resource constrained environment, a planning strategy is necessary to optimize an agency's investments in its ATR/WIM program. This section summarizes the ATR/WIM site selection criteria and program prioritization methods reviewed in the literature.

2.1.4.1. ATR Siting

Continuous vehicle volume data are required to develop the hour-of-day, day-of-week, and month-of-year factors that are used to expand short-term counts to AADT (FHWA 2013). Therefore, traffic factor grouping has substantial impact on the site selection for ATRs.

The Georgia Department of Transportation (GDOT) uses one primary criterion and six secondary criteria for selecting the location of a new ATR site.

- Primary Selection Criterion
  1. Minimum of five to eight ATR sites per traffic factor group depending upon the traffic patterns and precision desired.
- Secondary Selection Criteria
  1. Critical nodes on high volume roads that are used in the step down method.
  2. Replacement of ATR sites that were eliminated due to construction.
  3. Adequate coverage of each of the seven GDOT Districts to ensure geographic differences in travel trends are captured.
  4. Minimum of one operational ATR site per Interstate route.
  5. Minimum of one operational ATR site on other major arterials.
  6. Area of particular interest to GDOT management for planning purposes or to meet specific Federal requirements (GDOT 2012).

In addition to the selection criteria developed by agencies, some research studies have been conducted on optimizing ATR locations using statistical methods. In the early 1990s, Mountain-Plains Consortium sponsored a project for the optimal placement of ATRs (Cheng, Nachtsheim and Benson 1992). The study yielded two computer-based statistical methods using an exchange algorithm and a two-stage sampling algorithm to locate a set of ATRs, with the purpose of improving the overall efficiency and accuracy of AADT estimates. In the exchange algorithm, ATR sites are sequentially added to and deleted from the site design, which generates highly efficient designs without exhaustively searching through all possible designs. In the two-stage sampling approach, similar sites are statistically clustered, and then the optimal weights are calculated for each cluster. Based on these optimal weights, a random sample of sites is selected from within each cluster. The State of Delaware also launched a project to establish a comprehensive statewide traffic counting program comprised of ATR and WIM sites (Faghri, Glaubitz and Parameswaran 1996). In the first phase of the project, methodologies using descriptive analysis and seasonal grouping were developed to determine the number and location of sites needed for each of the three types of traffic monitoring devices.

2.1.4.2. WIM Siting

Unlike ATRs that only record traffic counts and classification, WIMs also measure the magnitude of the forces applied by the vehicle and convert this force measurement into an estimate of vehicle weight, which imposes higher requirements on site selection. Currently, the most commonly accepted standards on WIM site selection is ASTM E1318 (2009). The specification provides the requirements for WIM site condition with regard to road alignment, cross slope, lane width, surface smoothness, pavement structure, climate environment, power, and data communication. ASTM E1318 forms the foundation for the WIM site selection criteria and procedures developed by WIM users and vendors.

Site selection was examined by the Oklahoma Department of Transportation in a research project conducted on advanced WIM (Sluss, et al. 2007). The study provides a general checklist of site selection criteria shown in Table 10.

Table 10: WIM Site Selection Criteria

Criterion	Objective	Criteria
1	Distance from controller unit	Drive time (minutes)
2	Roadway Geometry	Alignment, cross-slope, lane width
3	Pavement structure	Thickness
4	Traffic mix	Percent trucks and total volume
5	Multiple lanes	Number of lanes
6	Power and Communications	Distance to service
7	Right-of-way	Distance to safe parking
8	Adjacent space	Park calibration truck
9	Space for structure	Area of building
10	Sign bridge structure	For mounting overhead devices
11	Roadside pole	For mounting overhead devices
12	Lighting	Security and night visibility
13	Pavement condition	Rutting, cracking, and smoothness
14	Pavement rehabilitation	Rehabilitation schedule
15	Circuit time for calibration truck	Cycle time
16	Sight distance	For clear visibility
17	Proximity to highway patrol and enforcement site	Ground truth for weights
18	Access to satellite sites	Distance from primary site
19	Safety features	Longitudinal barriers
20	Traffic congestion	Free-flow or stop-and-go
21	Bending plate WIM	Existing, buildable, or not buildable

Table Source: Sluss, et al. (2007)

The study also states, "In the preliminary site evaluation, steps need to be taken to find that there are no alternative routes to circumvent the system by overweight trucks. The site chosen should be such that it is not a point of high congestion such that more delays may creep into the highway traffic."

Pavement surface roughness is an important factor during WIM site selection. FHWA's Turner-Fairbank Highway Research Center sponsored a research project on the roughness criteria for WIM scale approaches (Karamihas and Gillespie 2002). The study yielded international roughness index IRI limits of 0.95 and 4.17-ft/mi (0.789-m/km) for long range and short range WIM approaches. Short range approaches were considered to be the pavement about 9.8-ft (3-m) preceding the scale, the scale itself, and about 1-ft (0.3-m) beyond it, while long range approaches included about 82-ft (25-m) preceding the scale, the scale itself, and about 9.8-ft (3-m) beyond.

The WIM site selection criteria suggested by Han, Bennet and Luk (2010) includes specific requirements on road geometry and pavement conditions. It is strongly recommended that the road section between 164-ft (50-m) upstream and 82-ft (25-m) downstream of the system meets the following geometric characteristics:

- Longitudinal slope < 1 percent (class I site) or < 2 percent (other site classes) and as far as possible must be constant (site classes according to European specification COST 323).
- Transverse slope < 3 percent.
- Radius of curvature >3280-ft (1000-m). Ideally a straight road would be preferred.

Han, Bennett and Luk (2010) further recommend that rutting and deformation does not exceed 0.16-in (4-mm) over the whole width of the lane and that the maximum IRI is less than 10.6-ft/mi (2-m/km) for the 16-in (40-cm) preceding and following the sensor.

Cardinal Engineering Inc. (undated), a WIM vendor, summarized the general WIM site selection step as follows:

1. Refer to ASTM 1318 for required roadway characteristics, i.e. smoothness, curvature, slope, etc.
2. Conduct a site survey to determine proximity to utilities and, if required by the application, to the weigh station.
3. Narrow the field of choices to two or three then take another look to make certain that there are no other factors (merging traffic, adjacent power transmission lines, etc.) that could adversely affect the performance of the scale.
4. Adequately identify the site with coordinates and description.
5. After the final selection is made, ensure that any scheduled paving or striping in the area will not affect the scale.

In addition to the criteria provided by WIM users and vendors, several research studies have been conducted to develop analytical models and procedures using optimization algorithms to determine WIM locations. Mahmoudabadi and Syedhosseini (2013) proposed a procedure to determine WIM locations for best performance using the number of once-checked trucks' axle loads, unnecessary actions, and average installing costs as optimization criteria. Besinovic, Markovic and Schonfeld (2013) proposed a model based on k-shortest paths to allocate WIM checkpoints while considering that overweight trucks try to bypass checkpoints along the shortest unmonitored alternate routes. The model was formulated as a binary program and applied to minimize the damage due to overweight trucks, including pavement damage and environmental damage.

Sayyady, et al. (2013) performed research into models and algorithms for locating WIM sensors on a large-scale highway network. One scenario considered in the study was how to find the optimal locations for a given number of WIM sensors among a given collection of candidate locations. Using the Integer Programming Model (IPM), the optimized locations for WIM sensors were obtained through maximizing the similarity of truck load distribution patterns for the set of WIM sensor locations.

At the other end of the spectrum, new sites can be more subjectively selected using a process formally labeled by FHWA as "informed placement" (Krupa and Kearney 2009). This method relies on general professional knowledge of locations with high incidences of overweight truck activity to guide WIM site location. Fernando, et al. (2009) indicated that Indiana similarly sited new installations on "troublesome" roads (and goes on to comment that they used piezoelectric systems designed to provide VWS capability).

2.1.4.3. System Prioritization and Planning

As necessary as ATR/WIM systems are for traffic data collection and detecting overweight trucks, these systems, particularly WIMs, require resources to install and maintain. Therefore, prioritization and planning such systems within resource constraints is a major issue for transportation agencies. This literature review found few studies and standards that address this issue.

ATRs need to collect continuous data to be used for developing hour-of-day, day-of-week, and month-of-year factors that are used to expand short-term counts to AADT. The precision and accuracy of the factors that are developed will always be improved if more ATRs are available, obviously a balance must be struck between the number of sites and the accuracy of the factors (FHWA 2013). Having well established state-wide goals and objectives for the precision and accuracy of the traffic monitoring program will help in determining what the balance point is for the number of sites. The TMG recommends that the division responsible for factor development should work toward having the number of sites required to achieve the desired accuracy and reliability. If more data is needed, the availability of such data from other existing traffic counting programs should be investigated. Mn/DOT leverages the data collected by local road agencies, such as county and city entities, to expand the quantity of data collected for local roads (CTC and Associates LLC 2012). Han, Bennett and Luk (2010), for example, recommend that continuous WIM stations are also used as continuous vehicle volume count sites.

The TMG does also provide a general guide for creating and maintaining a WIM program, however, this guide does not address prioritization of WIM sites within resource constraints. The general guide states:

1. Review existing weight data collection program,
2. Develop an inventory of available weight data collection locations and equipment,
3. Determine roadway weight groups to be monitored,
4. Establish roadway weight groups,
5. Determine appropriate number of weight data collection locations,
6. Determine the number of days that should be counted at a given WIM site,
7. Select WIM sites, and
8. Integrate WIM sites with remaining count program.

In a survey conducted by Cottrell and Kweon (2011), only nine out of 25 responding agencies indicated that their WIM programs were developed following the TMG guidelines.

Han, Bennett and Luk produced a WIM management and operation manual for Austroads in 2010. In the WIM network strategy section of this manual, it lists various factors that need to be considered in developing/guiding a WIM program:

- The purpose of WIM data. It will influence the type of sites, permanent, portable etc., their number, location and type of technology.
- Opportunities to integrate WIM with other technologies such as Automated Vehicle Identification Systems.
- A plan and methodology for determining network coverage in terms of site location, number and type.
- The technologies available, their strengths and weaknesses/characteristics relevant for the required purpose.
- The equipment's full life cycle costs (installation, calibration and maintenance).
- The cost of the systems used for data processing and reporting including quality assurance (QA) systems and processes.
- A staged plan for implementation including integration with road design, construction and maintenance processes to minimize installation and ongoing maintenance costs.
- Staff numbers and skills requirements including training expenses.
- Justification and feasibility.
- Opportunities to incorporate costs into and link to other corporate programs or initiatives such as long term pavement performance, enhancement of safety and air quality, Safe Systems, weight enforcement, etc.
- Contribution of WIM sites to traffic data collection program (volume, classification, speed) as additional permanent traffic counting sites.
- A time horizon of 5 to 10 years.

The manual also describes the current practice of road agencies in Australia and New Zealand on establishing the required number of sites. The required number of sites is determined by assessing the sample size required to achieve the desired statistical accuracy (e.g. 90 percent confidence level with ±10 percent accuracy) for selected "truck weight groups". Some criteria for defining truck weight groups include: geographic groups, functional classification, and truck volume.

Several studies pointed out the importance of cost in WIM site selection. In the study conducted by the Oklahoma Department of Transportation (Sluss, et al. 2007), it is stated that cost factors should be considered during WIM site selection. Similarly, in the study performed by Sayyady, et al. (2013), a scenario for allocating WIM sites with a budget constraint was examined. The budget-constrained problem was considered an extension of the well-known p-median problem, and a new Lagrangian heuristic algorithm was presented to solve the problem. However, those studies didn't consider other resource constraints and factors that influence WIM site selection.

2.1.5. Concluding Remarks

The reviewed literature focused on four subareas of traffic data collection programs, namely data collection technology, data transmission and management, data users and uses, and data collections site selection/prioritization. With continuing advances in technology, traffic data collection systems similarly continue to improve relative to quality and cost, both through ongoing development of traditional sensing systems as well as the introduction and development of new systems. As a result, a variety of approaches are used for ATR and WIM systems. For ATRs these systems range from traditional pneumatic tubes and inductance loops, to more recently introduced radar, video, magnetic, etc. systems. For WIMs these systems range from single load cells, bending plates, and piezoelectric sensors, all of which have been commonly used since the 1990's, to emerging fiber optic sensors. Each of these technologies has its strengths and weaknesses, and to-date there is no single technology that monopolizes the market. That being said, and centering on the primary focus of this investigation, i.e., WIM systems, piezoelectric sensors are possibly the most frequently mentioned type of sensor, and more specifically, quartz piezoelectric sensors, relative to balancing data quality and cost. Contemporary cost information, however, was sparse in the literature, making any cost based comparisons made herein less certain in nature.

Data transfer and communication is an integral part of a traffic data collection program. The most commonly employed communication technologies are landline, cellular, and wireless technologies. Specifically, high-speed wireless and network technologies (e.g. DSRC, mobile network, Ethernet) are necessary to transmit real-time data and are the development trend for data communication of new generation of ATRs/WIMs. After the raw data are transferred to the data control center, an application software program is then utilized to process the raw data. The typical software is capable of generating output reports in the FHWA's TMG Card Format. The software is also capable of generating daily, weekly, monthly, or continuous summary reports in hourly increments based on vehicle speed, classification, ESAL, and weight summaries on a lane by lane or directional basis. A variety of such software packages have been developed by agencies and vendors to serve for specific purposes, such as data submittal, weight enforcement, and data storage and presentation.

Traffic data serve many transportation related activities, including weight enforcement, pavement design, transportation planning, policy making, freight management, traffic safety, asset management, etc. WIM data in particular is essential to pavement design and is increasingly being used in weight enforcement. To accommodate application of the relatively new mechanistic-empirical pavement design method as implemented in the MEPDG, several states have conducted studies to develop axle load spectrum using WIM data. Moreover, software packages are available to process WIM data to create input files for MEPDG based software. Relative to the use of WIM technologies in vehicle weight enforcement, Europe has a long history of using the WIM/SWIM system for direct weight enforcement. Although direct WIM weight enforcement has not been approved in the United States, (i.e., wherein tickets are issued simply based on WIM weights), many states have employed WIMs or VWS (sometimes in conjunction with a LPR system or an automatic vehicle identification system) to facilitate weight enforcement. Montana has done significant work in this regard, with other pioneer states including California, Florida, and Minnesota. Recognizing inherent advantages of WIM as opposed to static scales for weight enforcement, some states have begun to retrofit existing WIM systems to serve as VWS and/or insist that all new WIM sites have VWS capability.

To facilitate use of traffic data, many states make historical traffic data available on the internet. Increasingly these data are presented using interactive maps and are integrated into a GIS database to assist in their use across a spectrum of other activities (such asset management, planning, etc.).

Due to resource constraints, every effort should be made to optimally locate any new data collection sites. A single accepted method for prioritizing new data collection sites does not exist. Criteria for site selection may include competing priorities of collecting sufficient data system wide to a) provide a desired level of statistical accuracy to project vehicle operations through space and time at a project level, b) allow for more efficient weight enforcement based on identification of problem areas, and c) provide adequate data for planning purposes throughout the state independent of absolute volume of traffic. Selection methodologies range from the use of mathematical algorithms to significant reliance on informed opinion. On a positive note, this situation allows each state to develop and use a prioritization scheme appropriate to their individual situation. Of course, once a site is generally selected there are further constraints on its associated physical characteristics that need to be met to ensure safe and reliable data collection (i.e., pavement condition, geometrics, etc.).

2.2. Survey Study

To investigate the current traffic data collection practices and technologies in other states, a questionnaire was sent to selected states. Not intended to be exhaustive, the survey focused on gathering information from states that are similar to Montana with areas of low population density, geographically extensive highway networks, and natural resource based economies. The TDCA Section identified seven states and provided contact information of the traffic data collection program in each state. Those seven states were Idaho (ID), Oregon (OR), Minnesota (MN), Maine (ME), Colorado (CO), North Dakota (ND), and South Dakota (SD). The survey, itself, reviewed and augmented by the MDT TDCA Section consisted of four major sections:

1. Overview of traffic data collection program,
2. Data collection technology,
3. Traffic data collection, analysis, and presentation, and
4. Traffic data users.

The complete questionnaire is presented in Appendix A, along with the responses that were received. Responses were only secured from three states – ND, SD and ME. Note that before the survey questionnaire was sent out, the research team searched the open literature and each state DOT website and filled in some of the requested material in an attempt to reduce the effort required to complete the entire questionnaire.

Extensive follow-up contacts were made with those entities that did respond to further verify important information and clarify various issues, including missed, misunderstood, and ambiguous answers.

2.2.1. General Description of Traffic Data Collection Program

This section summarizes the information requested to generally describe the traffic data collection program of each respondent, including number of ATR/WIM sites, practices for management/operation of their traffic program, and program planning/prioritization efforts.

2.2.1.1. Size of WIM and ATR Programs

Table 11 shows the number of ATR and WIM installations in each responding state at the time of the survey (2013). The traffic data collection programs of ND, SD, and ME are very comparable in size, consisting of approximately 15 WIM sites and 50 to 65 ATRs. Note that while at the time of this survey (2013), Montana had a similar number of ATRs (62), Montana's WIM program was considerably larger, consisting of 33 sites. Referring to Table 11, in general, the percentage of functioning ATRs is noticeably much higher than that of WIMs. This difference is attributable at least in part to the greater resource demands in maintaining WIM versus ATR sites. ND and ME have two permanent WIM/ATR sites shared with partners outside of the DOT, indicating the multiple uses of and interest in traffic data beyond the state DOT.

Table 11: Size of Current WIM and ATR Traffic Data Collection Program

State	Number of WIM sites	Number of Functioning WIM sites	Number of ATR sites	Number of Functioning ATR sites	Number of WIMs/ATRs owned by data sharing partners outside of DOT
SD	15	14	62	62	None
ND	13	7	50	49	2
ME	16	9	69	66	2

Relative to other technologies currently used for collecting traffic data year-round, ND reported the use of Miovision video technology (Miovision 2013), which is marketed by the manufacturer as a simple reliable alternative to pneumatic tubes for short term traffic counts. ME indicated that they employ radar cameras, a nonintrusive ATR technology appropriate for both short and long term traffic counts.

With only three responses to the survey, additional documentation related to the overall size of permanent and short term traffic counting was used to supplement this section. The number of ATR sites in Montana is comparable to many peer states with similar areas of low population density, geographically extensive highway networks, and natural resource based economies, as shown in Table 12. Idaho and Oregon, however have a notably greater number of ATR systems than the other states shown in Table 12, including Montana, with a greater density of coverage relative to both highway system extent (miles of road) and volume of traffic carried (daily vehicle miles of travel (VMT)). As noted above, the number of WIM sites in Montana is considerably greater than in surrounding states. Montana has diverse economic activity with significant and distinct commercial vehicle operations, which may merit being better monitored with an increased number of WIM sites.

Table 12: ATR/WIM Sites, Roads, and Traffic for a sampling of states

State	ATR Sites	WIM Sites	Total Permanent Sites	State Owned Miles of Road	Daily VMT (thousands)
CO	~100	Unknown	Unknown	9,061	81,236
ID	~180	~13	~193	4,985	23,812
ME	~70	~16	~86	8,366	28,273
MN	~70	~22	~92	11,811	90,787
MT	63	43	106	11,004	23,310
ND	~50	~13	~63	7,394	18,816
OR	~180	~22	~202	7,659	54,703
SD	~60	~15	~75	7,766	16,954

CO ATR: Stolz (2010)
ID ATR & WIM: Idaho Transportation Department (2016)
OR ATR: Oregon Department of Transportation (2015)
OR WIM: FHWA (2013)
State own road miles and daily VMTs: FHWA (2015)

Table 13 provides information about the number of annual short-term counts performed in Montana and other states and their associated state owned road miles and traffic levels.

Table 13: Short-Term Counts, Roads, and Traffic by State

State	Annual Short-Term Counts	State Owned Miles of Road	Daily VMT (thousands)
AR	~4100	16,418	68,679
CO	~2500	9,061	81,236
IL	~3100	15,976	158,759
ME	~3300	8,366	28,273
MT	**~3000**	**11,004**	**23,310**
NE	~3500	9,949	34,587
NV	~2900	5,387	33,754

AR, IL, NE, & NV counts: CTC & Associates LLC (2012)
CO annual counts: Stolz (2010)
ME annual counts: Maine Department of Transportation (2016)
State own road miles and daily VMTs: FHWA (2015)

Referring to Table 13, the number of short-term counts conducted by MDT is similar to the number of short term counts conducted by multiple other states with somewhat similar amounts of traffic and road miles. The number of short term counts performed by an agency is dependent on many factors, and while this simple comparison cannot take into consideration all these parameters, it does show that the number of short-term counts in these states are of the same order of magnitude.

2.2.1.2. Management and Operations of Traffic Data Collection Programs

The staffing, organizational structure, and duties of the traffic data collection units in DOTs vary significantly from state to state. The traffic monitoring program in SD has six permanent employees and one supervisor, most of whose work load is on short-term traffic data collection instead of permanent ATR/WIM sites. In ND, different sections are in charge of traffic data collection and ATR/WIM site maintenance and calibration. The traffic data collection section has six full time employees (FTEs), including one section leader, two traffic data analysis/quality control office personnel, and three traffic data collection field personnel with one only devoting 50 percent of his working time to traffic data collection duties. The traffic data collection unit in ME is in charge of ATR/WIM functions and performs preliminary analysis of traffic data, while the majority of the data analysis is accomplished by the transportation analysis division of the Bureau of Planning.

Table 14 presents the level of effort used in accomplishing various traffic data collection duties in the three responding states. Referring to Table 14, it is a common practice for state DOTs to contract out the installation and repair functions of ATRs/WIMs. ND contracts out the installation and repair function of both ATRs and WIMs. ME has one Senior Technician who oversees the WIM program and performs some maintenance and repair work of WIMs, but contracts out most of this as well as all installation activities. SD contracts out the repair and calibration of WIMs with IRD. Since SD is satisfied with the current number of ATR/WIM sites they have no plan to add more new site, new ATR/WIM installation is not a major issue for SD. Note that even for those functions that are contracted out, the DOTs still assign personnel to oversee them.

Table 14: FTE for Each Traffic Data Collection Duty

Function	SD	ND	ME
Installation	0.5	Contracted out	+
Maintenance	0.5	8	+
Repair	0.5	Contracted out	+
Calibration	0.5	8	1 for WIM
WIM/ATR Data Processing	0.5 for collecting and 0.5 for analyzing	2	No specific FTEs assigned

\+ 1 for ATR/ most of WIM contracted out for each function

As for the ATR/WIM functions done in house, ME has one technician who is responsible for installation, maintenance, and repair of all volume and classification sites; ND assigns eight FTEs for ATR/WIM maintenance and calibration (whom are administratively in a separate division/department from the Data Collection Department); and all the personnel in the SD's traffic monitoring program allocate only about one percent of their working time to each of the ATR/WIM functions. It is important to note that according to the SD engineer who responded to the questionnaire, most of the hours and labor of the traffic monitoring staff in SD are spent on short-term traffic data collection, since the permanent ATR/WIM sites operate automatically.

The number of personnel responsible for ATR/WIM data processing and their work load also varies across states. ND assigns two FTEs for ATR/WIM data processing, quality control, and analysis. SD has one individual responsible for data collection and one individual for data analysis, but they only allocate 50 percent of their working time to those duties (0.5 FTE for each task). In ME, the majority of the data analysis is accomplished by the transportation analysis division rather than the traffic monitoring program. The employees in the transportation analysis division all have mixed duties; therefore, no specific level of FTE is assignable precisely to ATR/WIM data analysis in ME.

Table 15 shows the WIM calibration practice of the three responding states. All three states follow the ASTM E1318 (2009) standard procedure, using a truck with known weight to perform WIM calibration. The test vehicles are the Type 9 truck specified by ASTM weighting up to 80,000-lbs (36290-kg). Each state uses the same system calibration interval of once a year. SD usually calibrates its systems in the summer; ND calibrates its systems in late summer or fall, while ME performs system calibration in late fall and early spring. The criteria used for WIM calibration varies between the three states. SD uses a threshold of ±10 percent for load cell WIMs and ±15 percent for bending plates, since load cells are more accurate systems than bending plates. ME uses a stricter threshold of ±5 percent for WIM calibration. ND responded that they make calibration runs with the calibration vehicle until they are satisfied that the site cannot be calibrated any further or that the results cannot get any better; thus, ND does not have specific calibration thresholds.

Table 15: WIM Calibration

States	SD	ND	ME
Method	truck with known weight	calibration vehicle with known weight	calibrated truck
Test Vehicle	SDDOT supplied class 9 semi	5-axle semi-tractor/trailer loaded between 76,000 to 80,000-lb (34470 to 36290-kg)	class 9 vehicle weighing 80,000-lb (36290-kg)
Threshold	±10% for load cells; ±15% for bending plates	no specific threshold	±5%
Cycle	yearly	yearly	yearly

Table 16 shows the annual ATR and WIM program costs by various services and duties in the surveyed states. The costs of the various state programs are difficult to compare based on the disparities in the information provided by the respondents in this regard. SD does not have cost records by task across their program, but they did report the combined cost of all ATR needs is $10,000, and annual calibration costs (a contracted service) of $20,000. ND bids out ATR/WIM installation and repair, with annual costs varying based on the number of sites involved. ND estimated the combined cost of maintenance and data collection (power, phone lines, etc.) at $35,000 to $40,000 per year. ND specifically reported that $110,000 was spent annually on traffic data analysis (SD and ME did not report this cost).

ME has detailed cost information for most program tasks for both their ATR and WIM systems. The ATR and WIM site installation are the biggest expense for ME, especially WIM installation, which costs $85,000 to 150,000 per site. ME performs ATR and WIM maintenance in-house, at annual estimated costs of $30,000 and $35,000, respectively. ME estimated their annual system repair costs to be $10,000 for ATRs (done in-house) and $25,000 for WIMs (contracted out). WIM calibration costs were reported by ME to be $30,000 per year. Recall ME does calibration in-house. Data collection and transmission costs (power, phone lines, etc.) were reported by ME to be $35,000 and $10,000, respectively, for their ATR and WIM programs.

Table 16: Annual Costs for ATR and WIM programs

Services and Duties	Annual Cost ($)					
	SD		ND		ME	
	Done in house	Contracted out	Done in house	Contracted out	Done in house	Contracted out
Installation	*	+	+	N/A depends on the number of sites being installed, but this work is bid out	ATR- $60,000	WIM $85-150,000 per site
Maintenance	*	+	$35-$40k (includes Traffic Data Collection)	+	ATR- $30,000 WIM- $35,000	+
Repair	*	+	+	N/A depends on the number of sites being repaired, but this work is bid out	ATR- $10,000	WIM- $25,000
Calibration	*	WIM - $20,000 yearly	$10,000	+	WIM- $30,000	+
Traffic data collection from WIM and ATRs (i.e. telephone, power, etc.)	*	+	$35-$40k (includes Maintenance)	+	ATR - $35,000 WIM- $15,000	+
Traffic data analysis	*	+	$110,000	+	+	+
Distribution (i.e. compiling/printing of monthly, annual publications, etc.)	*	+	This is an estimate only < $5000	+	ATR- $2,500 WIM- $1000	+

* Combined cost of all Services and Duties is $10,000.
+ Information not provided in response.

2.2.1.3. Program planning/prioritization

Each of the responding states employed different strategies in developing their ATR/WIM programs. SD responded that they followed the TMG for determining the current locations of ATR/WIM sites and will do so in planning/prioritization of future ATR/WIM sites. SD is satisfied with their current permanent traffic data collection program. At the time of the survey, SD had only one more WIM site scheduled to be installed in 2014. SD has no plans to add more new sites in the near future; thus, program planning/prioritization is not an issue in SD.

The first 12 WIM sites in ND were selected near static weigh stations to supplement weight enforcement activities, since these weigh stations were open only during limited times. Since 2006, ATR/WIM sites have been determined using a long range ITS Deployment Plan based on

a) traffic volume needs for design, b) growth, and c) gaps in coverage. ND will continue to use and update its ITS Deployment Plan, as well as listen to stakeholders and customers in the planning/prioritization of future ATR/WIM activities/sites.

ME has different strategies in determining data collection locations based on the nature of the data to be collected, i.e., volume, classification and/or weight data. The majority of volume sites have been located on the higher Federal functional classes and concentrated in larger cities/towns with high priority given to the Interstate System. Most of the 16 counties in ME were given at least one site. Permanent classification sites were placed in areas requested by the Bureau of Planning based on major trucking and recreational traffic routes. WIM locations were selected to give a broad cross section of interstate truck traffic using both major and minor routes. Planning for new sites in ME is generally based on a) needs of the Bureau of Planning, b) areas where significant development has occurred, and c) changes in commercial vehicle weight laws.

2.2.2. Data Collection Technology

This section summarizes the ATR/WIM technologies, and technologies for communication between ATR/WIM sites and traffic control centers currently employed by the responding states, along with new ATR/WIM technologies that they are testing for possible future deployment.

2.2.2.1. Current Technologies

Table 17 presents the brand and/or technologies currently employed by the three responding states for ATRs, WIMs, and data communication. Referring to Table 17, inductive loop, piezoelectric, and radar systems are the most popular ATR technologies in the three responding states, while piezoelectric, bending plate, and load cell WIM systems are commonly used. This outcome is consistent with the findings from the literature review. The common brands employed across these states include Peek (inductance loop ATR), Wavetronix (radar ATR), Kistler (quartz piezoelectric WIM), and IRD (WIM load cell and electronics). Communication with sites often appears to be landlines, with some fiber optic and cellular operations.

Table 17: WIM and ATR Technologies

State	SD	ND	ME
ATR	Peek ADR 6000 system, piezoelectric, Wavetronix radar sensors and loops.	PEEK portable ADR and road tubes, Diamond Traffic portable volume counters and road tubes, Miovision Video technology, PEEK permanent models ADR	ATR Volume – Peek ADR counters, inductance loops ATR Classification – Peek ADT counters, Wavetronix Smart IQ Radar sensor, Measurement Specialties Brass Lingini Class 2 piezoelectric sensors and inductance loops
WIM	IRD load cells, bending plates and Kistler quartz piezoelectric	IRD WIM electronics and Kistler piezoelectric sensors	Ecm Hestia 2 and 6 lane systems using Kistler instrument Quartz sensor; Mettlor Toledo systems using Kistler sensors
Communication	Telephone line	Fiber optic, hard line telephone, cellular	Landlines (dial up @ 9600 Baud) and cellular communication

2.2.2.2. New Technologies under Testing

Survey respondents indicated some new communication and ATR technologies are under investigation in their states. ND expected to test the use of IP addressable communications at several WIM locations in fall of 2013. In addition, a traffic data sensor study is being performed by the Advanced Traffic Analysis Center (ATAC), which is a branch of NDDOT and North Dakota State University. ME also reported that they are testing the Aldis Gridsmart camera for volume counting. That being said, no new WIM sensor technology testing was reported by the three states.

2.2.3. Traffic Data Collection, Analysis, and Presentation

This section summarizes the questionnaire responses regarding data items collected, data formats used, types of data analysis performed, and data presentation/accessibility, as well as future goals in these regards.

2.2.3.1. Types of Data Collected

As might be expected, all three respondents reported that traffic volume and vehicle classification data are collected at their ATR sites, weight data along with volume and classification data are collected at their WIM sites. ND and ME indicated that speed data are also collected, while SD indicated that while they collect speed data, they do not focus any attention on it since they are not currently required by FHWA.

2.2.3.2. Data Format

SD and ME indicated that their ATR traffic data are binned, while their WIM data maintains IVRs. ND indicated that their ATR and WIM data include both IVR and binned data.

2.2.3.3. Data Analysis

All respondents generally analyze the traffic data they collect to generate typical information on vehicle volume, classification, speed, and weight by location and time. ND responded that they perform weight trend and speed analyses by time-of-day and day-of-week on the traffic data collected. Traffic data analysis in ME is mainly accomplished by the Transportation Analysis Division of the Bureau of Planning. The Traffic Monitoring Section of the Traffic Engineering Division performs some basic analysis such as generating AADT and weekly group mean factors. The analysis of WIM data is mainly for pavement design, including calculation of ESALs for the traditional design method and developing seasonal variation and truck load distributions by vehicle type required by the MEPDG.

2.2.3.4. Data Presentation and Accessibility

All respondents make data available to some degree and in various formats through the internet. SD responded that a GIS system is used internally to display traffic data but that they have no intention of more generally making GIS based data display available in light of associated costs and possible user inability to take advantage of such a system. Data reports are available for download online in portable document format (PDF) for external users. In ND, all the portable traffic counts data are available on the NDDOT website for external users to view. Other traffic data are not available online at this time, but are accessible to external users upon request. NDDOT provides customers with traffic data in several types of formats depending on their needs, such as ArcGIS/ArcMAP shape files, PDF, and Excel files. In ME, the latest annual traffic count report by county and by municipality is available online for download in PDF. Additionally, annual traffic volume by site, day and hour-of-day are generated and made available on their website. Traffic data are scanned into the Department's electronic filing system and are also available by request.

2.2.3.5. Future Goals

As for the future goals regarding data collection, analysis, and presentation of ATR and WIM data, ME expressed the intention to develop a comprehensive software system to collect, analyze, and store all types of traffic data and to provide more information to the public online. Currently, the in-house programs in ME utilize Microsoft Access/Excel and Visual Basic to process and store traffic data. A GIS system is being considered to allow for easier traffic data retrieval.

2.2.4. Traffic Data Users

This section summarizes the questionnaire responses regarding traffic data users and unmet data needs.

2.2.4.1. Current traffic data users

With a few exceptions, all three states indicated they currently provide data to all the internal users (planning staff, traffic operations, traffic safety, highway design, weight enforcement, and speed enforcement) and external users (FHWA, colleges/universities, consulting companies, and realty companies) listed in the questionnaire. SD and ND responded that their traffic data have not been used for speed enforcement. In addition, SD noted that the state legislature does not allow them to use weight data for weight enforcement. Besides all the uses listed in the questionnaire, ME also indicated that they provide real time speed and traffic condition data as well as highway images for major highways for their traveler information system.

2.2.4.2. Unmet data needs

Only ME indicated they had unmet data needs. One such need is for more classification data in urban areas as requested by their Bureau of Planning; however, there are only a few technologies that are able to provide these data and they are expensive. A second need is to process their speed data to meet new federal reporting requirements.

2.2.5. Concluding Remarks

The current practices of selected states (specifically SD, ND, and ME) relative to traffic data collection (from permanent ATR and WIM sites), data processing, and data uses were investigated through a questionnaire completed by these states. The questionnaire focused on states that are similar to Montana with areas of low population density, geographically extensive highway networks, and natural resource based economies.

Results of the questionnaire revealed that the three responding states have comparable sized WIM and ATR programs, with 50 to 70 ATR sites and approximately 15 WIM sites. Montana has a similar sized ATR program with 64 permanent sites, but a much larger WIM program with 42 sites. Additional literature related to the overall size of permanent and short-term traffic counting found that Montana has a similar total number of permanent and annual short-term counts as many other states. The staffing, organizational structure, and duties of the traffic data collection units varied considerably from state to state, making it difficult to formulate comparisons of program level-of-effort and costs. Further complicating such comparisons are the degree to which various tasks are accomplished by outside contract. It appears to be common practice to contract out installation and repair functions of ATRs/WIMs, although perhaps MEs practice well describes the variability of practice in this regard, wherein these functions are done in-house by ME for ATR systems but contracted out for WIM systems. Whether done in-house or contracted out, all three responding states follow the ASTM standard procedure for WIM calibration, which is performed annually. Relative to prioritization/planning of future data collection sites, each state had a unique approach in this regard, from generally following TMG guidelines, to satisfying state specific needs based on projected growth or other factors.

From a technology perspective, the questionnaire found that inductive loop, piezoelectric, and radar systems are the commonly used technologies for ATRs, and piezoelectric sensors, followed by bending plates and load cells are common for WIMs. The popular brands among responded states include Peek and Wavetronix ATR systems, and IRD/Kistler WIM systems. Dial-up landlines and cellular communication are the common communication technologies for ATR/WIMs reported in the survey.

Commonly collected traffic data include volume, classification, and weight. Usually traffic counts and traffic data reports are made available online for users to view and download. Traffic data are also accessible to external users by request, with the data provided in various types of formats (e.g. ArcGIS/ArcMAP shape files, PDF, and Excel) depending on the users' needs. There is a trend of making more traffic data available and more easily accessible to the public. SD reported, however, that while they made data available in map based GIS application for internal users, such a platform was not planned for external users due to cost and possible user system constraints.

The results of the questionnaire revealed that most of the internal and external users listed on the questionnaire are currently served by the responded states (i.e. planning staff, traffic operations, traffic safety, highway design, weight enforcement, speed enforcement, FHWA, colleges/universities, research institutes, consulting companies, and realty companies). In addition to the users listed in the questionnaire, some states also provide real-time traffic data to serve travelers through the Traveler Information System.

2.3. Summary

A comprehensive literature review on traffic data collection programs was conducted as the first task in this project to review MDT's traffic data collection program to ensure it provides the best possible traffic information in the most cost effective manner. This review was complemented by a survey of selected states expected to have general traffic operations similar to Montana to obtain more current and complete information on traffic data collection programs than might be available in the literature. While considering data collection by both automatic traffic recorders (ATR) and weigh-in-motion (WIM) systems, this review focused on WIM programs.

Both the literature review and survey found that many approaches are available to accomplish the various tasks associated with a data collection program, from basic data collection, transmission, analysis and dissemination, to the administrative structure of the program, itself. Further, relative to both individual tasks and the architecture of overall data collection programs, no one model has been consistently followed by state DOTs in performing their basic data collection function. Nonetheless, general observations from the literature review and survey (previously presented in more detail at the conclusion of each of these sections of this report) include:

- While sensor systems continue to evolve, well established technologies continue to be most frequently used i.e.:
    - pneumatic tubes and inductance loops for ATR, with radar and magnetic based systems offering promise and apparently being increasingly used, and
    - piezoelectric, bending plate, and single load cells for WIM (ordered by their relative degree of use).
- Current cost information was difficult to find, and the survey data in this regard were difficult to interpret. That being said, ATR systems remain less expensive than WIM

systems. With respect to one another, WIM systems, apparently as in the past, increase in cost from piezoelectric, quartz piezoelectric, bending plate, to single load cell systems.

- Communication technologies are landline, cellular, and wireless technologies. With high-speed wireless and network technologies (e.g. DSRC, mobile network, Ethernet) being necessary to transmit real-time data and are the trend for the new generation of ATRs/WIMs.
- Many software packages are available to check data for accuracy and to generate metrics needed for various activities such as weight enforcement, pavement design, transportation planning, freight management, traffic safety, asset management, etc.
- Many states make historical traffic data available on the internet. Increasingly these data are presented using interactive maps and are integrated into GIS databases.
- A rapidly emerging use of WIM is for real time weight enforcement using a virtual weigh station (VWS) approach (which can impact both site and hardware selection), with some states both using this as a criteria in locating new WIM installations as well making all WIM sites VWS compatible.
- Approaches to prioritizing future WIM site locations range from a qualitative "informed placement" approach based on professional opinion of the location of overweight vehicle problem areas, to analytical models acting on quantitatively expressed optimization criteria.
- ND, SD, and ME, the three states that responded to the survey, have comparable WIM and ATR programs, with Montana having a similar sized ATR program but significantly more WIM sites.
- The staffing and duties of the traffic data collection programs varied considerably between ND, SD and ME, making it difficult to formulate comparisons of basic level-of-effort and costs.
- ND and SD contract out installation and repair functions of ATRs/WIMs, although perhaps ME's practice well describes the variability of practice in this regard, wherein these functions are done in-house by ME for ATR systems but contracted out for WIM systems.

3) MDT TRAFFIC DATA COLLECTION PROGRAM DESCRIPTION/INVENTORY

Working with MDT, the composition and organizational structure of their traffic data collection program was reviewed and characterized, focusing on program

- size, relative to the number and nature of the data collection sites being used;
- data collection technologies, focusing on sensor type, typical installation layout, and data communication technology;
- personnel and administrative structure, relative to the number of employees, management structure and job duties;
- costs, including all site related equipment and activity costs (i.e., installation, maintenance, operation and calibration), and data reduction and dissemination costs as done by in-house and by contracted personnel, and planning, encompassing prioritization of future sites and future goals of the overall program.

3.1. Size of the Traffic Data Collection Program

MDT collects traffic data using a combination of short and long term counts. The short-term count program employs portable equipment to gather traffic data over a duration ranging from 48 hours to several days. The locations at which short-terms counts are conducted are not fixed, and they significantly outnumber the permanent data collection sites, as short term counts are relatively inexpensive to perform. ATRs and WIMs form the permanent data collection program, which are generally employed to continuously monitor roadway use at fixed sites on the state's highway network. In addition to monitoring the traffic at fixed sites, data gathered from permanent ATR/WIM systems are also important in converting/factoring/seasonally-adjusting short-term traffic counts to estimate traffic flow across the entire year.

3.1.1. Short-Term Counts

MDT uses three approaches to conduct short-term counts, namely road tubes, non-intrusive traffic data collection camera units, and manual counts. There are approximately 5,800 locations across the state at which short-term counts are collected. Data, however, are not collected at every site each year. Approximately, 3,000 short-term counts are conducted annually. Table 18 shows the count cycle for short-term counts on different highway systems. In 2012, over 3,000 portable counts were conducted, of which 65 were non-intrusive traffic data collection camera unit counts and the rest were road tube counts. Approximately 300 manual counts were also conducted using Jamar boards to verify WIM/ATR performance and obtain data on recreation vehicle (RV) traffic.

Table 18: Short-Term Count Cycle

System	Cycle
Interstate	Annual
Non-Interstate NHS	Annual
Primary	Biennial
Urban	Annual
Secondary	Biennial
State Highway	Every three years
Off System	Every three years
Interstate Ramps	a minimum every six years (higher volume ramps get counted on a minimum three year cycle)

Given the usefulness of traffic data and the relatively low cost of installing and operating portable equipment, multiple agencies aside from MDT employ portable devices to collect traffic data. Cities, counties, and MPOs across Montana have and continue to do counts using portable equipment at various sites, especially in urban areas. MDT shares its short-term counts with, and gets data from multiple agencies. With the implementation of the TDCS, all short-term counts are uploaded to a shared database.

3.1.2. ATR/WIM Systems

As of June, 2016 a total of 64 ATRs are operated by MDT across the state's highway network. The locations of these ATRs are shown in Figure 1, and selected site characteristics are listed in Table 19 and Table 20. Referring to Table 19 and Table 20, MDT has four types of ATR sites based on the data collected, namely volume only sites (VOLUME), class by length sites (LENGTH), axle classification sites (AXLE), and motorcycle (MC-CLASS) sites. Table 21 summarizes the number of each type of ATR. The number of length based classification sites is three times of the number of axle based classification sites. All the length based classification sites employ loop technology. MDT intends to upgrade them to axle based classification sites with piezoelectric technology. Relative to age/condition, it has been over 10 years since approximately one-third of the permanent ATR sites have received a major equipment upgrade.

In addition to the volume and class sites, MDT has 17 motorcycle capable sites. The ATR motorcycle sites are an important component in MDT's traffic data collection program, as FHWA requires that each state provide motorcycle VMT as part of the Highway Performance Monitoring Systems (HPMS). In addition to meeting FHWA's requirements, MDT also needs to maintain a sufficient number of ATR motorcycle sites to characterize use of the highway system by this vehicle type (e.g., recreational versus commuter travel).

According to the latest updated data (September 27, 2016), MDT lists 42 WIM sites in their inventory. The location of the WIM sites is shown on Figure 1, and selected site characteristics are presented in Table 22.

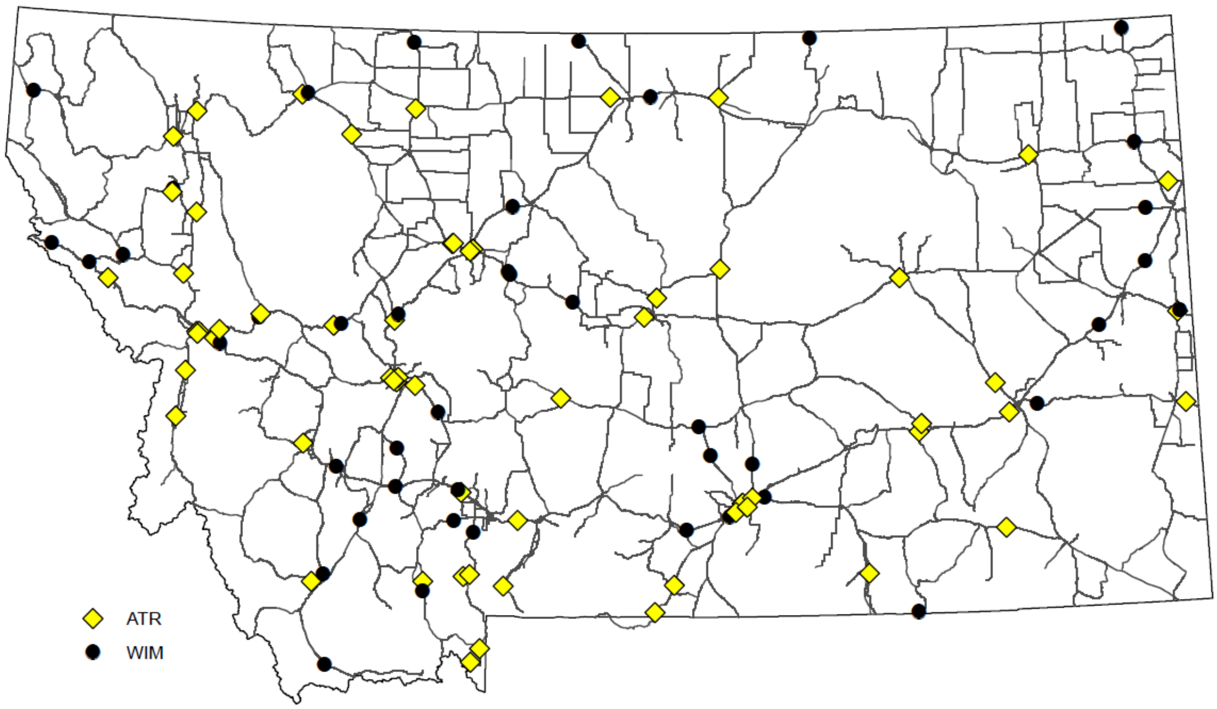


Figure 1: WIM and ATR Sites (MDT GIS Data; ESRI ArcMap)

Table 19: ATR Sites (Part I)

SITE ID	Communication Method	Sensor Type	Secondary Sensor Type	Data Collected	Year Established	Last Major Upgrade
A-02	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1961	06/06/13
A-03	Phone	PDVF Piezo	Ind. Loop	AXLE	1988	10 + Yrs
A-05	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	1940	8/10/2010
A-06	Cell. Internet	Ind. Loop	Ind. Loop	VOLUME	1939	10 + Yrs
A-08	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	1961	7/16/08
A-09	Cell Internet	Ind. Loop	Ind. Loop	LENGTH	1940	10 + Yrs
A-10	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1940	9/15/2010
A-12	Cell Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	1940	6/7/2012
A-13	Phone	Ind. Loop	Ind. Loop	LENGTH	1940	10 + Yrs
A-14	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1940	8/15/2011
A-15	Phone	Ind. Loop	Ind. Loop	LENGTH	1941	10 + Yrs
A-18	Phone	Ind. Loop	Ind. Loop	LENGTH	1970	10 + Yrs
A-19	Phone	Ind. Loop	Ind. Loop	LENGTH	1950	8/10/2006
A-20	Phone	PDVF Piezo	Ind. Loop	LENGTH	1950	2010
A-21	Phone	Ind. Loop	None	VOLUME	1956	11/1/13
A-22	Phone	Ind. Loop	None	VOLUME	1989	10 + Yrs
A-23	Phone	Ind. Loop	Ind. Loop	LENGTH	1957	10 + Yrs
A-24	Phone	Ind. Loop	Ind. Loop	LENGTH	1957	10 + Yrs
A-26	Phone	Ind. Loop	None	VOLUME	2010	1/26/10
A-27	Phone	PDVF Piezo	Ind. Loop	AXLE	1961	10 + Yrs
A-28	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	1961	9/7/11
A-29	Phone	Ind. Loop	Ind. Loop	LENGTH	1962	10 + Yrs
A-30	Cell. Internet	PDVF Piezo	Ind. Loop	AXLE	1962	2014?
A-31	Cell. Internet	PDVF Piezo	Ind. Loop	LENGTH	1963	8/4/2009
A-32	Phone	Ind. Loop	None	VOLUME	1970	10 + Yrs
A-33	Phone	Ind. Loop	None	VOLUME	1965	10 + Yrs
A-34	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1965	2014?
A-35	Phone	Ind. Loop	Ind. Loop	LENGTH	1965	10 + Yrs
A-36	Cell. Internet	Ind. Loop	Ind. Loop	LENGTH	1966	10 + Yrs
A-37	Phone	Ind. Loop	None	VOLUME	1966	7/20/2004
A-38	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1967	8/27/2009
A-39	Cell. Internet	Ind. Loop	Ind. Loop	LENGTH	1967	10 + Yrs
A-40	Phone	Ind. Loop	Ind. Loop	LENGTH	1968	10 + Yrs
A-42	Phone	Ind. Loop	None	VOLUME	1972	10 + Yrs
A-43	Phone	Ind. Loop	Ind. Loop	MC-CLASS	1972	8/15/2013
A-44	Phone	Ind. Loop	N/A	VOLUME	N/A	2/28/13
A-46	Cell. Internet	Ind. Loop	Ind. Loop	MC-CLASS	N/A	5/2/13
A-47	Cell. Internet	PDVF Piezo	Ind. Loop	LENGTH	1980	5/1/07
A-49	Phone	Ind. Loop	Ind. Loop	LENGTH	1980	10 + Yrs

Table 20: ATR Sites (Part II)

SITE ID	Communication Method	Sensor Type	Secondary Sensor Type	Data Collected	Year Established	Last Major Upgrade
A-50	Phone	Ind. Loop	None	VOLUME	1981	4/20/2006
A-51	Phone	Ind. Loop	None	VOLUME	1981	12/30/13
A-54	Phone	Ind. Loop	None	VOLUME	1984	10 + Yrs
A-56	Cell. Internet	PDVF Piezo	Ind. Loop	AXLE	1986	4/26/10
A-57	Cell. Internet	PDVF Piezo	Ind. Loop	AXLE	1992	2013
A-58	Phone	Ind. Loop	Ind. Loop	LENGTH	1986	2015
A-59	Cell. Internet	PDVF Piezo	Ind. Loop	AXLE	1990	8/9/10
A-60	Phone	Ind. Loop	Ind. Loop	LENGTH	1982	8/26/04
A-61	Phone	PDVF Piezo	Ind. Loop	AXLE	1991	9/14/2004
A-63	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1992	8/5/09
A-64	Cell. Internet	Ind. Loop	Ind. Loop	LENGTH	1992	10 + Yrs
A-66	Phone	PDVF Piezo	PDVF Piezo	MC-CLASS	1992	2014
A-67	Phone	Ind. Loop	None	VOLUME	1993	10/30/2012
A-68	Phone	Ind. Loop	None	VOLUME	1993	10 + Yrs
A-69	Phone	Ind. Loop	None	VOLUME	1995	2/23/10
A-70	Phone	Ind. Loop	Ind. Loop	LENGTH	1998	2007
A-71	Cell. Internet	PDVF Piezo	Ind. Loop	AXLE	2002	8/21/12
A-72	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2009	2009
A-73	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2009	2009
A-74	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2009	2009
A-75	Manual	PDVF Piezo	PDVF Piezo	MC-CLASS	2011	2011
A-76	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2012	2012
A-77	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2012	2012
A-78	Cell. Internet	PDVF Piezo	PDVF Piezo	MC-CLASS	2015	2015
A-79	Cell. Internet	PDVF Piezo	PDVF Piezo	AXLE	2016	2016
A-80	Cell. Internet	PDVF Piezo	PDVF Piezo	AXLE	2016	2016

Table 21: Number of Each Type of ATR

ATR Type	Number	%
MC-CLASS	20	30.8
AXLE	10	15.4
LENGTH	20	30.8
VOLUME	15	23.1

Table 22: WIM Sites

SITE ID	Communication Method	Sensor Type	Secondary Sensor Type	Year Established
W-101	Wireless Internet	Quartz Piezoelectric	Loop	1996
W-103	Phone	Quartz Piezoelectric	Loop	1997
W-104	Wireless Internet	Quartz Piezoelectric	Loop	1996
W-107	Wireless Internet	Quartz Piezoelectric	Loop	1997
W-110	Wireless Internet	Quartz Piezoelectric	Loop	1997
W-111	Wireless Internet	Quartz Piezoelectric	Loop	1998
W-113	Phone	Quartz	Loop	1999
W-114	Phone	Quartz Piezoelectric	Loop	1999
W-115	Phone	Quartz Piezoelectric	Loop	1999
W-116	Wireless Internet	Quartz Piezoelectric	Loop	1999
W-117	Wireless Internet	Piezoelectric	Loop	1999
W-118	Phone	Quartz Piezoelectric	Loop	1999
W-120	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-121	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-122	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-123	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-124	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-125	Phone	Quartz Piezoelectric	Loop	2001
W-126	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-127	Wireless Internet	Quartz Piezoelectric	Loop	2001
W-128	Wireless Internet	Quartz Piezoelectric	Loop	2005
W-129	Wireless Internet	Quartz Piezoelectric	Loop	2007
W-130	Wireless Internet	Piezoelectric	Loop	2005
W-131	Wireless Internet	Quartz Piezoelectric	Loop	2006
W-132	Phone	Piezoelectric	Loop	2006
W-133	Wireless Internet	Quartz Piezoelectric	Loop	2008
W-134	DSL	Quartz Piezoelectric	Loop	2008
W-135	DSL	Quartz Piezoelectric	Loop	2008
W-136	Phone	Quartz Piezoelectric	Loop	2009
W-137	Wireless Internet	Quartz Piezoelectric	Loop	2010
W-138	Wireless Internet	Quartz Piezoelectric	Loop	2011
W-141	Wireless Internet	Quartz Piezoelectric	Loop	2012
W-142	Wireless Internet	Quartz Piezoelectric	Loop	2012
W-143	Wireless Internet	Quartz Piezoelectric	Loop	2013
W-144	Phone	Quartz Piezoelectric	Loop	2013
W-145	DSL	Quartz Piezoelectric	Loop	2013
W-146	Wireless Internet	Quartz Piezoelectric	Loop	2014
W-147	Wireless Internet	Quartz Piezoelectric	Loop	2016
W-148	Wireless Internet	Quartz Piezoelectric	Loop	2016
W-149	Wireless Internet	Quartz Piezoelectric	Loop	2016
W-203	Wireless Internet	Quartz Piezoelectric	Loop	2000

The Motor Carriers Service Section of MDT used to operate four bending plate WIM sites for weight enforcement screening purposes only. As the sites deteriorated, the TDCA section replaced the bending plates with Kistler Quartz piezoelectric sensors and assumed responsibility to maintain those sites. The one remaining bending plate WIM (Station ID: W-201) is no longer functional. TDCA is working to relocate the existing site which will be equipped with Kistler sensors and included in the WIM inventory. MDT has concluded that quartz piezoelectric WIM sensors are more cost effective than bending plate systems in meeting their traffic data collection needs, based in part on the results of two studies they sponsored at Montana State University (MSU) on WIM system performance (Bylsma and Carson 2002, Carson and Stephens 2004).

3.1.3. Future Goals

A major future goal of MDT's data collection program is to expand and improve the traffic count exchange program, i.e., - sharing data with local governments/entities. In addition to short term counts, efforts are underway to include data from permanent/continuous counters in the traffic count exchange program. In Missoula, for example, MDT shared the responsibilities of operating three permanent ATR sites with local Missoula agencies. The local agencies (consisting of the City of Missoula and the Missoula MPO) paid for installation of these three ATRs within its urban boundaries. MDT staff maintains the equipment and downloads and processes the data from the ATRs. Missoula is responsible for paying the power and phone bills for the sites. Also, if the sites are extensively damaged beyond regular wear and tear (i.e. hit by a car - which has happened numerous times), Missoula is responsible for purchasing new electronic equipment, cabinets, etc. for repairing the sites, while MDT field operation staff will conduct the repair work.

In addition to incorporating both short term and permanent counts in the exchange program, future efforts will also be made to improve and optimize the exchange program. With MDT and local governments/entities working together, both agencies can adjust their traffic data collection systems to reduce redundancy in terms of collected data type and data collection sites, and thus save staff resources at both the state and local levels. Further, opportunities will be pursued to improve MDT's traffic count coverage for lower function class roads through collaboration with local governments. Interactions with local governments and other entities as part of the data exchange program will also be used to increase their awareness and knowledge about traffic data, how they are processed and how they can be used.

3.2. Data Collection Technologies

Various technologies are employed by MDT for portable and permanent traffic data collection in Montana. Compared to portable sites, the technologies used for permanent sites usually have a higher level of automation and reliability. To supplement the automatic methods for short-term data collection, manual methods are employed to collect certain types of data that serve a specific purpose. This section documents the technologies used for portable short term and permanent sites in Montana, along with the future development and needs.

3.2.1. Short-Term Sites

Three types of technologies/methods are employed in Montana to collect short-term data, namely, road tube counters, non-intrusive video equipment, and manual count boards. The portable equipment usually consists of sensors installed on top of the roadway surface or located at the edge of the road and controllers temporarily placed along the edge of the road. There are approximately 5,800 short term count sites across Montana, however not all counts are taken every year. Counts are taken at approximately 3,000 short-term sites per year. This does not include the approximately 400 counts received each year from data sharing partners.

3.2.1.1. Road Tube Counters

Road tube counters use road tubes (rubber hoses) as sensors to record axle crossings as tires strike the tube. Data collected includes volume, vehicle classification (FHWA 1-13), and speed. The data collection duration is 48 hours for vehicle volume and classification counts. The counter programming and road tube layout determine the type of data that can be collected. Figure 2 shows a typical layout of a road tube counter capable of collecting classification data. Notably, such a layout typically requires two road tubes in each lane in the direction of travel so that vehicle speed can be determined and used in interpreting the data to infer vehicle configuration. The road tubes are connected to an electronic counter that logs and processes the data generated as vehicles cross the pneumatic tubes. MDT uses a single tube setup for volume counts. MDT has 296 active portable tube counters.

3.2.1.2. Non-Intrusive Traffic Data Collection Camera Units

Non-intrusive traffic data collection camera units continuously record images of traffic from a fixed field of view. The equipment used in Montana, from Miovision (Ontario, Canada) does not capture images of license plates or of vehicle occupants. Currently, the TDCA Section has nine Miovision Camera units, of which 2 units are 5 years old, 3 units are 4 years old, and 4 units are 3 year old. The equipment is usually mounted on a mast tied to a support pole (e.g. street light or sign post) and is chained /padlocked for security. Figure 3 shows a unit secured to a traffic light pole.

Figure 2: Typical Vehicle Classification Road Tube Setup (Wuertley and Little 2013)

The video data are processed via a computer program from the vendor to determine volume and vehicle classification. This service is contracted out to the Miovision company. Note that unlike the road tube counters that classify vehicles into the FHWA 1-13 classifications (FHWA 2014), the non-intrusive traffic data collection camera units classify vehicles based on their length using a calibrate pixel measurement process. Vehicle length based classification is not unique to this particular system, but is also typical of other non-intrusive traffic data collection equipment, such as radar and acoustic units. If FHWA classification data are required, they can be obtained through reviewing the raw video and manually classifying the passing vehicles. The count duration for non-intrusive traffic data collection cameras varies from 48 hours to several days. It is a technology used by multiple agencies (e.g. MDT and MPOs) in Montana to collect short term traffic data.

Cameras are a non-intrusive sensing technology, i.e., sensors do not need to be placed in the roadway. Thus, an advantage of non-intrusive traffic data collection camera units is that they do not require traffic technicians to work in the roadway, which makes them safe to install and operate. Another advantage of using this technology for short term counts is that they are better at classifying motorcycles than road tubes.

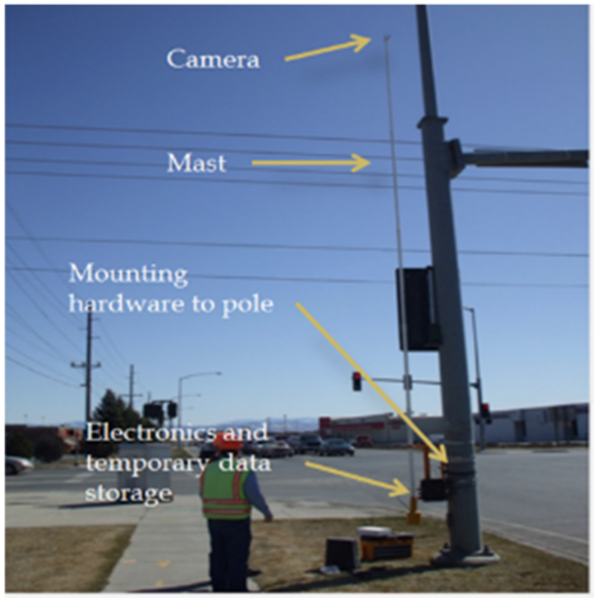


Figure 3: Typical Non-intrusive Traffic Data Collection Camera Unit Setup (Wuertley and Little 2013)

3.2.1.3. Manual Count Board

For the manual method, traffic data are collected visually by traffic technicians and entered manually into an electronic count board (Jamar brand boards are used) via push-button controls. In addition to volume and vehicle classification (FHWA 1-13), data collected manually can also include special data such as number of bicycles, pedestrians, and recreational vehicles. The count duration is typically four hours. Manual counts are used as a quality control check on all permanent sites, as well as for intersection studies and special studies as needed by MDT. The four-hour manual counts used for special studies are mainly to provide the vehicle distribution (13 vehicle class) needed to develop project level accumulated vehicle loading forecasts for roadway design. While longer term automated counts (i.e., tube counts) are preferable to manual counts, such automated counts can be difficult to conduct at some locations (mainly urban areas). Miovision camera units can be used in such locations, but Miovision's post-processing only classifies vehicles into six classes, namely, motorcycle, car, pickup, bus, small commercial, and articulating commercial. Thus, manual counts need to be conducted on the data collected by the Miovision camera units in order to generate the vehicle distribution based on 13 vehicle classes. Manual counts have been conducted in response to requests for safety improvements relating to noise abatement studies or potential re-routing of traffic.

3.2.2. Permanent Sites

ATR and WIM are the two principal types of permanent data collection equipment. A typical permanent site consists of 1) sensors embedded in the pavement for data collection as appropriate for the nature of the site; and 2) infrastructure that includes shoulder-mounted pull boxes, conduit (cabinet-to-pull box, pull box-to-pull box under the road where applicable), and a cabinet to hold various electronic components. The cabinet includes an electronic controller, with hard line or wireless communication access.

3.2.2.1. ATR Sites

Piezoelectric sensors and inductive loops are the two major technologies used for ATRs in Montana. The ATR piezoelectric sensors are made by Measurement Specialties, Inc. (MSI), and the inductive loops are laid out by TDCA personnel using 14 AWG type 51-3 wire provided by various suppliers. The ATR electronics vendor is Diamond Traffic Products.

Based on the data collected, there are four configurations of ATRs in Montana, namely volume only sites, class by length sites, class by axle sites, and motorcycle sites. For volume and length classifier sites, inductive loops are used. Axle classifier sites use both piezoelectric sensors and inductive loops. Motorcycle capable sites only use piezoelectric sensors (no inductive loops). The piezoelectric sensors used at ATR sites are a BL sensor, a type of PVDF piezoelectric sensor provided by MSI.

Figure 4 through Figure 7 show the schematic layouts of the four site configurations. Note that for the configuration in Figure 7, both half-lanes need to be operational in order to collect motorcycle and vehicle count data. If just one half-lane is operational, the site collects vehicle counts only.

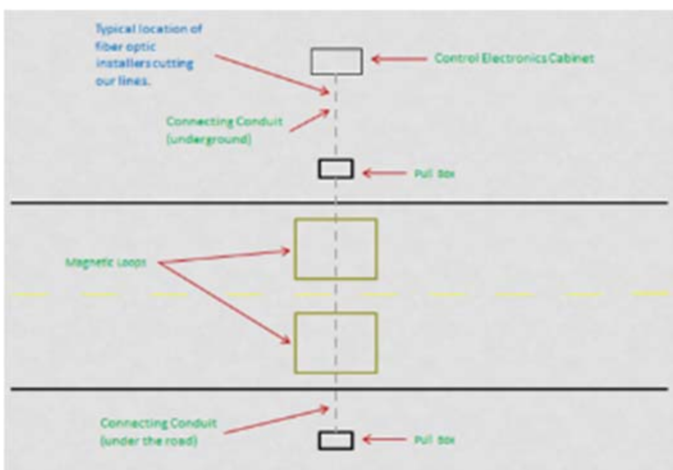


Figure 4: Schematic Layout of an ATR Site–Volume Configuration (Wuertley and Little 2013)

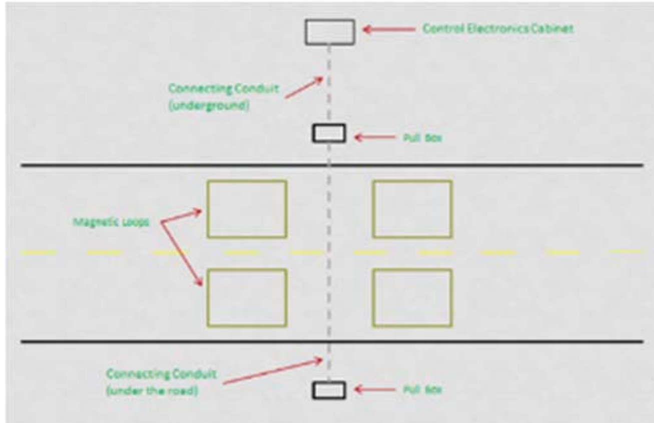


Figure 5: Schematic Layout of an ATR Site–Length Configuration (Wuertley and Little 2013)

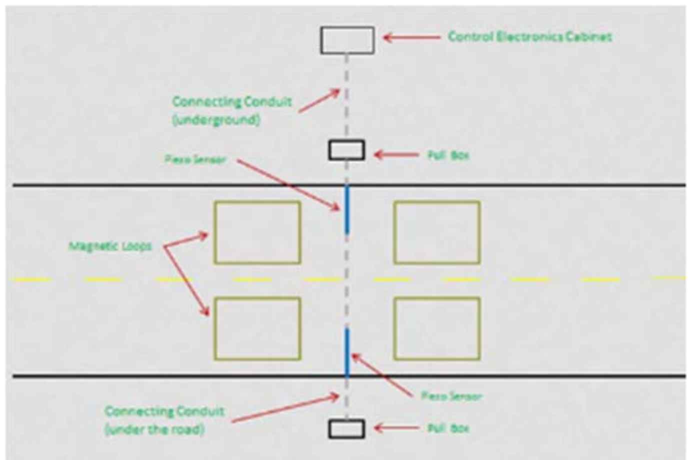


Figure 6: Schematic Layout of an ATR Site– Standard Axle Classifier
(Wuertley and Little 2013)

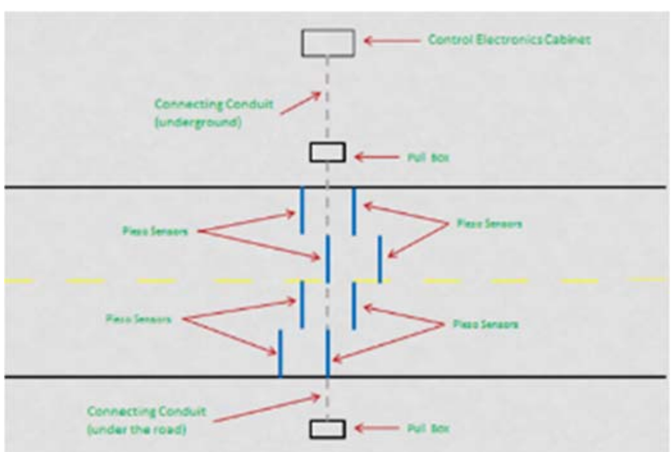


Figure 7: Schematic Layout of an ATR Site– Motorcycle Configuration
(Wuertley and Little 2013)

3.2.2.2. WIM Sites

Figure 8 presents a typical configuration of a WIM site. Piezoelectric sensors are the main WIM technology used in Montana. Almost all the WIM sites use Kistler quartz piezoelectric sensors. Currently, there are a few sites using ceramic piezoelectric sensors provided by ECM, Inc. (Electronique Contrôle Mesure, Inc.), which will be upgraded to Kistler quartz sensors as schedules, time, and funding permit. Moreover, MDT will use Kistler quartz piezoelectric sensors for all new WIM sites as MDT has found that the quartz piezoelectric technology used in Kistler sensors results in a more accurate, reliable, longer lasting and lower maintenance system compared to other WIM options. Relative to accuracy, the quartz based piezoelectric sensors notably are more inherently stable than other WIM sensor options across the broad range of temperatures experienced in Montana. This inherent temperature stability results in improved performance at the low levels of traffic often encountered in the state.

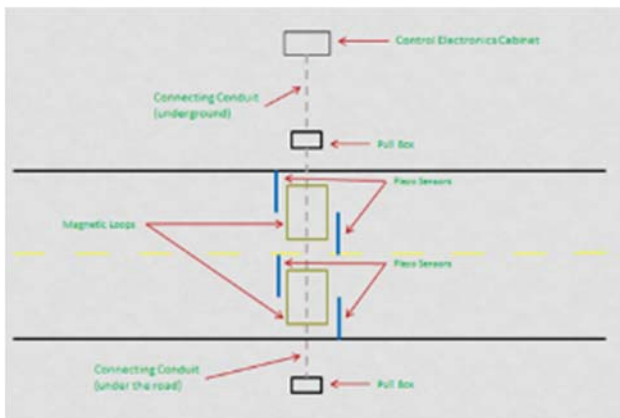


Figure 8: Schematic Layout of WIM Site (Wuertley and Little 2013)

3.2.2.3. Communications

Hard line and cellular internet modems (wireless) are the most commonly employed communication technologies used by MDT for permanent data collection sites. In addition, digital subscriber lines (DSL) are used by two WIM sites, while a manual method is used at one ATR site due to its remote location on the Beartooth Highway (i.e., data is downloaded by connecting a computer to the system at the site). Table 23 presents the number of permanent sites using each type of communication method. Hard line phone is more commonly employed for ATRs, while hard line phone and wireless internet are almost equally used for WIM sites. For wireless internet used for ATRs, most of them are for motorcycle capable sites. Cellular broadband has been considered by MDT, but has not been used due to low availability in remote areas.

Table 23: ATR/WIM Communication Methods

Type	ATR	WIM	Total
Phone	52	17	69
Wireless Internet	9	18	27
DSL	0	2	2
Manual	1	0	1

3.2.3. Future Goals

Collecting traffic data in urban areas is generally problematic, and improving data collection in these areas is one major focus of MDT's traffic data collection program. Outside of urban areas, the currently employed data collection technologies generally meet the needs of MDT, especially the Kistler quartz piezoelectric sensors, which have been found to be very accurate, easy to maintain, and relatively insensitive to Montana's weather conditions. As sensors are replaced at existing WIM sites, MDT intends to transition to using all Kistler quartz piezoelectric sensors, and to use Kistler sensors at all new WIM sites (unless another sensor proves to better meet the needs and conditions mentioned). That being said, most available traffic data collection technologies have issues when deployed in urban environments where stop and go traffic, pavement conditions, and complex traffic movements generally degrade their performance. MDT continues to seek ways to improve collection of vehicle classification data within cities and urban areas.

MDT is looking for a new type of sensor that is capable of collecting volume data on interchange ramps and roadways in urban settings. The sensors and loops currently used on rural roadways can work in these environments, but their installation could be more involved and expensive as real estate in and around interchanges and in urban areas is much more restrictive than it is on the mainline. Further, and of greater concern, roadway closures for system installation and maintenance is problematic on ramps and in urban environments from both a traffic operations and safety perspective.

MDT is investigating puck-style magnetometers epoxied into a borehole in the pavement with wireless data transmission to a nearby receiver. This technology is suitable for use on ramps and high volume urban roadways. These sensors and associated data collection equipment can be installed with minimal interruption to traffic. MDT installed some of these sensors in a test site on an Urban Minor Arterial roadway in Helena and is evaluating the performance of this technology. These sensors only collect volume data, and presently this data cannot be imported directly into the TCDS. MDT will work with its software vendor to overcome this limitation if the sensor technology proves to be effective.

Another technology that addresses concerns with safety and interruption of traffic during sensor installation and maintenance is microloop sensors, which are magnetic sensors placed under the roadway in PVC conduit (Global Traffic Technologies 2007). This conduit can be located up to

24 inches below the road surface and can be installed during or after roadway construction. The sensors can be installed, maintained and re-configured without interfering with the road surface or with traffic. This technology may also merit investigation for ramps and urban environments.

3.3. Composition and Organizational Structure of the Traffic Data Collection Unit

The traffic data collection unit in MDT is the TDCA Section, which is one of two sections under the Data and Statistics Bureau along with the Road Inventory and Mapping Section (RIMS). The TDCA Section consists of fourteen permanent employees, plus a supervisor, and a unit supervisor. In addition, three seasonal staff positions are available as needed.

The TDCA Section is responsible for short-term and permanent traffic data collection, traffic data processing, and data QA/QC and analysis, as well as data presentation/display. The short-term count program within the TDCA Section has five FTE positions, with the program manager located in Helena, a Statewide Trainer/Traffic Technician located in Great Falls and three Traffic Technicians located one each in Glasgow, Missoula, and Billings. The short-term count program is responsible for the deployment, maintenance, and operation of short-term counts, and the collection and initial quality review and submission of the attendant short-term data. Up to three seasonal traffic technicians can be hired based on the needs of the manual/short-term count program and to support special studies.

The Electronics Equipment Unit (EEU), which manages the ATR/WIM installation and maintenance program within the TDCA Section, has five FTEs, with one Unit Supervisor, and four Electronic Repair Technologists (ERTs), all located in Helena. Even when WIM installations are contracted out, the Unit Supervisor or an ERT oversees the installation. In addition, the EEU staff is involved in ATR/WIM site selection and budgeting, and the four electronic repair technologists perform equipment calibration and purchasing.

The TDCA Section has four FTE's for data download, processing and dissemination/display. Two FTEs are assigned to download, process and perform QC. One FTE works specifically with WIM data; the other FTE, with ATR data. Both FTE's are responsible for conducting short term counts and for assisting with site installation as needed. In addition, the section has one FTE assigned for traffic data analysis (such as developing adjustment factors, AADT for off system roadways, etc.) and one FTE particularly for WIM data analysis and reporting. There is one FTE who has the responsibility to incorporate the traffic data into a GIS and is also in charge of data requests. All the data processing staff is located in Helena.

3.4. Management and Operations of Traffic Data Collection Programs

Traffic data collection sites, especially the permanent/continuous sites, involve expensive and sophisticated electronic equipment, which are a major capital investment for state DOTs in addition to the costs associated with staff resources to maintain the sites. After initial installation, proper maintenance, operation, and management of all this equipment is essential to ensure it functions at its full potential and hence maximizes the outcome of the capital investment. The TDCA Section of MDT is responsible for these critical tasks for MDT's data collection systems. Specifically, the EEU staff is responsible for maintaining the equipment and the data analysts/planners are responsible for ensuring the equipment's data output meets MDT's data quality standards.

3.4.1. Short-Term Count Field Operations

The TDCA Section performs installation, removal, calibration, maintenance, repair, and data retrieval functions for short-term data counts. Only video camera image processing is contracted out (to the equipment vendor), as the video camera vendor controls the processing program. Maintenance for short term sites mainly consists of repair/replacement of road tubes. Maintenance of pneumatic road tubes is done by Traffic Technicians using a device that simulates the air puffs generated when vehicles compress the tubes on the roadway. Further, when counts are being taken, MDT personnel routinely check to see if the tubes have come loose.

Data from portable count devices are transferred in the field to computers (typically laptops) via a wired interface using vendor-provided software. The data are typically uploaded to a central count database. The data are checked for quality and accuracy before being incorporated into the traffic data system and made public. Also, as mentioned in previous sections, many cities, counties, and MPOs across Montana collect short term traffic data using portable equipment at various sites, especially in urban areas. Through its traffic count exchange program, MDT shares short-term counts with, and gets data from multiple agencies across the state.

3.4.2. Continuous ATR/WIM Site Field Operations

ATR sites are installed by field operations personnel within the TDCA Section, while WIM systems are installed by TDCA Section personnel or outside contractors. In the case of new WIM sites that are incorporated into a road construction project and are funded by the project, installation is contracted out. The TDCA Section additionally has its own funds that are available to install new WIM sites, with this installation also being contracted out. Equipment necessary to restore existing WIM sites that are removed as part of road construction projects is paid for by those construction projects, and TDCA Section field operations personnel rebuild the installations. Note that in the case of contracted installations, MDT assigns personnel to oversee contractor operations.

Annual routine winter maintenance is done on all ATR/WIM sites starting in early fall and continuing into December. TDCA Section field personnel visit each site at least once a year and conduct a thorough on-site inspection and perform maintenance/repair activities as necessary.

During these on-site inspections, field personnel conduct equipment tests and check all the system components, including sensor condition, site condition, batteries, etc. A detailed check list for ATR winter maintenance activities is attached in Appendix B. In addition to checking the equipment, field operations personnel also record the pavement condition at each site, since pavement condition has significant impact on site function. No quantitative measurements of the pavement surface condition are made, only qualitative observations are noted on the maintenance sheet.

Calibration of ATRs is performed during the winter maintenance cycle. Not all the ATR sites can or need to be calibrated. Volume only sites are not calibrated, since volume ATR sites use only one sensor per lane. The sensor loop either works (detecting the presence of a vehicle), or it does not work. Most of the volume only sites are in urban areas, where calibration runs are difficult to make due to the continuous presence of traffic. To calibrate ATR sites collecting speed and length data, a service truck of known length is driven through the sites at a known speed (verified with a radar gun), and the measurements made by the site equipment are then compared to these known vehicle length and speed values. Equipment parameters are adjusted until the systems report accurate values.

As stated previously, manual counts are done as a quality control check on all permanent ATR and WIM sites. These counts are used to evaluate the accuracy of the number of vehicles detected and vehicle classification. These manual counts, however, cannot determine the accuracy of the speed or length data being collected. Manual counts are done a minimum of four times per year (once each quarter) and are four hours in duration. Manual counts are also conducted if major changes in calibration parameters are made to correct previously reported problems.

The WIM winter maintenance activities are essentially the same as those for ATRs, only calibration is not performed on the WIM sites during the winter maintenance activities. WIM calibrations are typically done in the spring and late summer/early fall, with every site being evaluated at least once per year. WIM and ATR maintenance/calibration are not performed together due to differences in the equipment needed and procedures involved. New sites are calibrated twice a year for the first two years, since the deformation of new pavement in the initial one or two years affects the WIM sensors; usually the pavement settlement stabilizes after two years. Generally WIM calibration is done in accordance with ASTM E1318, but MDT has its own criteria on measurement tolerances, which is much tighter than the criteria in the ASTM standard. A Class 9 truck weighing 78,000 lbs. is used for calibration as shown in Figure 9. TDCA's calibration standard for sites with Kistler quartz piezoelectric sensors is to be within ±3% of the gross weight. This isn't possible at sites with rough pavement surface conditions that result in a lower accuracy. The ASTM standard criterion for Type II WIM systems is ±15% of gross weight.

For the sites using ECM sensors, the accuracy is around ±10% of the gross weight, sometimes reaching ±7%.

Figure 9: WIM Calibration Truck

In addition to routine annual maintenance, special maintenance or repair work is needed when the ATR/WIM equipment fails or has functional errors. Replacement of equipment parts and repair work are scheduled as needed, which also depends on weather, personnel availability, and any other roadway construction projects occurring in the area.

All of the tasks mentioned above are best performed during favorable weather conditions. That being said, Montana has a short construction season coupled with harsh winters often characterized by long uninterrupted periods of protracted cold and/or snow. This situation has a significant impact on the field operations of the TDCA Section, with a major amount of work being compressed into the short field/construction season, and scheduled maintenance and necessary repair work throughout the rest of year often having to be deferred due to severe weather conditions. MDT keeps records of all the repair work done, but the data are not in a readily queried database format. To improve this situation, MDT is developing an Equipment Maintenance Module as part of the department's new Traffic Data Management System (TDMS).

Relative to data retrieval, the ATR/WIM data are stored locally at the point of collection and polled daily via computers controlled by the central office. The data are downloaded directly to these computers, and then custom software programs distribute and process the files semi-automatically.

3.4.3. Site Management

MDT maintains detailed records for each permanent traffic data collection site. These records contain the characteristics/properties of a site, and include station ID, year the station was established, the method of data collection, the method of data retrieval, equipment costs, serial numbers, and detailed location information, etc. Table 24 presents a subset of data items that generate the Station Card which is part of the monthly FHWA data submittal.

Table 24: Station Description Record Items (FHWA 2014)

Field	Description	Field	Description
1	Record Type	22	Type of Sensor
2	FIPS State Code	23	Second Type of Sensor
3	Station ID	24	Primary Purpose - *NEW*
4	Direction of Travel Code	25	LRS Identification - *NEW*
5	Lane of Travel	26	LRS Location Point - *NEW*
6	Year of Data	27	Latitude - *NEW*
7	Functional Classification Code	28	Longitude - *NEW*
8	Number of Lanes in Direction Indicated	29	SHRP Site Identification - *NEW*
9	Sample Type for Traffic Volume	30	Previous Station ID
10	Number of Lanes Monitored for Traffic Volume	31	Year Station Established
11	Method of Traffic Volume Counting	32	Year Station Discontinued
12	Sample Type for Vehicle Classification	33	FIPS County Code
13	Number of Lanes Monitored for Vehicle Class	34	HPMS Sample Type
14	Method of Vehicle Classification	35	HPMS Sample Identifier
15	Algorithm for Vehicle Classification	36	National Highway System - *NEW*
16	Classification System for Vehicle Classification	37	Posted Route Signing
17	Sample Type for Truck Weight	38	Posted Signed Route Number
18	Number of Lanes Monitored for Truck Weight	39	Concurrent Route Signing
19	Method of Truck Weighing	40	Concurrent Signed Route Number
20	Calibration of Weighing System	41	Station Location
21	Method of Data Retrieval		

3.4.4. Evaluation of the Current System and Future Goals

Currently, TDCA Section field operations personnel perform the installation, maintenance, calibration, and repair of the portable and permanent sites, only the new WIM site installations are contracted out. This approach generally meets current operational needs, but resources are strained, particularly in completing summer maintenance and repair activities. As the number of sites increases, more staff will be needed to maintain the program, especially for field operations. In these regards, at locations where WIM installation is being done coincident with another roadway project, it may also be beneficial in the future to include WIM installation as a sub-element of the overall project, in order to reduce TDCA staff time spent coordinating with contractors on WIM installations handled as stand-alone elements of projects.

Pavement condition and pavement projects have significant impacts on the operation and accuracy of data collection sites, especially permanent sites, and reciprocally elements of pavement restoration and preservation projects may be affected if an ATR/WIM site is within the project area. Currently, the TDCA Section has a number of safeguards in place to prevent accidental damage to WIM/ATR equipment as a result of such activities. TDCA receives notification from Engineering or Maintenance staff when they identify a project that may affect an ATR or WIM site. TDCA staff review all project-related traffic data requests to determine if any inroad or roadside equipment is located within or near the project limits. Potential impacts and appropriate contact information are provided as part of the official response to the request for data. As an additional safe guard, WIM/ATR equipment is part of the statewide 811 Locate program. This is specifically aimed at providing notification to entities external to MDT. The TDCA Section also monitors the scheduled project lists and project status reports to anticipate when data will no longer be available from a site due to construction project activity.

The TDCA Section field operations personnel maintain a record of the maintenance activities at each site. While system assets are well documented through this inventory and maintenance data, this information is not incorporated into a database management system. Such a system, populated with updated data on a regular basis, would be useful in proactively managing these data collection assets. Such a system would have to be easy to access, use, and maintain for TDCA field and office personnel. Quantitative measurements of ATR/WIM site pavement conditions need to be developed to more objectively characterize site condition, and so that these data can be readily incorporated into an equipment management database.

Currently, ATR/WIM site condition is basically represented by its age (i.e., years in service), the accuracy of the data collected, and the level of maintenance required to keep it operational. Age is most easily quantifiable, but this single index cannot fully describe the site's physical and functional conditions. Using the framework of the above mentioned database management system, a systematic assessment approach/method needs to be developed to evaluate and determine ATR/WIM site condition. The method should consider the site service years, maintenance history including equipment repair costs, staff resource time dedicated to the site, calibration records, as well as site pavement condition to yield a composite index to describe the site's condition. Ideally, based on the assessed site condition, a guide/process can be developed to determine the optimal replacement cycle of ATR/WIM equipment to achieve the desired level of performance.

3.5. Resources Required for the Data Collection Program

Traffic data collection programs require considerable resources for system installation, maintenance, and data reduction, especially for the permanent ATR/WIM systems. Initial capital investment and ongoing field and office operations costs are the major expenses of the traffic data collection program. This section summarizes the costs of MDT's data collection program, with an emphasis on ATR/WIM systems (all cost information is adapted from Wuertley and Little 2013).

3.5.1. Initial Capital Investment

The ATR/WIM setup costs cover the acquisition and installation of sensors, electronics, and infrastructure. Equipment costs vary for different types, brands, and layouts of systems. Usually, the sensors include epoxy materials and cabling; the electronic equipment includes controllers, modems, batteries, solar panels (if used), regulators, surge suppressors, etc.; and the infrastructure includes pull boxes, conduit, cabinets, and concrete (if used). Table 25 presents the average costs of these three major equipment components and the estimated total installation costs of ATR and WIM systems. Referring to Table 25, the setup costs are approximately six times greater for WIM compared to ATR installations. As might be expected, four-lane configurations cost more than two-lane configurations. Note that among all types of ATRs, motorcycle configurations are the most expensive.

Table 25: ATR/WIM Setup Costs (Wuertley and Little 2013)

System	Component Cost ($)			Total Project Cost ($)	
	Sensors	Electronic Equipment (including communications)	Infrastructure	2-lane	4-lane
ATR	2,500/lane	2,000	1,700	8,700 (Motorcycle Config)	15,700 (Motorcycle Config)
WIM	15,000/lane	20,000	3,000	53,000	86,600

3.5.2. Annual Field Operations Expenses

While the initial setup cost for a portable counter is almost negligible compared to that of a permanent ATR/WIM, the annual operating costs of the short-term count program in Montana are still considerable, as almost 3,000 such counts are performed by TDCA staff each year. The total annual cost of the short-term count program, consisting of operating (labor, equipment, and travel) and supply costs, is $321,370, as detailed in Table 26. MDT conducted a total of 3,252 short-term counts in 2012, including 2,872 portable unit counts, 315 manual counts, and 65 Miovision counts. Based on these figures, the average approximate cost for each short-term count was $100.

Table 26: Annual Operations Costs of Short-term Count and ATR/WIM Programs

Item		Portable Program($)	ATR/WIM ($)
Operating Costs	Labor	152,900	194,393
	Equipment	116,970	105,826
	Travel	31,500	13,500
	Sum	301,370	313,719
Supply Costs		20,000	113,000
Contracting Costs		N/A	105,000 (WIMs only)
Communication Costs		N/A	32,000
Total Costs		321,370	563,719
Approximate Average Cost per Counter/Site		100	5,581

Table 26 also presents the annual operations costs for MDT's ATR/WIM program itemized by type of cost and unit cost per site. The indicated equipment costs for the ATR/WIM programs are for equipment associated with WIM calibration activities. In addition to the regular operating and supply costs, annual costs of the ATR/WIM programs also include communication and contracting costs, since MDT contracts out WIM installation. Based on the 2012 total of 101 ATR/WIM sites, the annual field operation costs per site is approximately $5,500.

3.5.3. Office Operations Costs

The major part of the office operation costs is the salaries of the office staff in the TDCA Section. This estimated cost is $356,000 annually. In addition, the office operation costs also include $104,107 per year in external contracted services (primarily for data processing). Thus the total office operation costs of MDT's traffic data collection program is $460,107 annually.

3.5.4. Summary of Program Costs

Total annual expenditures of the traffic data collection program are estimated to be approximately 1.9 million dollars, consisting of the approximately 1.3 million detailed above, and associated expenditures of 0.4 million dollars on personnel training, traffic data visualization and presentation, etc. That being said, due to weather and resource related constraints, necessary work to sustain the program (i.e., maintenance and repair) has had to be deferred; thus, program resource needs actually exceed the expenditures presented above.

3.6. Program Planning/Prioritization

MDT generally follows the procedure described in the TMG in prioritizing and selecting new traffic data collection sites. In addition, rules and criteria have been developed by MDT over time to supplement the TMG procedures and address specific needs and requirements in Montana. Various factors are considered for ATR/WIM program planning, among which the most important is satisfying traffic data needs.

3.6.1. New Site Selection

Traffic data needs are the primary driving factor in selecting new permanent data collection sites. One important use of permanent sites is to characterize the traffic pattern for each function class and help determine the factors to adjust short-term counts to project annual levels of use. MDT determines the required number of permanent sites for each function class according to the method provided in the TMG. Changes in traffic patterns in one function class and/or the need for improved accuracy in adjustment factors can create a need for new permanent sites. Permanent traffic monitoring sites are also located to capture specific seasonal and spatially varying traffic flows encountered in the state as a result of significant economic activity in the areas of agriculture, natural resource extraction and tourism. In addition, new site selection also addresses the data needs of cooperative programs. For instance, new WIM sites can be and have been added to facilitate weight monitoring, enforcement, and other activities of MCS. The Montana Highway Patrol (MHP) is another cooperative program that influences decisions on new site selection, since traffic data can be helpful in scheduling patrol activities. All such sites, however, still have to fit in some manner within the basic traffic data collection program and its objectives and needs.

The type of new permanent site, i.e., ATR or WIM, is usually determined by the nature of the traffic data needed to support the underlying activity that will use the data collected. Despite this general philosophy, most data users and MDT customers desire WIMs over ATRs, given that WIMs collect data encompassing all the data items collected by ATRs, and more. After a preliminary location is selected for a new site along a road section, MDT personnel are sent to the road section to evaluate if the road section and pavement condition are suitable for site installation. Condition items checked include roadway topography, utility availability, pavement conditions, and equipment specific criteria. These ATR/WIM site selection criteria are presented in more detail in Appendix C. Site upgrades from ATR to WIM are prioritized using similar criteria as for new site selection. In areas where motorcycle data are required, the upgrade of ATR to WIM is restricted, since the current WIM systems are not able to collect motorcycle data.

MDT follows the method provided by the TMG for short-term site selection. Generally speaking, each on-system road traffic section (generally demarcated by changes in traffic control and or geometric alignment along a route) has at least one designated short-term count site. If road traffic sections change, new short-term sites are added. If a new interchange is built, for example, short-term sites will be added to monitor the associated changes in traffic flow. Currently, short-term traffic counts on off-system routes (i.e., routes that are not part of the highway network under MDT jurisdiction) are not a major concern to MDT, but this could change in the near future given FHWA proposed rule-making.

3.6.2. System Planning/Prioritization

As with most public agencies, resource constraints dictate that careful program planning/prioritization are employed to ensure available resources are optimally used in meeting program objectives. Relative to installing/upgrading ATR and WIM sites, TDCA's EEU and data analysis staff meet once a year to discuss and rank installation/upgrade needs versus budget availability for the upcoming fiscal year. Because of variability of construction activities, the EEU supervisor maintains ongoing discussions throughout the season with all interested parties to review and adjust needs and current year repair and installation as necessary. The identified needs are prioritized based on how well they support: 1) improvements to the core Traffic Count Program (i.e. generating adjustment factors necessary to project year around traffic flows from short-term counts), 2) data needs for roadway design including pavement and safety, 3) enforcement (weight and speed), 4) FHWA reporting requirements, and 5) other objectives pertinent to a specific proposed project, judged in importance relative to the preceding criteria. Note, any WIM sites temporarily downgraded to ATRs or out of service are also identified and ranked with any new sites. Usually, restoration of existing sites is given higher priority over new site installations.

As mentioned, while meetings have mainly consisted of personnel from the TDCA Section, input is gathered on an ongoing basis from other impacted Divisions. However, attendance of pavement engineers could be of great help in project selection. If, due to roadway condition or other impediments, the highest priority site is not suitable for system installation/upgrade, consideration moves down the list until a viable site is found. It has happened in the past that the 12th ranked project was chosen for installation. On the other hand, a lower ranked candidate site could be chosen if roadway construction is scheduled at the proposed site location. Such sites are chosen for execution regardless of their ranking to synchronize installation with road construction to save resources and utilize project funds.

3.6.3. Evaluation of Current Methodology and Future Goals

Currently, MDT employs nine traffic factor groups and follows the TMG to determine the appropriate number of permanent traffic collection sites required to characterize each factor group. These groups are used with temporal (seasonal) adjustment factors to obtain annual traffic statistics from short-term counts. At the present time, these adjustment factors are applied to all short term counts statewide. Given Montana's geographically extensive highway network and the social-economic variance across different regions of the state, the TDCA Section has long recognized the need to develop traffic group factors at a more refined regional level. Further, to better support future work of this kind, new ATRs/WIMs need to be appropriately sited to better capture significant seasonal and geographic traffic patterns by region.

Relative to selecting/prioritizing new data collection sites, while MDT follows TMG methods and applies several customized criteria in this regard, the decision making process ultimately is subjectively driven. While this approach has generally fulfilled the needs of the past, the landscape is changing with increasing traffic data demands from various users within and beyond MDT, the social-economic development in the state, the evolution of ATR/WIM technologies, as well as ongoing budget constraints. A hybrid approach incorporating subjective and objective criteria in site planning/prioritization will result in more optimum resource allocation. Mathematical algorithms are available to develop a more objective approach assigning weight to various influential factors in optimizing the deployment of ATR/WIM systems within budget and resource constraints. Taking informed professional opinion into consideration and employing suitable mathematical algorithms, a system planning/prioritization scheme that is appropriate to the situation in Montana can be developed. Guidance on how to possibly move toward this approach are included in Chapter 7 of this report.

Relative to maintaining existing data collection sites, an asset management plan needs to be adopted that optimizes the nature and timing of equipment maintenance, calibration, repair and replacement activities with the objective of collecting the best possible data at the lowest possible cost. Similarly, and as is obvious, in purchasing sensor systems for new data collection sites, life cycle costs should be considered in addition to initial capital investment costs.

In addition, it's in MDT's interest for TDCA staff to work with Maintenance and Pavement staff to develop a pavement monitoring and repair agreement that prevents the loss of inroad sensors due to pavement failure at the site of the sensors. The cost effectiveness of implementing roadway maintenance at the site can be evaluated on an ongoing basis to determine if the cooperative effort is financially beneficial to the Department.

3.7. Summary

A comprehensive description and inventory of the traffic data collection program at MDT was conducted as the second task in this project to review MDT's traffic data collection program to ensure it provides the best possible traffic information in the most cost effective manner. Based on information provided by the TDCA Section and information available on MDT's website, the research team reviewed and documented

- the layout and characteristics of the basic traffic data collection network,
- the data collection technologies used,
- program management and operations,
- the organizational structure of the TDCA Section, program costs, and
- program planning/prioritization methodologies.

While considering both short-term counts and permanent sites, this task focused on permanent/continuous sites (ATR and WIM programs).

The TDCA Section of MDT is responsible for the traffic data program for the state's highway system, and its activities include basic data collection at short term and continuous/permanent sites located around the state; installation, maintenance, and operation of all equipment required for this data collection; transmission, processing (including QA/QC), analysis; and presentation/display of the data that is collected. Currently the primary components of the data collection program are the permanent ATR and WIM sites deployed across the state at which continuous traffic monitoring is performed (64 ATR and 42 WIM sites), and the approximately 5,800 locations across the state at which short-term counts are done, with approximately 3,000 such counts being conducted each year. The continuous sites primarily use inductive loops and quartz-piezoelectric sensors for ATR and WIM data collection. Short-term counts are conducted with road tube counters and non-intrusive traffic data collection cameras, with some manual counts also being performed to verify WIMs/ATRs are operating properly and collect classification distribution samples at volume only sites. TDCA Section field operations personnel (9 FTE) perform the installation, maintenance, calibration, and repair of the portable and permanent sites, only the new WIM site installations are contracted out. Data download, analysis and presentation/display processing is also done by TDCA Section personnel (6 FTE). Total annual program cost (labor, equipment, supplies, travel, contracted services, personnel training, etc.) is approximately 1.9 million dollars.

While MDT's traffic data needs have been generally met by the current traffic data collection program, the TDCA Section foresees the need for some changes in the future. In light of growing data needs/requests as design and planning methodologies and processes become increasingly data intensive, potential changes include among other things,

- expanding the traffic count data sharing/exchange program with local entities to increase the data collection coverage across the state, especially on lower functional classified roads, and optimize the allocation of limited resources;
- tackling technical barriers to collecting traffic data in urban areas, both volume and vehicle classification;
- continuing to expand on the accurate collection, reporting and analysis of motorcycle travel;
- identifying potential differences in the nature of traffic operations around the state based on economic and/or other factors to ensure such operations are fully characterized in the data being collected, with the possibility of developing traffic group factors by region, as appropriate;
- continuing to identify and implement efficiencies to allow available resources to meet the ever growing short-term and permanent data collection needs;

- improving physical management of the inventory of data collection equipment/facilities to optimize maintenance, replacement investments, and staff scheduling; and
- developing a more formal strategy for siting new data collection locations to optimize resource investment across competing priorities.

4) DATA COLLECTION, ANALYSIS, AND PRESENTATION

This chapter characterizes a) the basic data the TDCA Section of MDT is collecting on Montana's highways, b) the analyses being performed on this data, and c) the various delivery formats and venues subsequently being used. Large local/regional fluctuations in traffic volumes and in the composition of the traffic stream are encountered on many of Montana's highways both temporally and spatially, as the state's economy is agriculture, natural resource extraction and tourism intensive. Whether the data are being collected capture all of the important traffic flows on the state's highways can only be fully determined if the existence of these flows (and if appropriate, their causative factors) is known. Therefore, and as possible, such flows are also identified in this chapter, including vehicle movements associated with grain harvests, off-season farm-to-market movements, logging, energy development, and ore processing.

4.1. Summary of Basic Traffic Data Collected

Currently MDT continuously monitors traffic at 106 locations across the state using permanent ATR and WIM installations. Based on the various segments of the highway system they are located on, these installations actively collect data on approximately 11% percent of the total estimated VMT on the state highway system. Data collection at these permanent sites is augmented by short-term counts (typically 48 hours in duration) conducted at approximately 5,800 sites around the state, with approximately one third of the short-term counts being done in any given year. In general, the data being collected can be grouped in three broad categories, namely, volume, configuration, and weight. The following sub-sections of this report describe the data that are collected from the permanent/continuous ATR and WIM sites, and from the short-term count sites.

4.1.1. Data from Permanent ATR Sites

Montana's permanent ATR sites (64 locations around the state) are capable of collecting vehicle volume or vehicle volume and configuration data. The ATR systems fundamentally detect the passage of each vehicle/vehicle axle. To determine vehicle classification, it is usually necessary to also collect speed data to permit calculation of axle spacing and/or vehicle length, which is done based on the time required for an axle to pass two consecutive sensors at a known distance apart. Data are collected from the site using manufacturer supplied polling software, and are subsequently processed by a third party general purpose traffic data analysis software. For further analysis of the traffic data, it is also necessary that the data records include the time and date of the recorded event(s). Further information on analyses of this data is presented in a subsequent section of this report. IVR are only available from a limited number of ATR sites (19 sites). Otherwise, data are aggregated (also referred to as "binned") in 15 minute intervals. The IVR data available from selected sites is reported in Table 27. Similar information is available for data aggregated into one hour blocks.

Table 27: Typical ATR Data (MDT 2014)

Field	Description
Date	Date of record
Time	Time of record
Lane	Lane number
Speed	Speed of vehicle
Axles	Number of axles on the vehicle
Length	Total length of vehicle
Ax	Axle class – vehicle classification
Sp	Speed class
Ln	Length class
Gp	Gap class – not being used
Hd	Headway class – not being used
1-2	Space between axles
2-3	Space between axles
Spacing between axles continues for up to 13-14 axles	

4.1.2. Data from Permanent WIM Sites

Generally WIM sites are capable of collecting all of the data that ATR sites collect with the addition of weight data for each axle that crosses the site. Dependent upon the type of WIM installation, it is possible to collect the weight of the left and right side of each axle individually or to collect only each axle's weight. That being said, MDT primarily utilizes quartz-piezoelectric WIM systems that measure the weight of each tire assembly and combine the left and right sides of the vehicle into one weight for the whole axle. Axle weight typically is the parameter recorded and used in subsequent analyses. All WIM data from the 42 sites around the state are in the form of individual vehicle records. The axle weight data is used to determine the weight of each axle group (i.e., single, tandem, tridem, quadrum) and the gross vehicle weight (GVW). Table 28 presents the data collected and parameters calculated at a typical WIM installation for each individual vehicle.

4.1.3. Data from Short-term Sites

Short-term counts are performed using portable devices such as pneumatic road tubes or video equipment. The type of data collected in short-term counts is often limited by the capabilities of the data collection device. Data collected can be as simple as the total number of axles to cross a given point, or as complex as the speed and axle spacing of each vehicle. Portable WIM systems also exist. That being said, MDT is not currently utilizing the portable WIM systems due to the low accuracy and high labor costs associated with calibration and deployment of these devices.

Table 28: Typical WIM Data (MDT 2014)

Field	Description
MO	Month
DA	Day
YE	Year
HO	Hour
MI	Minute
SE	Second
VHNUM	Sequential vehicle number
SN	Station number
LN	Lane number
Viol	Sensor violation (vehicle did not hit sensor properly)
CA	Vehicle Scheme F Class
GR81	Axle arrangement
Spee	Vehicle Speed
Leng	Total Vehicle Length
ESAL	Equivalent single axle load
TODT	Length from first axle to last
TWT3	Total Vehicle Weight
WT1	Weight of first axle
DT12	Distance between first and second axle
WT2	Weight of second axle
Weight and Distance pairs are repeated for as many axles as are detected	

Table 29 presents the data typically collected from short-term counts. In addition to those items in Table 29, information on the station setup is included with the raw data. This information includes the type of counting device, serial number of the counting device, and the settings used for the count. While data are captured for every vehicle that passes the counting device, the data that are stored on the device and later collected are grouped into 1-hr blocks or bins. Since short-term sites are mainly used to collect traffic volume, storing binned data does not cause any reduction in accuracy, and it is less memory intensive than retaining every vehicle record.

Table 29: Typical Short-term Data (MDT 2014)

Field	Description
Date	Date of count
Time	Time of count
Lane 1	Number of vehicles (two-hose setup) or number of axles (single-hose setup)

4.2. Data Analyses

The basic data described above are analyzed to determine various characteristics of the traffic on the state's highway system which are then used across a broad spectrum of planning and design activities at both the project-specific and network levels. Basic traffic characteristics of interest include traffic volume, classification, and weight, and associated metrics that can then be calculated from this information, such as AADT, VMT and ESALs. Since an essential part of any such analyses is an assessment of basic data quality, the principal quality control measures used by MDT are discussed first below, followed by descriptions of the various data analyses that are subsequently performed.

4.2.1. Quality Control

In order to obtain reliable information from the data that are collected by the ATR/WIM systems throughout Montana, MDT utilizes quality control procedures that screen the data automatically and/or manually for erroneous and missing entries.

Automated quality control checks are performed by software and consist of the items shown in Table 30. Referring to Table 30, many of these automated checks are tests of the "reasonableness" of the data collected as judged based on physical limits and historical values of the phenomena being measured or calculated. For example, a warning is issued if a vehicle is classified as having 14 or more axles, with an error assessed if the number of axles is at or greater than 20. As another example, records with a vehicle speed of greater than 90-mph are flagged with a warning message, with a recorded speed in excess of 155 mph resulting in an error message. Another test checks hourly lane volume, with values in excess of 3,500-veh/hr generating an error message. Traffic volumes in excess of this value are physically unreasonable at even moderate speeds. Individual vehicle records that result in a warning message are reviewed by an MDT technician, and a decision on the validity of the data is made based on the experience of the technician. Any records found to be in error are removed from the final data sets.

Relative to using historical data in the quality control process, AADTs are compared, for example, to prior year AADTs at the same location. If the reported AADT varies by more than a pre-determined percentage from the historic AADT at a given site a warning message is issued.

In addition to the checks listed in Table 30, all outcomes of the data analysis process are scrutinized by experienced personnel for possible anomalies not detected by the automated screening process. For example, the percentage of heavy vehicles determined on a segment of highway may appear to have significantly increased over the previous year, with no other changes to the traffic stream. This situation would not be flagged for further investigation by the automated quality control checks, but it would be seen as a concern by an experienced data analyst as being possibly caused by a problem with the data collection or analysis process.

If the data are missing for many days at a given site, it is possible that the missing data could result in mischaracterization of the traffic operations at that site. To prevent this from happening, MDT requires that at least one full day of data exist for each day-of-week for each month. If, for example, all Saturdays in a given month had no data, no traffic adjustment factor would be calculated for Saturdays in that month.

Table 30: Data Quality Control (MDT 2014)

Data Quality Error	Description	Error	Warning	Units
AADT vs History	Current AADT differs from historic AADT by more than given percentage	-	90	Percent
Annual ADT Threshold	Annual average day-of-week (DOW) traffic volumes must be available for every day of the week (total of seven values), if annual AADT is to be determined	6	-	Days
Annual Day-of-week threshold	Average DOW traffic volumes must be available for at least eight and preferably nine months, if average annual DOW traffic volume is to be determined	7	8	Months
Annual High Hour Threshold	Data must be available for at least 250 and preferably 300 days, if annual high hour peak volume is to be determined	249	299	Days
Annual Weekday Threshold	Average annual traffic must be available for at least four individual weekdays, if average annual weekday traffic volume is to be determined	3	-	Days
Annual Weekend Threshold	Average annual traffic must be available for at least one individual weekend day, if average annual weekend traffic volume is to be determined	1	-	Days
Axle Count High	Maximum number of axles comprising a credible vehicle	20	14	Axles
Axle Count Low	Minimum number of axles comprising a credible vehicle	1		Axles
Axle Spacing High	Maximum credible spacing between consecutive axles	99	50	Feet
Axle Spacing Low	Minimum credible spacing between consecutive axles	2	3	Feet
Axle Weight <> GVW	Sum of reported axle weights and GVW are within 90 percent of one another	90		Percent
Axle Weight High	Maximum credible single axle weight	500	-	100's of lbs
Axle Weight Low	Minimum credible single axle weight	5		100's of lbs
Axles vs Spaces	Axles minus one must equal spaces	On As Error	-	Axles
Axles vs Total Axles	Axles counted does not equal total axles	On As Error	-	Axles
Bumper/Axle1 High	Not used	-	-	-
Bumper/Axle1 Low	Not used	-	-	-
Consecutive Hourly Zeroes	Maximum credible number of hours with no traffic	12	6	Hours
Consecutive Identical Number	Maximum credible number of hours with the same traffic volume	8	4	Hours
Direction Data Missing	No direction data	On As Error	-	-
Directional Split	Maximum credible directional split	80	60	Percent
High 9/11 First Axle Weight	Maximum credible steer axle weight for class 9 and 11 vehicles	400	150	100's of lbs
High Volume vs History	Check if current calculated AADT is at least 90 percent of historical AADT		20	Percent

Data Quality Error	Description	Error	Warning	Units
Hours Collected	Number of hours collected per day exceeds	23	-	Hours
Invalid Date	Date is invalid	On As Error	-	Date
Length < Wheelbase	Vehicle length is less than wheelbase	On As Error	-	Feet
Length = Wheelbase	Vehicle length equals wheelbase	-	On As Warning	Feet
Low 9/11 First Axle Weight	Minimum credible steer axle weight for class 9 and 11 vehicles	5	70	100's of lbs
Low Volume vs History	Current calculated volume is at least 80 percent of historical volume	-	80	Percent
Maximum Hourly Volume Directional	Maximum credible hourly volume in one direction	14000	-	Volume
Maximum Hourly Volume Lane	Maximum credible hourly volume in one lane	3500	-	Volume
Missing Data	Data entry check	On As Error		-
Monthly ADT Threshold	Average DOW traffic must be available for at least six days of the week, if monthly ADT is to be determined	5	-	Days
Monthly DOW Threshold	Data from a least one DOW during the month must be available to calculate the average traffic for that DOW in that month	0	-	Days
Monthly Weekday Threshold	Average DOW traffic must be available for at least four individual weekdays of that month, if average monthly weekday per month is to be determined	3	-	Days
Monthly Weekend Threshold	Average DOW traffic must be available for at least one individual weekend day of that month, if average monthly weekend traffic volume is to be determined	1	-	Days
No Class Code	Vehicle not classified	On As Error	-	-
Speed 0	Speed equals zero	On As Error	-	mph
Speed High	Speed exceeds given value	155	90	mph
Speed Low	Speed is lower than given value	9.9	39.9	mph
Split Counter Files	Counter file split		On As Warning	-
Too Many Invalid	Number of invalid records exceeds value	30	-	Percent

4.2.2. Measures of Traffic Volume

Data collected at permanent ATR/WIM sites is used to determine traffic volume over various time intervals. The average daily traffic volume by day-of-week for each month is obtained by averaging the weekday (Monday through Thursday), Friday, Saturday, and Sunday traffic for a given month. This averaging is done to help eliminate possible bias in the day-of-week results due to random variations in traffic volumes across the month. As a minimum requirement, data for at least one day for each day-of-week must be collected for a given month. If this requirement is not met, the data for that month is not used in any further analysis.

AADT is determined using an average of averages method as recommended by the TMG. The basis for this calculation is the values determined for the average daily volume of traffic by day-of-week for each month. The average daily traffic volumes by DOW are averaged across the year (i.e. average of twelve values, one from each month), as indicated in Equation 1. This approach, reportedly, is a simple but relatively robust approach to minimizing potential bias from missing data (FHWA 2013).

$$AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijk}\right)\right] \quad (1)$$

where,

VOL	=	Daily traffic for day k, of day-of-week i, and month j,
i	=	Day-of-the-week,
j	=	Month-of-the-year,
k	=	1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week, and
n	=	The number of days of that day-of-the-week during that month (usually between one and five depending on the number of missing data).

4.2.3. Configuration

Vehicle configuration (classification) is determined using computer algorithms acting on overall vehicle length and/or axle spacing. Length based classification simply assigns vehicles to one of two classifications, over 47-ft and less than 47-ft in total length. This threshold length was selected based on the lengths of common heavy vehicles. If supported by the basic data collected and stored, a more refined classification can be performed using algorithms that act on axle spacing to sort vehicles by their FHWA Scheme F classification. FHWA Scheme F recognizes 13 fundamental vehicle types, which have been customized in Montana with various subgroups to better capture specific types of vehicles commonly observed on the state's roadways. The set of vehicle classification algorithms typically used with ATR data is presented in Table 31, while the classification scheme generally used with WIM data is shown in Figure 10. In addition to the 13 configurations given in FHWA Scheme F, two other "configurations" are used to report erroneous data, namely Class 14 and Class 99. Class 14 vehicles are those that were reported to be vehicles, but upon further scrutiny of the data are believed in error, for example, a record with a vehicle speed of zero miles per hour. Class 99 vehicles are those that have been reviewed by TDCA personnel and found to be legitimate, but do not fall within any established classification. If FHWA classified data needs to be evaluated in length based terms, vehicles in Classes 5 through

13 are assumed to correspond to vehicles over 47 feet in length. Further, many elements of traffic data (e.g., AADT) are reported in various aggregations of vehicle classifications. Vehicle configurations are often aggregated into the broad categories of commercial vehicles (Class 5-13), or small and large trucks (Class 5-7 and Class 8-13, respectively) and busses (Class 4). Further information on the classification and presentation of data is presented in the Data Dissemination section of this report.

Table 31: MDT Configuration Definitions (MDT 2014)

Definition	FHWA Scheme F Classification	Number of Axles	Spacing Between Sequential Axles (ft)
1	Type 1	2-3	1-6.5,2-8
2	Type 2	2-3	6.6-9.9,6.1-19.5
3	Type 2	4	6.6-9.9, 6.1-18, 1-10
4	Type 3	2-3	10-14.9, 6.1-23
5	Type 3	4	10-14.9, 6.1-40, 1-13
6	Type 3	5	10-14.9,*,*,1-5
7	Type 4	2-3	20-40,3-6
8	Type 5	2	15-19.9
9	Type 5	4	15-19.9, 6.1-40, 1-10.5
10	Type 5	5	15-19.9,*,*,1-5
11	Type 6	3	*, 3-6
12	Type 7	4	*, 3.3-6, 3.3-6
13	Type 8	3	*, 6.1-42
14	Type 8	4	*, 3.3-42, 3.3-42
15	Type 9	5	*, 3.3-6, *, 3.3-23
16	Type 9	5	*, *, *, *
17	Type 10	6	*, 3.3-8, 3.3-6, *, 3.3-11
18	Type 10	6	*, 3.3-6, *,*, 3.3-11
19	Type 10	7	*, 3.3-8, 3.3-6, *, 3.3-6, 3.3-6
20	Type 10	8	*, 3.3-8, 3.3-6, *,3.3-6, 3.3-6, 3.3-6
21	Type 11	5	*,13.3-27,4-16.7,10-26.7
22	Type 12	6	*, 3.3-6, 13.3-27, 6.7-13.3, 10-27
23	Type 12	6	*, 10-40, 3.3-6, 8-20, 10-30
24	Type 13	7	*, 3.3-8, *, *, *, *
25	Type 13	7-10	*, *, *, *, *, *, *, *, *

* Any distance between axles

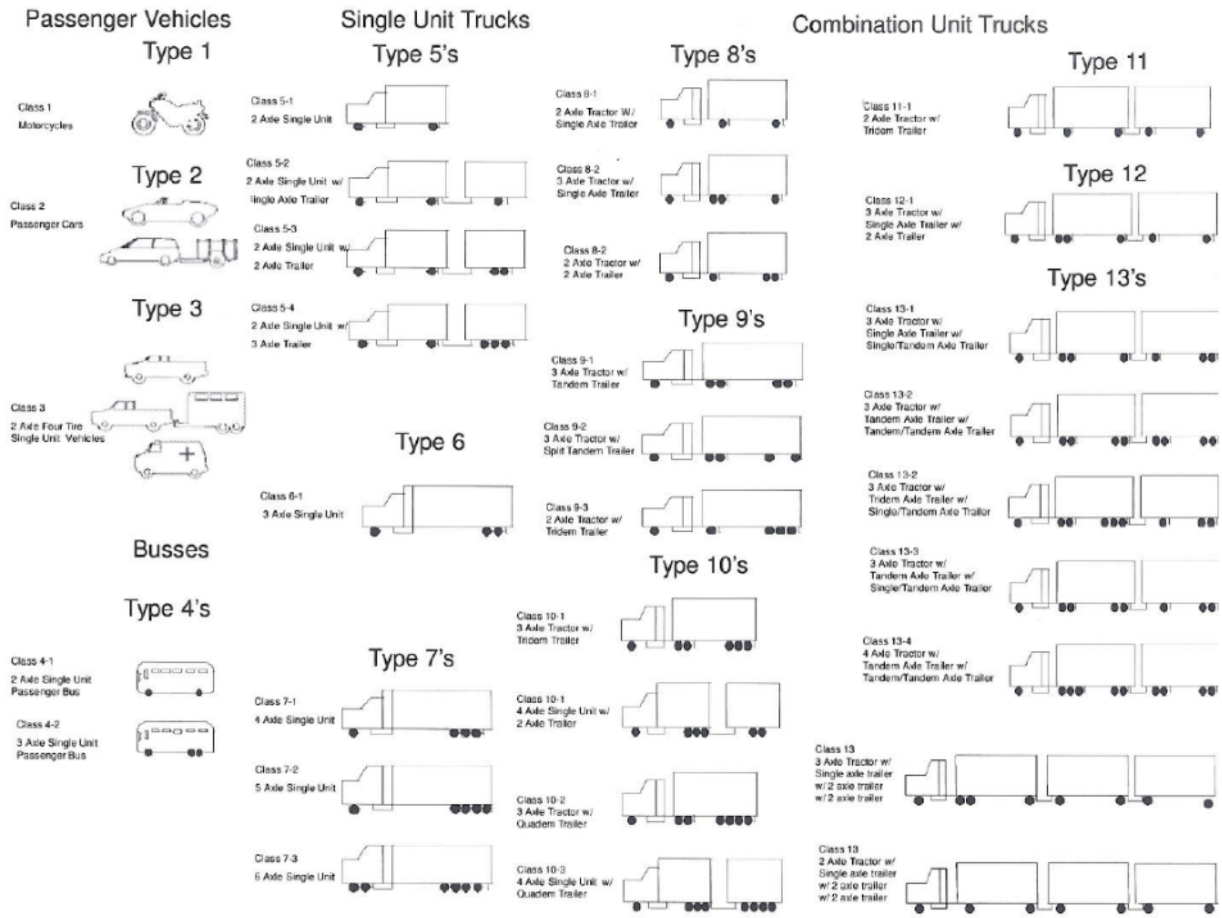


Figure 10: FHWA Scheme F

4.2.4. Traffic Factors

Traffic Factors are generated for use in determining AADT at a given location by expanding the results of short-term traffic counts conducted at that location for just a few days during the year. The ADT during the short-term count is multiplied by a factor developed from data collected at permanent ATR/WIM sites expected to have a similar composition of vehicles. Two sets of factors are generated, one for expanding single-hose volume counts, and one for expanding two-hose classification counts. In the latter case, the traffic factor simply needs to account for variations in traffic operations at various times throughout the year, while in the former case it must also address the expected number of combination vehicles in the traffic stream. These factors vary by the time interval during the year when the short-term count was conducted, as well as by the traffic factor group on which the count was taken. Table 32 presents the traffic factor groups used by MDT. MDT currently determines factors for each traffic factor group (total of nine groups), for each day of the week, for each month of the year. Thus, a total of 756 individual factors are determined

(Duke 2013). Although traffic factors are generated for Fridays, it is the policy of MDT to not perform short-term counts on Fridays due to the atypical nature of the traffic.

Table 32: Traffic Factor Groups used by MDT

Abbreviation	Classification
RI	Rural Interstate
UI	Urban Interstate
RPA	Rural Primary Arterial
UPA	Urban Primary Arterial
RMA	Rural Minor Arterial
RMC	Rural Major Collector
UC	Urban Collector
UMA	Urban Minor Arterial
REC	Recreational

Traffic factors are generated from each ATR/WIM site using Equation 2. Next, for a given group, the factors from all of the ATR/WIM systems within that traffic factor group are averaged. Further information on the format in which the factors are published can be found in the Data Dissemination section of this chapter.

$$Factor_{i,j} = \frac{AADT_j}{ADT_i} \tag{2}$$

where,

$Factor_{i,j}$ = Traffic factor for time interval i at site j,
ADT_i = Average daily traffic for time interval i for two-hose configurations or average number of axles for time interval i for single-hose configurations, and
$AADT_j$ = Average annual daily traffic for site j.

4.2.5. Weight Data

All weight data are collected by WIM systems, with the primary use of this data being in pavement design. Currently in Montana, vehicle demands for pavement design need to be quantified in terms of ESALs, which are calculated from the weight carried on the individual axle groups comprising each vehicle in the traffic stream. An alternate pavement design process uses axle load spectra rather than ESALs in quantifying vehicle demands for pavement design, and while not currently used by MDT, programs are in place that can generate these spectra from the data collected at WIM sites. WIM data are also used to support Montana's weight enforcement efforts, as described below.

4.2.5.1. ESALs

Design ESALs are a cumulative traffic load applied to a pavement during its design life, expressed in terms of the equivalent number of passages of an 18,000-lb single axle over that pavement. Notably, ESALs serve to convert a mixed stream of traffic of different axle loads and axle configurations to a common unit of structural demand. Following the AASHTO-Pavement Design Guide (AASHTO 1993), roadways are designed to carry the total number of ESALs that they are projected to experience across their design life, often 20 years. Design ESALs are a function of the volume, classification, and weight of the traffic traveling on a given roadway. Derived through empirical testing, design ESALs vary a) as a fourth order of axle weight, b) by axle configuration, i.e., single, tandem, tridem and quadrum, c) by roadway strength, and d) by terminal level of pavement condition assumed at its failure. For a given roadway strength and level of terminal serviceability, equations are available to calculate ESAL factors for each vehicle based on axle configuration and weight.

ESAL values are first calculated for each individual vehicle record by the TDCA Section, and then aggregated across the weight group and vehicle classification based on their intended use, i.e., network or project level analyses. For network level analyses, ESAL factors are aggregated across the categories of interstate highways as well as minor and major arterials for the broad vehicle classifications of small trucks (Class 5-7), large trucks (Class 8 -13), and busses (Class 4). For project level work, ESAL factors are determined for each vehicle classification for the weight group of roadway consistent with the project location. All factors are calculated as an average of the ESAL factors for the individual vehicles captured at corresponding WIM sites over the past year. The ESAL factors are applied to the traffic count of interest to estimate total ESALs of demand on a particular network based on pavement type, rigid versus flexible, or at a specific project site.

To ensure accuracy, the ESAL factors are visually checked by a TDCA Section staff member for any abnormal values based on the staff member's experience. These checks include reviewing the number of erroneous vehicle classifications within the data set being used, i.e. types 14 and 99; scale, validation, and speed errors; and the percentage of type 14 vehicles to total commercial vehicles. These checks are performed on a per lane basis and a total quantity per site. In addition to the aforementioned checks, general trends in vehicle classification, volume, and weight are compared with those observed historically and at other similar sites to further identify possible anomalies in the results

4.2.5.2. Axle Load Spectra

Axle Load Spectra are used to quantify vehicle weight related pavement demands in the Mechanistic-Empirical Pavement Design Guide (ARA 2004). Currently MDT does not use this approach, but it is possible to generate load spectra from the WIM data being collected and the software that is being utilized. Axle Load Spectra, as the label implies, provide frequency distributions of axle group loads by vehicle configuration.

4.2.5.3. Weight Enforcement

A decade ago MDT developed STARS that included the Measurement of Enforcement Activity Reporting System (MEARS) (Stephens and Carson 2005). The MEARS software was specifically configured to use WIM data to identify where and when overweight vehicles were operating on the state highway network. This functionality is now available to MDT as part of the commercial software package, TCDS, a subscription based software and database service offered by MS2. This and other features of this software are described in more detail in subsequent sections of this report.

4.2.6. Expansion of Short-term Counts

Short-term traffic counts are performed for 48 hours. These counts are then expanded into an estimated AADT for the site using the Traffic Factors for the given factor group and time-of-year. A seasonal adjustment factor is applied to all short term counts. Because single tube volume counts are only capable of recording individual axles (not vehicles), these counts have an additional axle adjustment factor applied to them.

Seasonal and axle adjustment factors vary by day of the week and month of the year. The appropriate factors are applied to each record. An AADT is then created for each 24 hour period. The adjusted records are averaged together to create a single estimated AADT.

The appropriate factor that corresponds to the type of short-term count (single hose, volume only or two-hose, classification) must be used. Equation 3 presents the method employed to expand a short-term count.

$$AADT = Factor_{i,j} * ADT_i \tag{3}$$

where,

AADT	=	Estimated average annual daily traffic,
$Factor_{i,j}$	=	Traffic factor corresponding to time i for group j, and
ADT_i	=	Average daily traffic for time i as determined by the short-term count.

4.2.7. Vehicle Miles of Travel

VMT are determined by multiplying the length of a roadway section by the number of vehicles that travel the section in a given time, either daily (DVMT) or annually (AVMT). The estimated or actual AADT for a roadway section is multiplied by the number of days in the year to determine the total vehicles that traveled the section within the given year. The end result of this calculation can be used to create traffic flow maps, estimate vehicle emissions, etc. Approximately 11 percent of the on-system VMT in Montana are captured by permanent ATR/WIM sites. The remaining VMT is estimated based on short-term counts.

4.3. Data Dissemination

The following section presents the various reports MDT publishes to disseminate traffic data. These reports typically are available online as downloadable files. In addition to reports, MDT also has an online interactive map-based GIS application available on their website that displays a variety of traffic data. MDT also uses a web-based traffic data management tool, MS2, which is available to internal and select external users. All of the published reports in this section can be found at: http://www.mdt.mt.gov/publications/datastats/traffic_reports.shtml.

4.3.1. Traffic by Sections

The Traffic by Sections (TBS) report is published annually and includes traffic data for all of the highway sections that are monitored by the TDCA section. Roadways are segmented based on: a) major intersections that cause changes in traffic, b) political boundaries such as urban boundaries and county lines, and c) for interstates, every interchange. The TBS report includes referencing and description information, AADT, and the daily vehicle miles of travel (DVMT) for all vehicles, with sub-breakdowns by various vehicle groupings (e.g., commercial vehicles (Class 5 -13), small trucks (Class 5-7) and large trucks (Class 8-13), etc.).

The 2012 TBS report Table 33 shows a sample of the data that are available in the TBS report by specific route segments. Table 34 presents a sample of the data available for AADT/DVMT aggregated by route.

Table 33: Sample of Traffic by Sections

2012					Location		County	Truck Percentages				Weighted AADT			
Dept Route	Reference Point Beg	Reference Point End	Sctn Length	Section Description				Small (5 7)	Large (8 13)	Comm (5 13)	Traffic Type	2010	2011	2012	DVMT
N-1	119+0.622	120+0.114	0.504	JCT N-109 (KALISPELL ALT ROUTE)	KALISPELL	CITY	FLATHEAD	1.3	1.1	2.4	All Vehicles		11530	16460	8296
											Commercial		336	389	196

Table 34: Sample of Weighted AADT/DVMT Summary by Route

Secondary			Average Annual Daily Traffic (AADT)							Daily Vehicle Miles Traveled (DVMT)						
Dept Route	Rural/ Urban	Miles	MC (1)	Pass Vehicles (2-3)	Buses (4)	Small Trucks (5-7)	Large Trucks (8-13)	Comm (5-13)	All Vehicles (1-13)	MC (1)	Pass Vehicles (2-3)	Buses (4)	Small Trucks (5-7)	Large Trucks (8-13)	Comm (5-13)	All Vehicles (1-13)
S-442	Rural	8531		154	4	4	4	8	170		1315	34	34	34	68	1452
	Urban															
	Route Total	8531		154	4	4	4	8	170		1315	34	34	34	68	1452

4.3.2. Vehicle Miles of Travel

Two reports exist summarizing VMT on state roads in Montana. The first is the Annual VMT report; the second, Montana's Estimated Monthly VMT report. The Annual VMT report, presented for illustrative purposes in Figure 11, is a table presenting the VMT for each of

Year	Interstate	NI-NHS	Primary	Secondary	Urban	On-System Total	Off-System Total*	Statewide Total
1966	0.800		1.510	0.429		2.739		3.838
1967	0.852		1.581	0.453		2.886		4.080
1968	Unavailable							
1969	0.875		1.734	0.489		3.098		4.439
1970	0.958		1.842	0.544		3.344		4.867
1971	1.043		2.007	0.565		3.615		5.079
1972	1.181		2.095	0.602		3.878		5.373
1973	1.181		2.117	0.630		3.928	1.761	5.689
1974	1.174		1.930	0.472	0.430	4.006	1.817	5.823
1975	1.184		1.933	0.471	0.434	4.022	1.701	5.723
1976	1.290		2.202	0.362	0.532	4.386	1.742	6.128
1977	1.393		2.350	0.372	0.622	4.737	1.774	6.511
1978	1.497		2.427	0.423	0.610	4.957	2.064	7.021
1979	1.442		2.635	0.428	0.602	5.107	1.596	6.703
1980	1.410		2.359	0.405	0.639	4.813	1.794	6.607
1981	1.443		2.552	0.433	0.645	5.073	1.930	7.003
1982	1.435		2.518	0.417	0.631	5.001	1.667	6.668
1983	1.487		2.661	0.440	0.671	5.259	1.920	7.179
1984	1.525		2.685	0.469	0.705	5.384	1.982	7.366
1985	1.599		2.695	0.472	0.626	5.392	2.178	7.570
1986	1.632		2.709	0.486	0.637	5.464	2.273	7.737
1987	1.719		2.743	0.510	0.664	5.636	2.398	8.034
1988	1.788		2.787	0.517	0.651	5.743	2.372	8.115
1989	1.899		2.890	0.531	0.677	5.997	2.252	8.249
1990	1.986		2.934	0.541	0.683	6.144	2.187	8.331
1991	1.962		2.892	0.531	0.677	6.062	2.253	8.315
1992	2.114		3.113	0.558	0.719	6.504	1.997	8.501
1993	2.115		3.195	0.578	0.770	6.658	2.048	8.706
1994	2.156		3.256	0.605	0.809	6.826	2.291	9.117
1995	2.281	2.409	1.183	0.632	0.775	7.280	2.119	9.399
1996	2.308	2.361	1.169	0.639	0.784	7.261	2.159	9.420
1997	2.350	2.339	1.141	0.653	0.802	7.285	2.037	9.322
1998	2.427	2.337	1.175	0.679	0.832	7.450	2.043	9.493
1999	2.417	2.401	1.202	0.704	0.832	7.556	2.228	9.784
2000	2.436	2.434	1.214	0.722	0.835	7.641	2.214	9.855
2001	2.480	2.508	1.205	0.733	0.822	7.748	2.263	10.011
2002	2.736	2.638	1.303	0.717	0.889	8.283	2.203	10.486
2003	2.737	2.733	1.342	0.741	0.902	8.455	2.442	10.897
2004	2.829	2.774	1.363	0.763	0.908	8.637	2.540	11.177
2005	2.814	2.776	1.362	0.768	0.916	8.636	2.491	11.127
2006	2.833	2.761	1.367	0.766	0.910	8.637	2.628	11.265
2007	2.905	2.776	1.381	0.770	0.930	8.761	2.545	11.306
2008	2.686	2.592	1.303	0.753	0.916	8.250	2.532	10.782
2009	2.787	2.681	1.322	0.770	0.941	8.501	2.509	11.010
2010	2.750	2.723	1.326	0.804	0.944	8.547	2.638	11.185
2011	2.810	2.706	1.326	0.814	0.945	8.602	3.064	11.666
2012	2.954	3.346	1.172	0.771	0.582	8.824	3.034	11.858
2013	3.030	3.373	1.009	0.658	0.814	8.884	3.144	12.028
2014	3.053	3.432	1.042	0.653	0.844	9.026	3.130	12.156
2015	**3.070**	**3.469**	**1.033**	**0.673**	**0.870**	**9.115**	**3.230**	**12.345**

Figure 11: Annual Vehicle Miles of Travel (in billions)

Montana's designated highway systems, also referred to as "On-System" routes; Interstate, Non-Interstate National Highway System (NI-NHS), Primary, Secondary, and Urban. The remaining routes are referred to as "Off-System" and generally consist of lower functional class roadways. Data collection on the Off System routes is minimal. TDCA currently generates default AADTs that it assigns to any Off System route segment that doesn't have actual traffic counts conducted either by MDT or one of its data sharing partners.

The second report is a table presenting the VMT for each month of the year. The monthly report is further broken down into urban and rural components. Figure 12 presents an illustration of the monthly VMT table.

Rural '14	Jan	143	198	159	501	Urban '14	Jan	47	111	77	235	736
	Feb	134	184	150	468		Feb	43	105	74	222	690
	Mar	159	228	178	564		Mar	50	123	80	254	819
	Apr	181	242	189	612		Apr	50	133	94	277	889
	May	206	294	223	722		May	50	159	116	324	1,047
	Jun	249	353	265	867		Jun	60	202	123	384	1,251
	Jul	294	395	325	1,014		Jul	73	241	163	476	1,490
	Aug	295	385	309	989		Aug	70	232	158	460	1,449
	Sep	229	316	243	788		Sep	53	171	109	333	1,120
	Oct	221	287	215	724		Oct	50	160	117	327	1,051
	Nov	192	260	197	649		Nov	45	140	101	286	935
	Dec	199	252	210	660		Dec	42	134	94	270	930
	AVMT	*2,500*	*3,395*	*2,664*	*8,559*		*AVMT*	*632*	*1,911*	*1,305*	*3,848*	*12,407*
Rural '15	Jan	151	202	166	519	Urban '15	Jan	50	116	80	246	765
	Feb	154	207	170	531		Feb	45	119	83	246	778
	Mar	177	248	196	622		Mar	52	135	88	275	897
	Apr	193	256	200	649		Apr	50	140	98	288	936
	May	216	305	234	754		May	51	166	118	335	1,090
	Jun	263	382	292	937		Jun	61	217	130	408	1,345
	Jul	308	414	343	1,065		Jul	75	251	166	493	1,558
	Aug	309	392	324	1,026		Aug	71	239	160	470	1,495
	Sep	233	331	255	819		Sep	53	177	112	341	1,160
	Oct	229	298	217	744		Oct	50	160	118	327	1,072
	Nov	200	276	210	686		Nov	46	143	105	294	980
	Dec	196	257	218	671		Dec	46	133	96	275	946
	AVMT	*2,631*	*3,569*	*2,825*	*9,024*		*AVMT*	*649*	*1,996*	*1,353*	*3,997*	*13,022*

Figure 12: Montana's Estimated Monthly Vehicle Miles Traveled (in millions)

4.3.3. Annual and Monthly ATR/WIM Reports

The Annual ATR/WIM Report contains data collected by the permanent ATR/WIM sites throughout Montana on daily and hourly traffic volumes. The following descriptions are provided of the specific information contained in these reports:

The Yearly ATR Profile includes:

- the average daily traffic for each day of week and for each month (i.e. the average traffic for Sunday in January versus a Sunday in July),
- the average daily traffic for the week (Sunday through Saturday),
- the average daily traffic for the weekday for each month (weekday is defined as Monday through Thursday for traffic reporting purposes),

- percentage, by month, of average daily traffic (Sunday through Saturday) as compared to the average weekday traffic (Monday through Thursday),
- percentage, by month, of average daily traffic (Sunday through Saturday) as compared to the yearly average daily traffic is shown on the Yearly Peak Hourly Volumes Report,
- the traffic mix (Passenger vehicles, small trucks, and large trucks) as percent of the total AADT. This is only displayed for sites that are capable of collecting FHWA 13 class data, and
- the directional distribution of vehicles.

The Yearly Peak Hour Volume report includes:

- The current and historical AADT, and
- The 10th, 20th, 30th (generally used as the design hour volume -DHV), 50th and 100th peak hour traffic volumes, shown as percentages of the daily traffic.

In addition to the above descriptions of the data, the introduction includes a map presenting the location of the ATR/WIM sites throughout Montana and an FHWA Scheme F vehicle classification chart.

Figure 13 and Figure 14 present examples of the Yearly ATR Profile and the Yearly Peak Hour Volume tables, respectively, for an ATR site.

Montana Department of Transportation
MDT

Yearly ATR Profile
For Year: 2012
Jefferson County
Station A-002
Ascending Direction: East

Location ID: 22-2-2
Functional Class: Principal Arterial - Rur
Traffic Factor Group: RPA
US-287/US-12 near Clasoil, 9 miles east of Helena N-8 (C000008) RP 55.3
Traffic Mix: Pass: 93.89% Sm Truck: 0.94% Lg Truck: 5.03%
Directional Split E: 50% / W: 50%

	Average Daily Number of Vehicles							Avg. Day (Entire Week)	Avg. Weekday (Mon-Thu)	% Avg. Day is of Avg. Weekday	% Avg. Day is of Yearly Avg.
	Day of the Week										
	Sun	Mon	Tue	Wed	Thu	Fri	Sat				
JAN	4,053	4,868	5,052	4,767	5,030	5,933	4,696	4,914	4,929	99.70%	81.09%
FEB	4,338	5,285	5,188	5,195	5,439	6,371	4,745	5,223	5,277	98.98%	86.19%
MAR	5,010	5,239	5,385	5,661	5,966	6,864	5,449	5,653	5,563	101.62%	93.28%
APR	5,414	6,076	5,943	6,166	6,406	6,830	5,737	6,082	6,148	98.93%	100.36%
MAY	5,608	6,202	6,318	6,352	6,705	7,819	6,290	6,471	6,394	101.20%	106.78%
JUN	6,328	6,681	6,394	6,720	7,181	8,072	6,648	6,861	6,744	101.73%	113.22%
JUL	7,039	7,018	6,927	6,784	7,489	8,190	6,673	7,160	7,055	101.49%	118.15%
AUG	6,526	6,644	6,536	6,734	7,186	7,979	6,561	6,881	6,775	101.56%	113.55%
SEP	5,683	6,226	6,272	6,303	6,631	7,738	6,325	6,454	6,358	101.51%	106.50%
OCT	5,805	5,976	5,818	5,996	6,360	7,544	6,235	6,248	6,038	103.48%	103.10%
NOV	4,891	5,528	5,911	6,332	5,334	5,905	4,925	5,547	5,776	96.04%	91.53%
DEC	4,216	4,962	4,989	5,519	5,704	6,294	4,913	5,228	5,294	98.75%	86.27%
Year	5,409	5,892	5,894	6,044	6,286	7,128	5,766	6,060	6,029	100.51%	

* NOTES:
UNDER CONSTRUCTION IN 2000

Figure 13: Sample of Yearly ATR Profile

Four types of reports are available with monthly ATR/WIM data. Three of the reports are similar in presentation and provide traffic data on different vehicle groupings: commercial vehicles, large truck, and all vehicles. These three reports provide monthly ADT and the change in traffic volume from year to year sorted by ATR/WIM site. The fourth report is the Monthly Calendar Report which presents the traffic volume in calendar format by day, direction, and month for each ATR/WIM site. Figure 15 and Figure 16 show an example of each report type.

Montana Department of Transportation
MDT

Yearly Peak Hourly Volumes
For Year: 2012
Jefferson County
Station A-002
Ascending Direction: East

Location ID: 22-2-2
Functional Class: Principal Arterial - Rur
Traffic Factor Group: RPA
US-287/US-12 near Claysoil, 9 miles east of Helena N-8 (C000008) RP 55.3

YEAR	AADT	Highest Hour Volume	Highest Hour %	10TH Volume	10TH %	20TH Volume	20TH %	* DHV 30TH Volume	* DHV 30TH %	50TH Volume	50TH %	100TH Volume	100TH %
1991	3,433	570	16.60%	483	14.10%	458	13.30%	448	13.00%				
1992	3,660	570	15.60%	491	13.40%	479	13.10%	464	12.70%				
1993	3,782	581	15.40%	510	13.50%	496	13.10%	483	12.80%	472	12.50%	438	11.60%
1994	4,043	594	14.70%	547	13.50%	529	13.10%	511	12.60%	493	12.20%		
1995	4,300	592	13.80%	559	13.00%	536	12.50%	528	12.30%	506	11.80%	476	11.10%
1996	4,416	689	15.60%	599	13.60%	565	12.80%	551	12.50%	539	12.20%		
1997	4,439	698	15.70%	574	12.90%	562	12.70%	542	12.20%	527	11.90%	499	11.20%
1998	4,861	657	13.50%	617	12.70%	603	12.40%	588	12.10%	565	11.60%	535	11.00%
1999	5,190	769	14.80%	657	12.70%	632	12.20%	614	11.80%	595	11.50%	561	10.80%
2001	5,230	833	15.90%	647	12.40%	621	11.90%	608	11.60%	570	10.90%	532	10.20%
2002	5,376	731	13.60%	653	12.10%	638	11.90%	627	11.70%	595	11.10%	561	10.40%
2003	5,444	728	13.40%	672	12.30%	650	11.90%	637	11.70%	615	11.30%	577	10.60%
2004	5,730	784	13.70%	695	12.10%	674	11.80%	657	11.50%	641	11.20%	606	10.60%
2005	5,650	749	13.30%	672	11.90%	661	11.70%	650	11.50%	627	11.10%	581	10.30%
2006	5,860	728	12.40%	689	11.80%	669	11.40%	656	11.20%	632	10.80%	598	10.20%
2007	6,182	795	12.90%	746	12.10%	723	11.70%	704	11.40%	676	10.90%	640	10.40%
2008	5,899	1,063	18.00%	750	12.70%	712	12.10%	696	11.80%	667	11.30%	624	10.60%
2009	6,538	877	13.40%	811	12.40%	780	11.90%	770	11.80%	744	11.40%	701	10.70%
2010	6,809	916	13.50%	860	12.60%	836	12.30%	816	12.00%	791	11.60%	760	11.20%
2011	6,010	788	13.10%	729	12.10%	697	11.60%	682	11.30%	656	10.90%	624	10.40%
2012	6,060	797	13.20%	739	12.20%	722	11.90%	704	11.60%	679	11.20%	637	10.50%

* NOTES:
UNDER CONSTRUCTION IN 2000

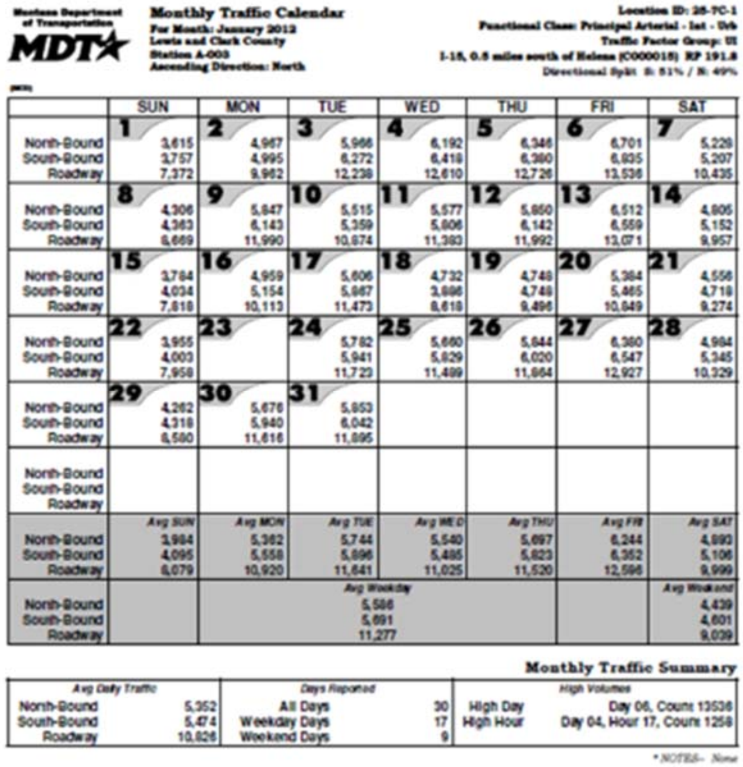
Figure 14: Sample of Yearly Peak Hourly Volumes

Montana Department of Transportation
MDT

Monthly Commercial (Class 5-13) Comparison
(Class Sites Only) (MATRC)
January 2012

Site	Sys Desc	Location	County	Year	Monthly ADT	% Change from same month last year	Monthly Average Weekday Traffic	% Change from same month last year	Monthly Average Weekend Traffic	% Change from same month last year	Number of days monitored this month
A-002	NHS	US-287/US-12 near Claysoil, 9 miles east of Helena N-8 (C000008) RP 55.0	Jefferson	2012	291	-8.78%	367	-9.38%	132	7.32%	31
				2011	319		405		123		31
A-003	INT	I-15, 0.5 miles south of Helena (C000015) RP 191.8	Lewis and Clark	2012	573	-1.72%	630	-4.98%	451	7.13%	30
				2011	583		663		421		31
A-005	PRI	MT-7, 1 mile south of Wibaux P-27 (C000027) RP 79.2	Wibaux	2012	90	9.76%	113	11.88%	48	41.18%	30
				2011	82		101		34		31
A-008	NHS	US 93, 0.5 miles south of Ravalli N-5 (C000005) MP 26.3	Lake	2012	315	0.32%	393	-1.75%	135	8%	30
				2011	314		400		125		28
A-010	NHS	US-2, 2 miles east of Wolf Point N-1 (C000001) RP 592.7	Roosevelt	2012	146	8.96%	189	9.25%	62	47.62%	29
				2011	134		173		42		31
A-014	SEC	S-278, 7 miles southwest of Dillon (C000278) RP 3.4	Beaverhead	2012	22		29		12		30
				2011							29
A-017	INT	I-15, 6.8 miles north of Lima (C000015) RP 22.3	Beaverhead	2012	766	-1.79%	843	-3.66%	621	3.33%	31
				2011	780		875		601		31
A-027	NHS	US-191, 3 miles north of US-191/MT-19 junction N-61 (C000061) RP 69.6	Fergus	2012	41	20.59%	51	21.43%	19	18.75%	31
				2011	34		42		16		31
A-028	STH	State Highway X-07611, 7 miles west of Great Falls (C007611) RP 3.8	Cascade	2012	50		66		19		31
				2011							
A-038	NHS	MT-200, 1 mile west of Jordan N-57 (C000057) RP 209.8	Garfield	2012	41	2.5%	47	-2.08%	28	16.67%	30
				2011	40		48		24		31
A-056	NHS	US-93, 1.5 miles north of Hamilton N-7 (C000007) RP 50	Ravalli	2012	135	-15.09%	173	-16.43%	46	-6.12%	31
				2011	159		207		49		31
A-059	INT	I-90, East of south Billings Blvd Int. (C000090) RP 447.8	Yellowstone	2012	2537	0.86%	2495	-1.11%	1929	8.68%	29
				2011	2515		2523		1775		31
A-061	INT	I-15, north side of Marias Int (C000015) RP 359.6	Toole	2012	742	5.25%	809	2.66%	594	13.14%	31
				2011	705		788		525		30
A-063	NHS	US-212, 1.5 miles east of Ashland N-37 (C000037) RP 76.7	Powder River	2012	320	1.27%	293	-2.33%	371	8.8%	31
				2011	316		300		341		31
A-072	PRI	US-287 South of Ennis P-13 (C000013) RP 39.5	Madison	2012	179	-2.72%	215	-4.02%	115	10.58%	31
				2011	184		224		104		31

Figure 15: Sample of Monthly Commercial Comparison



Montana Department of Transportation

MDT

Monthly Traffic Calendar
For Month: January 2012
Lewis and Clark County
Station A-003
Ascending Direction: North

Location ID: 25-7C-1
Functional Class: Principal Arterial - Int - Urb
Traffic Factor Group: UI
I-15, 0.5 miles south of Helena (C000015) RP 191.8
Directional Split S: 51% / N: 49%

	SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6	7
North-Bound	3,615	4,967	5,966	6,192	6,346	6,701	5,228
South-Bound	3,757	4,995	6,272	6,418	6,380	6,835	5,207
Roadway	7,372	9,962	12,238	12,610	12,726	13,536	10,435
	8	9	10	11	12	13	14
North-Bound	4,306	5,847	5,515	5,577	5,850	6,512	4,805
South-Bound	4,363	6,143	5,359	5,806	6,142	6,559	5,152
Roadway	8,669	11,990	10,874	11,383	11,992	13,071	9,957
	15	16	17	18	19	20	21
North-Bound	3,784	4,959	5,606	4,732	4,748	5,384	4,556
South-Bound	4,034	5,154	5,867	3,886	4,748	5,465	4,718
Roadway	7,818	10,113	11,473	8,618	9,496	10,849	9,274
	22	23	24	25	26	27	28
North-Bound	3,955		5,782	5,660	5,844	6,380	4,984
South-Bound	4,003		5,941	5,829	6,020	6,547	5,345
Roadway	7,958		11,723	11,489	11,864	12,927	10,329
	29	30	31				
North-Bound	4,262	5,676	5,853				
South-Bound	4,318	5,940	6,042				
Roadway	8,580	11,616	11,895				
North-Bound							
South-Bound							
Roadway							
	Avg SUN	Avg MON	Avg TUE	Avg WED	Avg THU	Avg FRI	Avg SAT
North-Bound	3,984	5,362	5,744	5,540	5,697	6,244	4,893
South-Bound	4,095	5,558	5,896	5,485	5,823	6,352	5,106
Roadway	8,079	10,920	11,641	11,025	11,520	12,596	9,999
		Avg Weekday					Avg Weekend
North-Bound		5,586					4,439
South-Bound		5,691					4,601
Roadway		11,277					9,039

Monthly Traffic Summary

Avg Daily Traffic		Days Reported		High Volumes	
North-Bound	5,352	All Days	30	High Day	Day 06, Count 13536
South-Bound	5,474	Weekday Days	17	High Hour	Day 04, Hour 17, Count 1258
Roadway	10,826	Weekend Days	9		

* NOTES- None

Figure 16: Monthly Traffic Calendar

4.3.4. Traffic Factor Tables

Traffic factor Tables are generated each year and are available to data sharing partners through TDCA's web-based traffic processing software, TCDS. One of the tables (Seasonal Factors) are used to expand short-term vehicle classification counts, while both the Seasonal Factors as well as the Axle Factors must be applied to expand the volume counts. Each table, regardless of whether it is Seasonal Factors or Axle Factors, gives a factor for each day of the week for each traffic factor group for each month of the year (total of 756 individual factors).The TDCS generates current year factors at the end of the year and then refactors all of the years short-term counts with the new factors. This allows short-term counts and factors to be developed from the same data time period.

4.3.5. ESAL Factors

ESAL factors are made available to the party requesting them, typically for pavement design (project level work) or planning (network level analyses).

4.3.6. Traffic Maps (GIS)

The online interactive map-based GIS tool made available by MDT allows users to select a highway section and retrieve selected traffic data. Figure 17 shows the screen shot when a user first visits the online map. Figure 18 shows the data presented after a site has been selected by the user. The following data are made available when a site has been selected:

- description (route number, route (mile) post, general physical location),
- site ID,
- county,
- MDT departmental route ID,
- MDT corridor route ID,
- wwner of traffic count,
- ATR/WIM ID,
- Vehicle classification site indicator,
- AADT: current year plus 4 years of historic AADT,
- section length, and
- percent commercial vehicles – most current data year only.

The AADT data can be presented in a graphical form as shown in Figure 19. Additionally, when the user zooms in on a region, the roads are symbolized using color and line weight to represent traffic volumes; this feature can be observed in Figure 20.

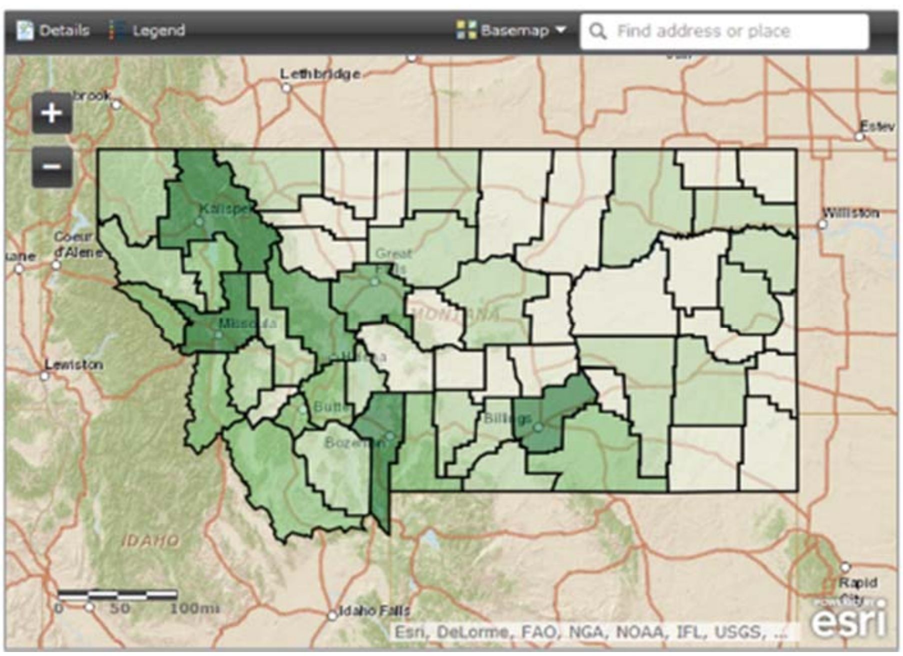


Figure 17: Interactive Online GIS (color reflects annual VMT)

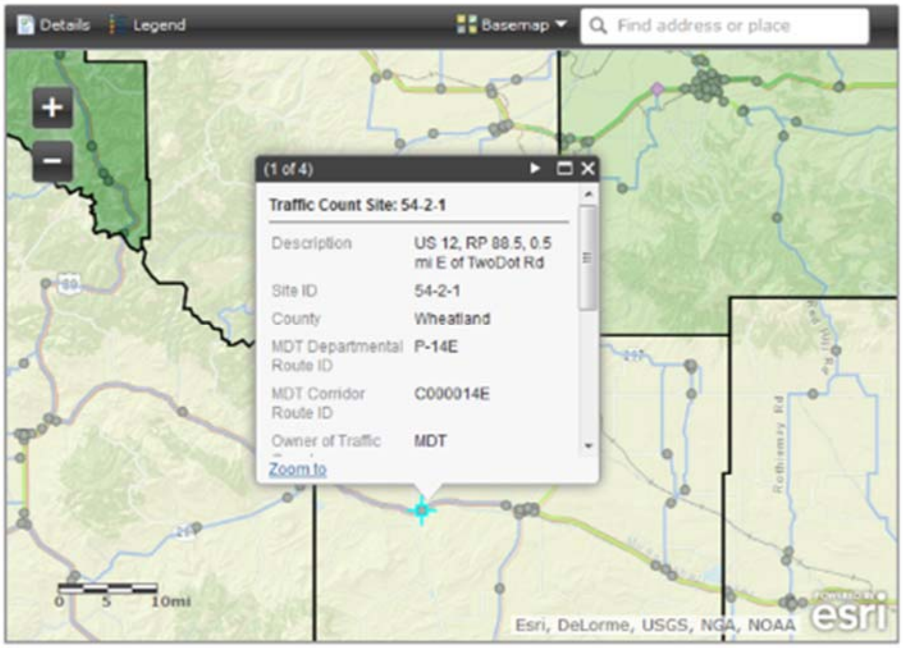


Figure 18: Typical Data from Selected Site

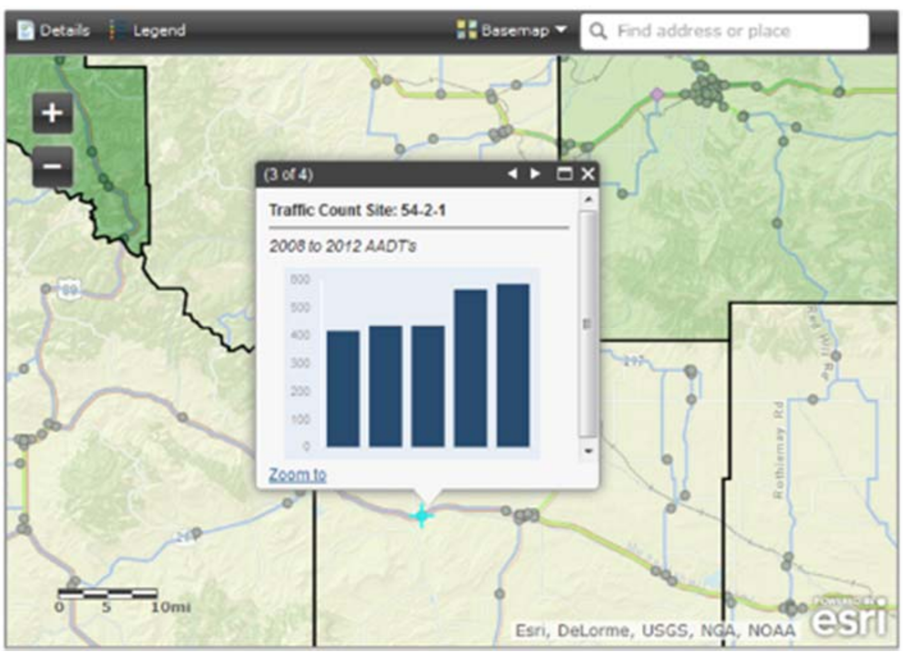


Figure 19: Typical Graphical Presentation of AADT Data for a Site

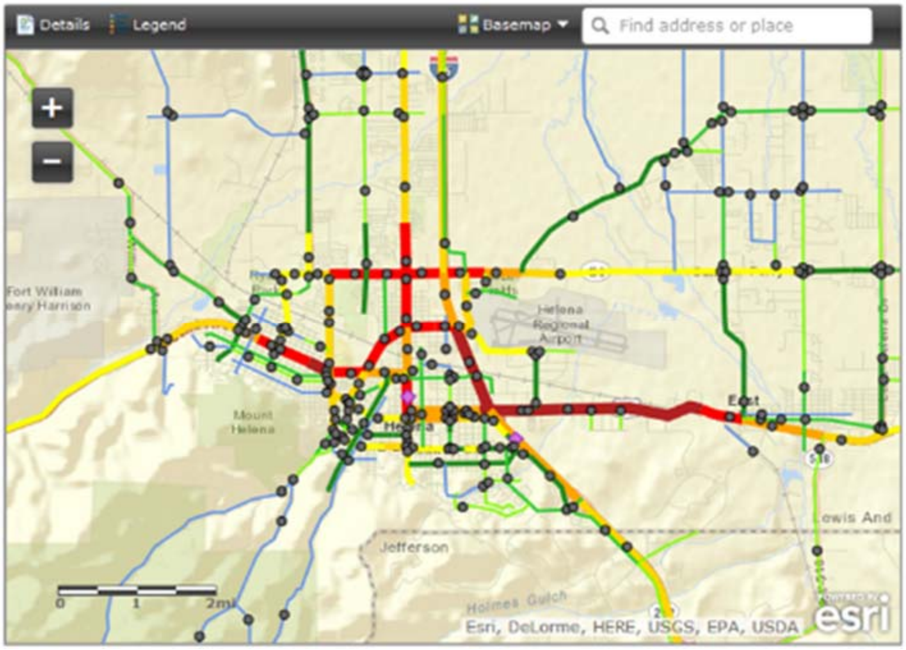


Figure 20: Symbolized Roads (“dots” represent traffic data collection sites, color of route reflects annual volume of traffic)

Also available in an online interactive GIS format is TDCA’s map presenting the location of current and proposed permanent ATR and WIM sites throughout the state (see Figure 21). The information presented when a site is selected is similar to the data from the aforementioned GIS system with the exception of a link to the yearly ATR/WIM report and photographs and schematics for the selected site. Also available is an overlay presenting the MDT maintenance districts; this information can be used to help to determine which sites are the responsibilities of which maintenance crew.

4.3.7. Traffic Count Database System

MDT uses the TCDS, a subscription based software and database service offered by MS2. TCDS performs various traffic data tasks from automatic quality control to data visualization. Having been designed to accept inputs from a wide range of traffic counting devices, TCDS allows for the consolidation of data into one central database. To visualize data, TCDS can output a variety of reports and maps. Figure 22 shows the web-based interface that allows the use of TCDS to access and visualize data from any location with internet access.

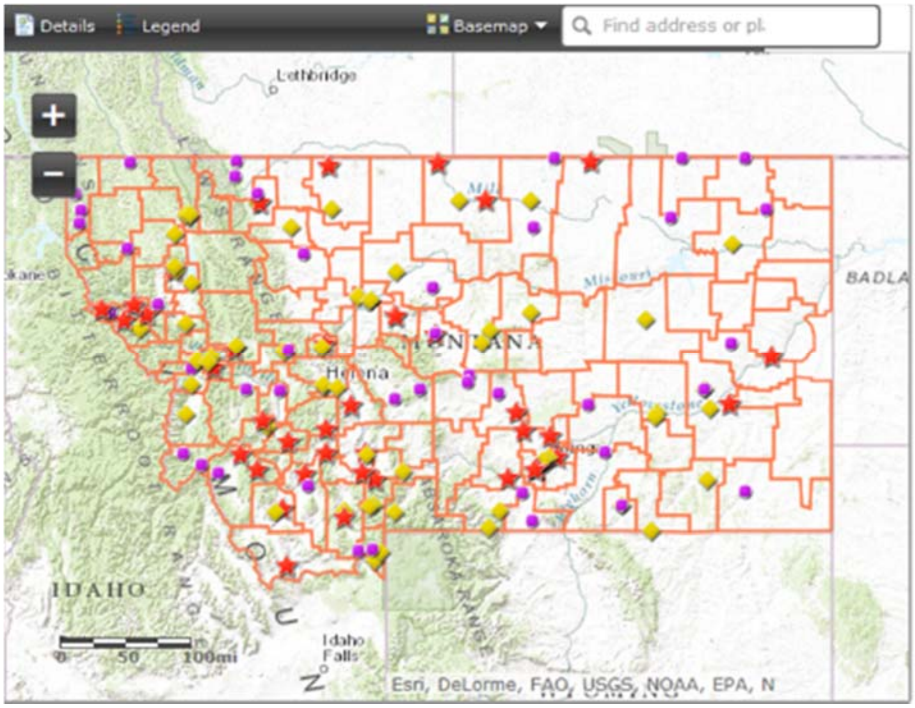


Figure 21: State Wide Distribution of ATR/WIM Sites (red stars represent WIM sites, yellow diamonds represent ATR sites, and purple circles represent proposed ATR/WIM sites).

MDT uses TCDS as a way to allow for timely internal access to traffic data (TCDS is not currently open to the public). TCDS produces a variety of reports from daily volume to individual vehicle records. A large selection of report types are also available.

After selecting a location, and dependent on the type of site, AADT, volume, speed, classification, or weight information is made available. Within each of these categories data are made available in a variety of formats including exportable tables and graphs. Figure 23 presents an illustration of the volume count data that are available. At the bottom of Figure 23 are the available ways for viewing the data. The "View Calendar" option allows for the user to select a given date for the selected site. The "View in Excel" option exports an Excel Spreadsheet of the selected data. The "Bar Graph" and "Line Graph" options display the data in the respective format. The "Weekly Report" displays a weekly report as shown in Figure 24. The "Monthly Report" option exports an Excel Spreadsheet with the selected month's data.

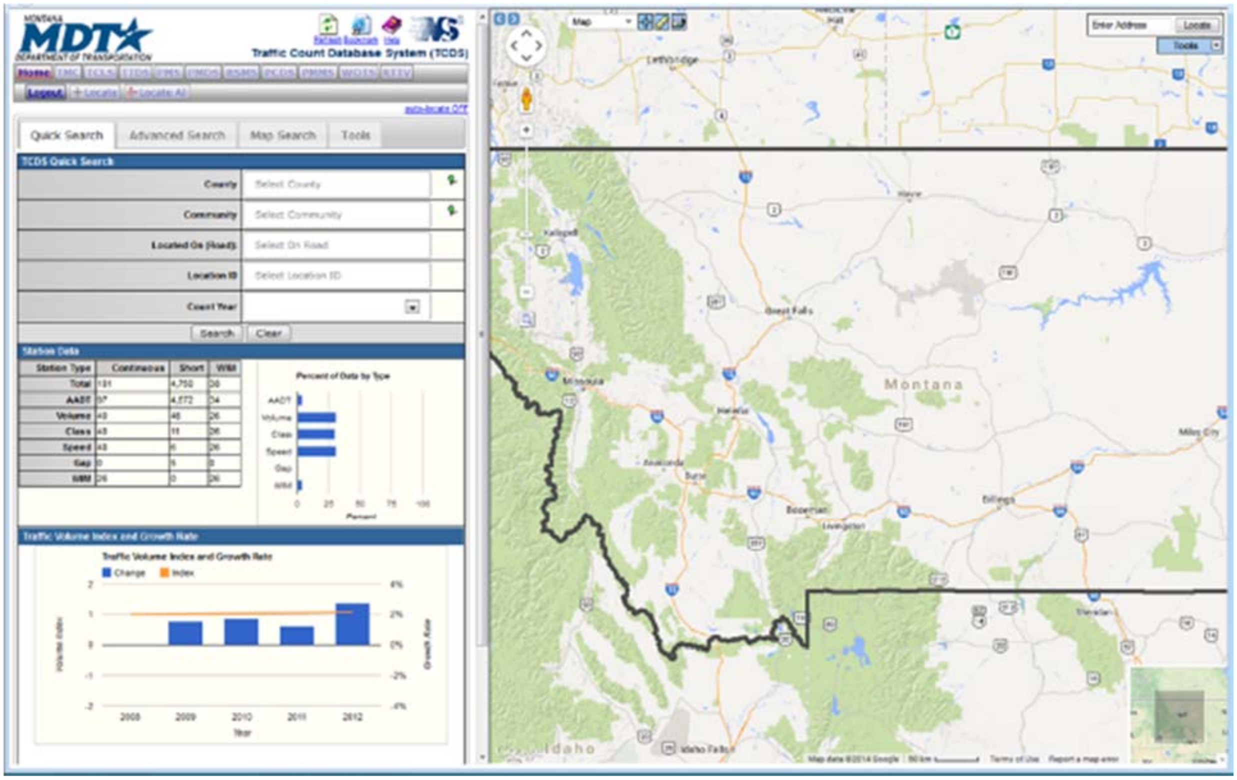


Figure 22: TCDS Dashboard

The “Weekly Report” shown in Figure 24 presents the data in both a visual and numerical way. The data are grouped by time-of-day and day-of-week. A histogram of the time-of-day occurrence allows users to quickly identify trends. Also available are a variety of descriptive statistics including peak hour time, volume, and percentage. As with much of the information available through TCDS, an option to export the information to an Excel Spreadsheet is available.

Figure 25 presents an example of the format that the bar graphs are presented, in this case speed data. As can be seen in Figure 25, the data are grouped by speed range, in this case five mile per hour groups. Many of the data available through TCDS can be visualized in this manner.

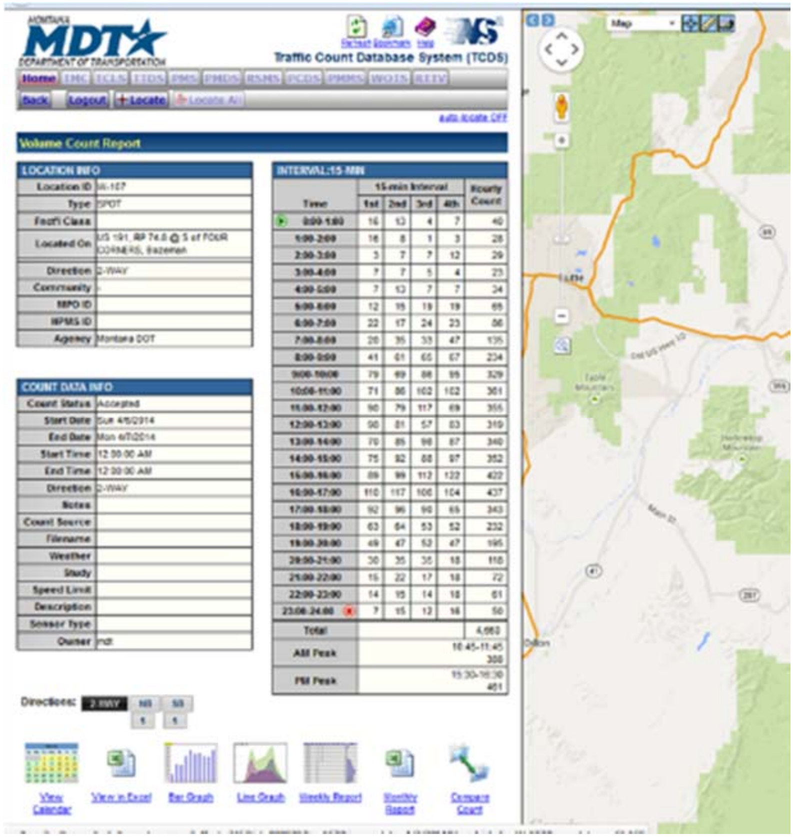
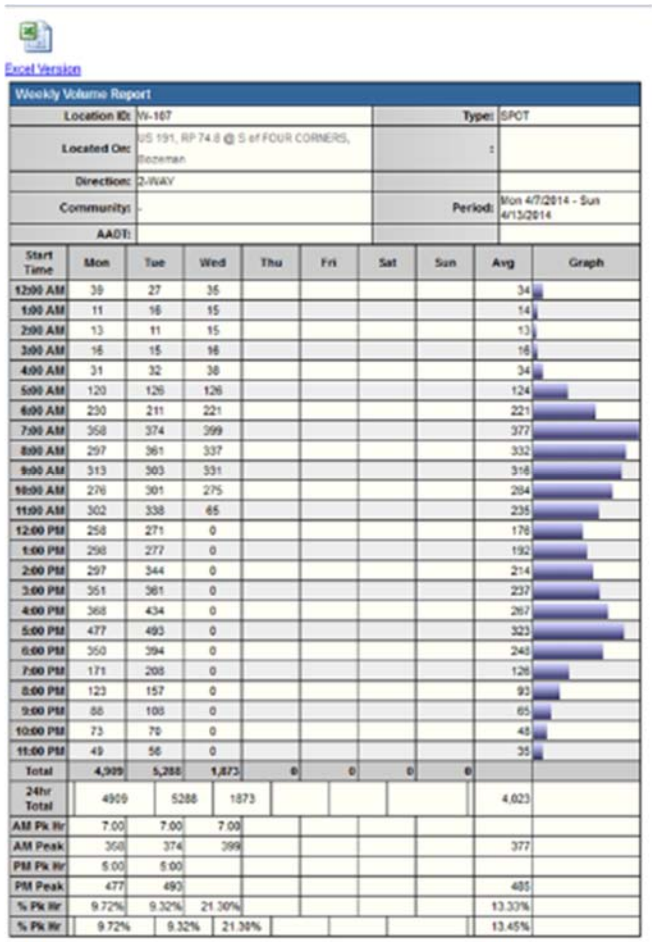


Figure 23: Volume Count Report for a Selected Site



Excel Version

Weekly Volume Report			
Location ID:	W-107	Type:	SPOT
Located On:	US 191, RP 74.8 @ S of FOUR CORNERS, Bozeman	:	
Direction:	2-WAY		
Community:	-	Period:	Mon 4/7/2014 - Sun 4/13/2014
AADT:			

Start Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Avg	Graph
12:00 AM	39	27	35					34	
1:00 AM	11	16	15					14	
2:00 AM	13	11	15					13	
3:00 AM	16	15	16					16	
4:00 AM	31	32	38					34	
5:00 AM	120	126	126					124	
6:00 AM	230	211	221					221	
7:00 AM	358	374	399					377	
8:00 AM	297	361	337					332	
9:00 AM	313	303	331					316	
10:00 AM	276	301	275					284	
11:00 AM	302	338	65					235	
12:00 PM	258	271	0					176	
1:00 PM	298	277	0					192	
2:00 PM	297	344	0					214	
3:00 PM	351	361	0					237	
4:00 PM	368	434	0					267	
5:00 PM	477	493	0					323	
6:00 PM	350	394	0					248	
7:00 PM	171	208	0					126	
8:00 PM	123	157	0					93	
9:00 PM	88	108	0					65	
10:00 PM	73	70	0					48	
11:00 PM	49	56	0					35	
Total	4,909	5,288	1,873	0	0	0	0		
24hr Total	4909	5288	1873					4,023	
AM Pk Hr	7:00	7:00	7:00						
AM Peak	358	374	399					377	
PM Pk Hr	5:00	5:00							
PM Peak	477	493						485	
% Pk Hr	9.72%	9.32%	21.30%					13.33%	
% Pk Hr	9.72%	9.32%	21.30%					13.45%	

Figure 24: Weekly Volume Report

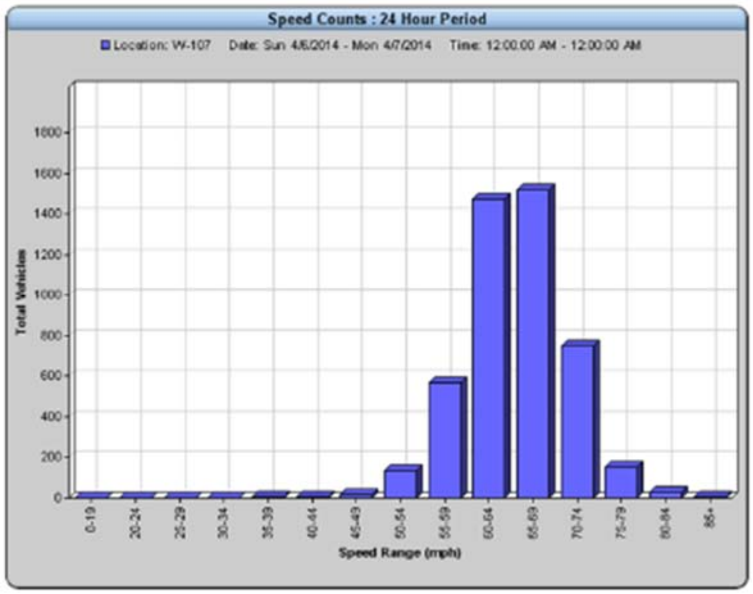


Figure 25: Speed Counts Graph

As mentioned in the Data Analysis section of this report, weight data from TCDS are used to help monitor and plan weight enforcement activities. For each WIM site, a variety of tabular and graphical reports are available. Figure 26 presents an interactive graph displaying the daily average GVW for a given site. The user can select and graph data for specific vehicle class(es) during a user-specified time span. This can be used to visually identify recurring trends in vehicle operations. Figure 27 illustrates one of the tabular formats in which the data can be presented. This table gives the number and percentage of overweight vehicles by vehicle class for the selected time period.

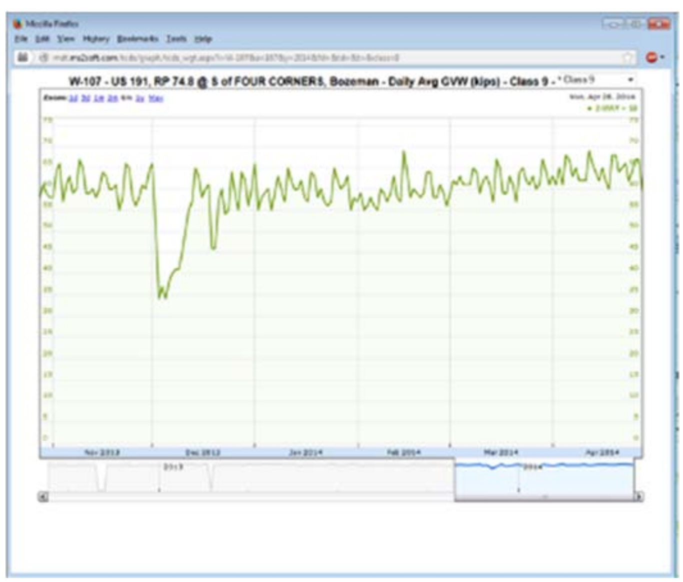


Figure 26: Interactive Daily Average GVW Plot

Gross Vehicle Weight by Class - 2014					
Distribution of Overweight Vehicles					
Class		Limit (kips)	Total	# Overweight	% Overweight
01	Motor cycle		4	0	0%
02	Car		310539	0	0%
03	Pick up		240868	0	0%
04	Bus	32	5953	2468	41%
05	2A SU	32	15760	356	2%
06	3A SU	46	2627	453	17%
07	>3A SU	54	560	377	67%
08	<5A 2U	66	1262	3	0%
09	5A 2U	80	19810	3258	16%
10	>5A 2U	88	2535	1173	46%
11	<6A >2U		31	0	0%
12	6A >2U		165	0	0%
13	>6A >2U	120	7529	33	0%
14	Other		664	0	0%

Figure 27: Gross Vehicle Weight by Class

4.4. Temporal and Areal Traffic Flows

While the cause and occurrence of spatial/temporal traffic flow fluctuations in Montana can be complex, some of these flows are readily recognized and can be characterized in varying degrees of detail. These various traffic flows are largely the result of the nature of economic activity in Montana, which is focused on agriculture, resource extraction (generally minerals/ore, forest products, and petroleum), and tourism. The following sections present a brief overview of some of the traffic flows associated with these activities. These traffic flows apparently have not previously been comprehensively and formally documented relative to their potential impact on traffic data collection activities and their potential use in planning such activities. Table 35

summarizes some of these traffic flows. Table 35 and the information it contains is offered as a possible starting point/framework to more thoroughly document such traffic flows for the TDCA Section as further information on the timing, location and extent of any such flows becomes known, notably through both a) formal studies (i.e., as may be done for other purposes but with pertinent information on traffic related to commodity flow) and b) expert assessment by experienced MDT personnel.

Referring to Table 35, for each commodity considered, the timing, general location and extent of the associated transportation activity are reported. As may be obvious, only commodities that move over the highway system are being considered. The extent of these flows is characterized in terms of the quantity of the commodity to be moved annually on Montana's roadways, and the equivalent number of trips involved per year, generally calculated using a standard payload of 25 tons per trip (approximately the payload of a common five axle tractor, semi-trailer, independent of the actual vehicle configuration employed). While very simplistic in nature, this analysis

Table 35: Identified Traffic Flows - Network Level (see Appendix D for source of values)

Nature of Activity	Brief Description	Temporal and/or Areal	Time of yr	Location	Degree of Activity	Trips per yr	Routes Impacted [b]	Vehicles per route per yr [b]
Agriculture - Crops					**tons/yr**	**25 tons/truck**		
Wheat	field to elevator (then majority out-of-state by rail	Temporal and Areal	late July through mid-September	primarily north central, central and northeastern	5,843,000	234,000	nk	nk
Alfalfa and Hay	destination less well defined	Temporal	mid June through mid-September	eastern two thirds	4,120,000	165,000 [a]	nk	nk
Sugar Beets	field to collection point, to processing plant	Temporal and Areal	mid-September to mid-November	east central and northeast	1,292,000	52,000	nk	nk
Barley	field to elevator (then majority out-of-state by rail)	Temporal and Areal	August through mid-September	primarily north central, central and northeastern	1,005,000	40,000	nk	nk
Agriculture - Livestock					**tons/yr**	**25 tons/truck**		
Cattle (beef)	field to feedlot (typically out of state)	Areal	all year	Statewide	552,000	22,080	nk	nk
Resource extraction					**tons/yr**	**25 tons/truck**		
Talc - Yellow-Stone Mine	mine to processing facility	Areal	all year	Southwest	300,000	12,000	nk	nk
Timber	forest to mill	Temporal and Areal	late June through March	West	670,000	27,000	nk	nk
Tourism					**tourists per year**	**3 people/veh**		
Glacier National Pk	traffic due to tourism	Temporal and Areal	May through November	Northwest	2,162,000	721,000	nk	nk

a value simply assumes all production leaves point of origin, which it does not

b nk – not known

generally reveals the relative contribution to traffic on the state's highways associated with various commodity flows. Of the commodities considered in Table 35, the predominant generator of intrastate commercial truck trips is agriculture - specifically, wheat and barley shipment from field to storage/transloading facility at 274,000 trips annually - with substantially fewer trips (i.e., 50,000 or fewer trips annually) generated by the other commodities considered. No claim is made, however, that all industries are fully represented in Table 35; rather, information is presented on selected major commodities and movements that can be found in various public databases. As this work moves forward, it is anticipated that information will be discovered on other commodity flows on the state's highways as well as more refined information on the movements already identified in Table 35. Any such information will be added to the Table as it becomes available.

The information presently provided in Table 35 is at the network level, i.e., estimates are provided for total annual trips by commodity as generated in relatively broad geographic areas, rather than trips on specific routes and further, specific segments of those routes. Ideally, the rightmost columns of Table 35 will be populated with this information. In these regards, an innovative approach was explored to using GIS databases and analysis techniques to bring together disparate data sets to predict temporal and spatial traffic flows around the state by specific route and commodity. Selected preliminary results from this analysis are presented later in this section, specifically for wheat and barley. Expert opinion may also be useful in attempting to determine detailed commodity flows and will be further explored as this project moves forward.

Note that in general, relative to traffic data collection and analysis, information on areal and spatially specific traffic flows should be useful in a) determining times to conduct short term counts on specific routes to ensure significant but intermittent traffic flows are adequately captured and b) developing traffic group factors to be applied to specific routes known to carry certain types of traffic associated with particular economic activities.

4.4.1.1. Temporal Traffic Flows

Viewing VMT in Montana as a function of time-of-year (shown in Figure 28) immediately reveals the degree of temporal variation in traffic flow on the state's highways. Referring to Figure 28, highway use almost doubles in the summer months of July and August, compared to the winter months of December and January. This pattern in highway use is due in part to seasonal activities associated with agriculture, timber production and tourism, as further presented below.

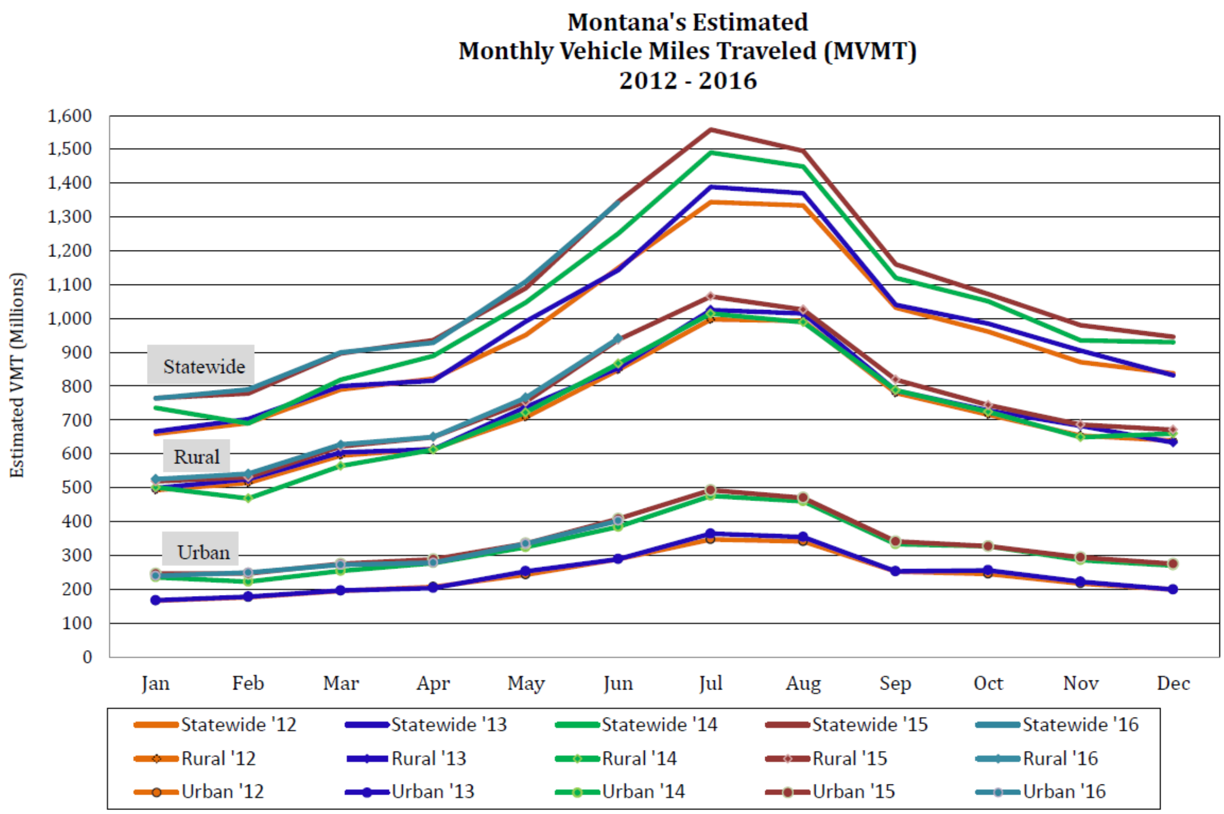


Figure 28: Montana's Estimated Monthly Vehicle Miles Traveled

Agricultural activities have a very clear time dependence based on when crops are being planted and harvested, and when livestock is being moved. The times at which large volumes of agricultural products move on the roadways varies significantly based on the commodities and regions involved (further detailed in the following section), but general trends in these activities do exist. Table 36 presents normal crop planting and harvesting times (as well as measures of volume produced) for the major crops raised in Montana. Referring to Table 36, the most significant agricultural crops by weight are hay/alfalfa, wheat, sugar beets, and barley. When these crops are harvested, they must be moved to collection/storage locations, processing facilities, and/or transloading facilities, all of which require over-the-road transportation. While over-the-road transportation demands may be greatest during the harvest times presented in Table 36 (generally, some subset of the period June through November), it is important to note that movement of these commodities is not limited to just these harvest periods. Wheat, for example, may be stored on or near its point of origin at harvest time, to be moved to a transloading facility when space at the facility becomes available and/or a more attractive sales price will be realized. Similarly, sugar beets may be collected at regional receiving stations at harvest time, and trucked to a central processing facility over the next several months.

Table 36: Crop Planting and Harvesting

Crop	Usual Planting Date			Usual Harvesting Date			2012 Production	Weight of Total Harvest (tons)
	Begin	Most Active	End	Begin	Most Active	End		
Hay, Alfalfa	--	--	--	Jun 18	--	Sep 23	3,000,000 Ton	3,000,000
Wheat, Spring	Apr 6	Apr 14 - May 12	May 18	Jul 30	Aug 7 - Sep 6	Sep 13	95,700,000 Bu	2,871,000
Wheat, Winter	Sep 6	Sep 12 - Oct 7	Oct 16	Jul 22	Jul 26 - Aug 12	Aug 17	84,630,000 Bu	2,538,900
Sugar Beets	Apr 14	Apr 20 - May 12	May 18	Sep 28	Oct 9 - Oct 27	Nov 4	1,292,000 Ton	1,292,000
Hay, Other	--	--	--	Jun 20	--	Oct 7	1,120,000 Ton	1,120,000
Barley, Spring	Apr 3	Apr 13 - May 11	May 20	Jul 27	Aug 3 - Sep 2	Sep 10	41,870,000 Bu	1,004,880
Corn for Silage	Apr 26	May 4 - May 28	Jun 4	Aug 26	Sep 6 - Oct 1	Oct 10	840,000 Ton	840,000
Wheat, Durum	Apr 25	May 1 - Jun 1	Jun 15	Aug 11	Aug 19 - Sep 22	Oct 4	14,420,000 Bu	432,600
Corn for Grain	Apr 26	May 4 - May 28	Jun 4	Oct 4	Oct 25 - Dec 3	Dec 8	6,600,000 Bu	231,000
Potatoes, Fall	May 7	May 17 - Jun 7	Jun 13	Sep 19	Sep 22 - Oct 23	Oct 31	3,744,000 CwT	187,200
Beans, Dry	May 5	May 10 - Jun 3	Jun 9	Aug 27	Sep 3 - Oct 2	Oct 11	466,000 CwT	23,300
Oats, Spring	Apr 18	Apr 26 - May 28	Jun 5	Aug 8	Aug 15 - Sep 9	Sep 22	810,000 Bu	12,960

Source: USDA (2013)

The movement of livestock, while dependent upon the season, is far less regular than that of crop products. Often the movement of livestock is at the discretion of the rancher and is highly variable based on market trends. This leads to complications with determining if livestock movement has a large impact on seasonal traffic volumes in Montana.

Resource extraction, while generally a year-round activity, does have some temporal dependence. The timber industry is a good example; the times and locations in which logging occurs are greatly dependent upon political pressures, permitting regulations, ecosystem considerations and road conditions (i.e., seasonal load restrictions). Generally, there is a pause in logging operations during the wet spring months, although adverse climatic conditions any time during the year can curtail harvest operations.

Tourism in Montana is a year-round phenomenon with summer recreation including fishing, backpacking, and sightseeing along with winter recreation including skiing and snowmobiling. Out-of-state tourist activity is greatest from July through September – accounting almost 50 percent of all visits, followed by the period April through June – accounting for approximately 25 percent of all visits (Nickerson 2014). While tourism results in increased traffic volumes, the associated vehicles tend to be in Classes 1 through 4, which as lighter configurations have only moderate impact on pavement design considerations.

4.4.1.2. Areal Traffic Flows

Similar to the temporal variations in traffic operations across the state, a large number of areal specific traffic flows exist due to Montana's extensive and varied nature. Crop production is spatially well documented at a relatively fine scale. Presented in Appendix E are maps summarizing the areal extent of each major crop grown in Montana based on data available from the United States Department of Agriculture (USDA). Wheat, the largest crop in the state, is grown in almost every county, although approximately 45 percent of the state's wheat is produced in the seven counties comprising the "Golden Triangle" defined by Great Falls, Havre and Shelby (MWBC 2014). The location of typical wheat producing acreage is shown in Figure 29 (in this case, specifically for spring wheat). The majority of the wheat grown in Montana is shipped out-of-state by rail (approximately 80 to 90 percent of the wheat produced) primarily to the west coast (USDA 2013). Barley is produced generally in the same regions of the state as is wheat, and again, most of this commodity is shipped out-of-state by rail. Thus, the primary roadway movement associated with wheat and barley is from field to rail elevator (sometimes, with intermediate on farm storage between field and elevator). Annual production of these crops, combined, is 6,848,000 tons, corresponding to 274,000 equivalent 25 ton truck trips (Table 35).

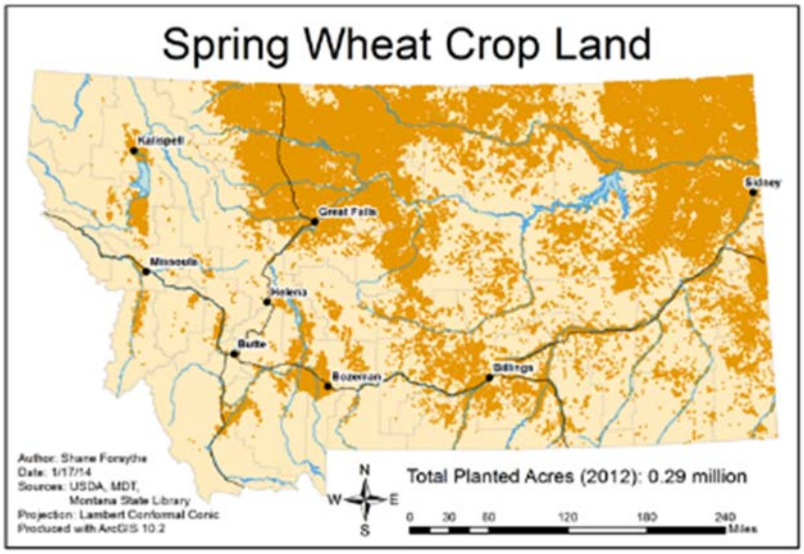


Figure 29: Spring Wheat Crop Land

The flow of other major crops grown in Montana - besides wheat and barley - as they move from field to market can be more difficult to predict. Notably, hay and alfalfa, grown primarily in the eastern two-thirds of the state, is second to wheat in tons produced (4,120,000 tons annually – Table 10), but transportation of hay and alfalfa is more complicated than is the case for wheat and barley, as these commodities are not directly transferred from a field to a centralized storage/transloading facility. Instead, hay and alfalfa can be stockpiled in a variety of locations and/or transported out-of-state by truck.

The next largest crop raised in Montana based on weight is sugar beets (1,292,000 tons annually, corresponding to 52,000 ~25 ton truck trips – Table 10). Sugar beets are somewhat more similar to wheat and barley again, in that sugar beet production is relatively well defined in geographic extent, with the sugar beets being moved from their point of harvest to reasonably well defined destinations. Sugar beets are primarily grown in the eastern part of the state in a region bounded by Roosevelt and Richland counties on the northeast running to Yellowstone and Carbon Counties in the south central part of the state (USDA 2013). Sugar beets are processed at facilities located in Billings and Sidney, MT (Sugar Producer Magazine 2013). Typically the beets are trucked either to a piling station or directly to the processing plant from the field, with the sugar produced than being shipped out-of-state by rail. The Sidney processing plant, for example, has five beet receiving stations in addition to the processing site, namely, Culbertson, Savage, Pleasantview, Powder River, and Sugar Valley (Sydney Sugars undated). Beets delivered to the receiving stations are trucked to the processing plant over the next several months after their harvest.

Other agricultural products included in Table 11 (corns, potatoes, beans and oats), collectively comprise less than 10 percent by weight of all crops listed in the table, and were not given further consideration in this study. Beef cows are the primary livestock raised in Montana, comprising 50 percent of the state's total livestock inventory – excluding poultry (USDA 2013). The majority of beef cattle are shipped live by truck to processing facilities out-of-state (GrowMontana undated). These shipments comprise 552,000 tons annually, which corresponds to only 22,000 ~25 ton truck trips (Table 10).

As would be expected, traffic associated with natural resource extraction is highly dependent upon the location of the natural resources. For example, talc mined south of Ennis, MT at the Yellowstone Mine (estimated at 300,000 tons annually, corresponding to 12,000 equivalent 25 ton truck trips) is transported to processing facilities near Three Forks or Sappington, MT throughout the year (MDEQ 2004). From these facilities, the talc is processed and further transported out-of-state by truck and by rail. Another example is the Stillwater Mine Complex in south-central Montana. Mine concentrates, i.e., ore that has been processed to obtain the 2 percent of material containing platinum group metals (Stillwater Mining Company 2013), are hauled nearly 40 miles from the mine site near Nye, Montana to the smelting and refining facilities near Columbus, Montana. Columbus is situated on the rail system, as well as on the primary east-west interstate highway in the state.

Other natural resource extraction activities and the associated highway traffic they generate are more complicated to describe in a spatial sense. Over the past couple of decades the timber industry has been affected by a variety of socio-economic factors that have made predicting its operations difficult, both spatially and temporally. A large amount of traffic related to hauling logs from the forest to a sawmill might be observed for example in one region, while in a seemingly similar region across the state no activity is observed. That being said, timber is primarily harvested in the south central and western part of the state. Selected information is available on logging activity by county as well as destination of the harvested timber by facility type (McIver, et al. 2013). Overall, approximately 670,000 tons of timber is harvested annually (based on board feet of production reported by Morgan, et al. (2012), which corresponds to 27,000 equivalent 25 ton truck trips (Table 10).

The rise of the oil industry notably in the region of the Bakken formation in western North Dakota and northeastern Montana has led to a rapid rise in traffic volumes, especially commercial truck volumes. These types of resource extraction are harder to characterize due to their rapidly changing nature, this is why MDT has cited them as areas of interest. In the case of traffic associated with extraction of oil from the Bakken formation in eastern Montana, MDT sponsored a study of expected highway impacts from this development that forecasts changes in traffic volumes on specific routes in a 13 county area based on various future levels of oil development (Dybing, et al. 2013).

The areal distribution of tourism can be determined more readily by looking at the locations of state and national parks along with other tourist attractions. MDT has addressed this by using a recreation traffic factor group. Primary out-of-state tourist destinations are Yellowstone and Glacier national parks, being visited by approximately 75 and 33 percent, respectively, of all out-of-state visitors (Nickerson 2010). At a minimum, several hundred thousand visitor trips can be attributed annually, for example, to Glacier National Park, alone.

4.4.1.3. Estimation of Commodity Flow by Route and Highway Segment

While identification of temporal and areal traffic flows as described by geographic region should be generally useful in planning traffic data collection efforts, it would certainly be beneficial if expected traffic operations could be more precisely estimated by specific route and highway segment. Considerable data is becoming increasingly available at finer and finer levels of detail in various GIS datasets. Notably, several factors embodied in these datasets reflect the temporal and geographic nature of commodity production and processing needs, which can in turn be analyzed in the context of the available highway network to estimate associated traffic flows by commodity, route and time-of-year. Requirements for such an analysis consist of detailed information on commodity origination, amount produced, and its destination.

To demonstrate the potential to estimate commodity flow by route and highway segment by spatial analysis, movement of wheat and barley from field to grain elevator was modeled. An overview of this analysis is presented below, with a more detailed description of the model and results being available in (Forsythe 2014). Information is available in agricultural databases on specific acreage across the state planted in these crops (e.g., see Figure 29), the amount harvested annually, and the general start time and duration of the harvest season (see Table 35 and Table 36). This information was analyzed in the context of the location of grain elevators within the state and the layout of the highway network connecting field and elevator. Relative to other commodities, the most detailed origin and destination information required to complete such an analysis appears to be available for wheat and barley (which incidentally, are major commodity movements by highway identified in Table 36). That being said, several assumptions still had to be made in completing this analysis as described below, which impacts the accuracy of the results. The results from such an analysis could well be sufficiently accurate to be very useful in optimizing traffic data collection efforts and in general planning activities.

Relating wheat and barley production and elevator locations to determine associated traffic demand during the harvest season by route was done spatially using a four step traffic demand model. For this work, it was assumed that harvest season traffic occurred over 52 days from July 22 through September 13, with the results simply presented as average trips per day of the harvest season. Spatially, model generation was accomplished using a methodology somewhat similar to that used by Dybing, et al (2013) in a study completed for MDT on increased traffic associated with energy development in the Bakken. Dybing, et al. utilized a geographic information system (GIS) to aggregate oil production data based on the United States Geological Survey (USGS) Land Survey System. Townships were used as the traffic analysis zones (TAZs) in their model. Use of a four-step model for commodity flow was also outlined in National Cooperative Highway Research Program (NCHRP) Report 606 (Cambridge Systematics, Inc. 2008). This model shares many similarities with a passenger trip model, but differs by using tons of commodities instead of passenger trips. The four-step model consists of:

1. Trip generation, how many trips are going to and from a given TAZ;
2. Trip Distribution, how are the trips distributed between the TAZs;
3. Mode Choice, what type of travel mode are the trips be performed with; and
4. Route Choice, what routes are being used for the trips.

The township grid for the state of Montana was selected for the TAZs in this study. Crop location data are made available through the USDA as a 30 meter grid cell raster. The ground cover attribute for each grid cell was remotely sensed and varied from urban land use to specific crop types. From this point, it was possible to determine the acres of a given land use by converting the number of grid cells per township to acres. After calculating the amount of each ground cover type in each TAZ, the data was further refined and condensed by removing the cover types that were not of interest. Wheat and barley were selected and analyzed concurrently due to their relatively known destination when leaving the field - grain elevators. The simplifying assumptions were made that all wheat and barley moved directly to elevators from the field, and that this movement occurred during harvest time. These assumptions can be refined as necessary in future analyses based on additional information on the nature of wheat and grain movements as identified in other studies (e.g., Tolliver, Dybing and Mitra 2006, Cambridge Systematics 2010). Location and capacity data for grain elevators were obtained from the Montana Wheat and Barley Committee. This data set included the point location, silo capacity, and rail capacity for each grain elevator in Montana.

For trip distribution, the TAZs were connected to the state highway network. Elevator and route selection was simply based on shortest travel time from field to elevator, where travel time was calculated as travel distance divided by estimated speed limit for the type of route being used. The model estimated commodity flow in tons, which was then converted to trips assuming 25 tons per trip by truck (say a 5 axle tractor, semitrailer).

The results of this analysis in terms of daily truck trips by route over the harvest season are presented in Figure 30. Qualitatively, it can be seen in Figure 30 that much of the predicted seasonal heavy truck traffic is located in areas with high agricultural production and densely located grain elevators. This is an expected result of the four-step model that was used. It also appears that the segments with high heavy truck volumes follow the major corridors through

Montana. This is an expected result in light of the synergistic relationship between transportation needs and the associated evolution of the transportation network often resulting in major roadways providing shortest paths between locations of codependent economic activity. Over the past several years, large grain elevators that can service 110 car shuttle trains are increasingly being used in moving grain out-of-state as a result of the rail related transportation efficiencies they offer. The locations of these shuttle loading facilities are also shown in Figure 30. Generally heavy truck traffic is predicted in the vicinity of these facilities, although possible non-travel time related inducements to grain growers to use these shuttle loading facilities have not been considered in the analysis. It may be possible to introduce the influence of such factors in future analyses.

Among other things, the results of this analysis can possibly be used to identify routes on which seasonal grain movements are a significant contribution to the total traffic reported annually, and therefore routes on which this seasonal event should be considered in planning traffic data collection efforts and in determining appropriate traffic group factors to be used in expanding short term counts. Similar analyses may also be conducted on other commodity flows with temporal and/or seasonal features for which origin and destination is reasonably known, say, for example, sugar beets and timber.

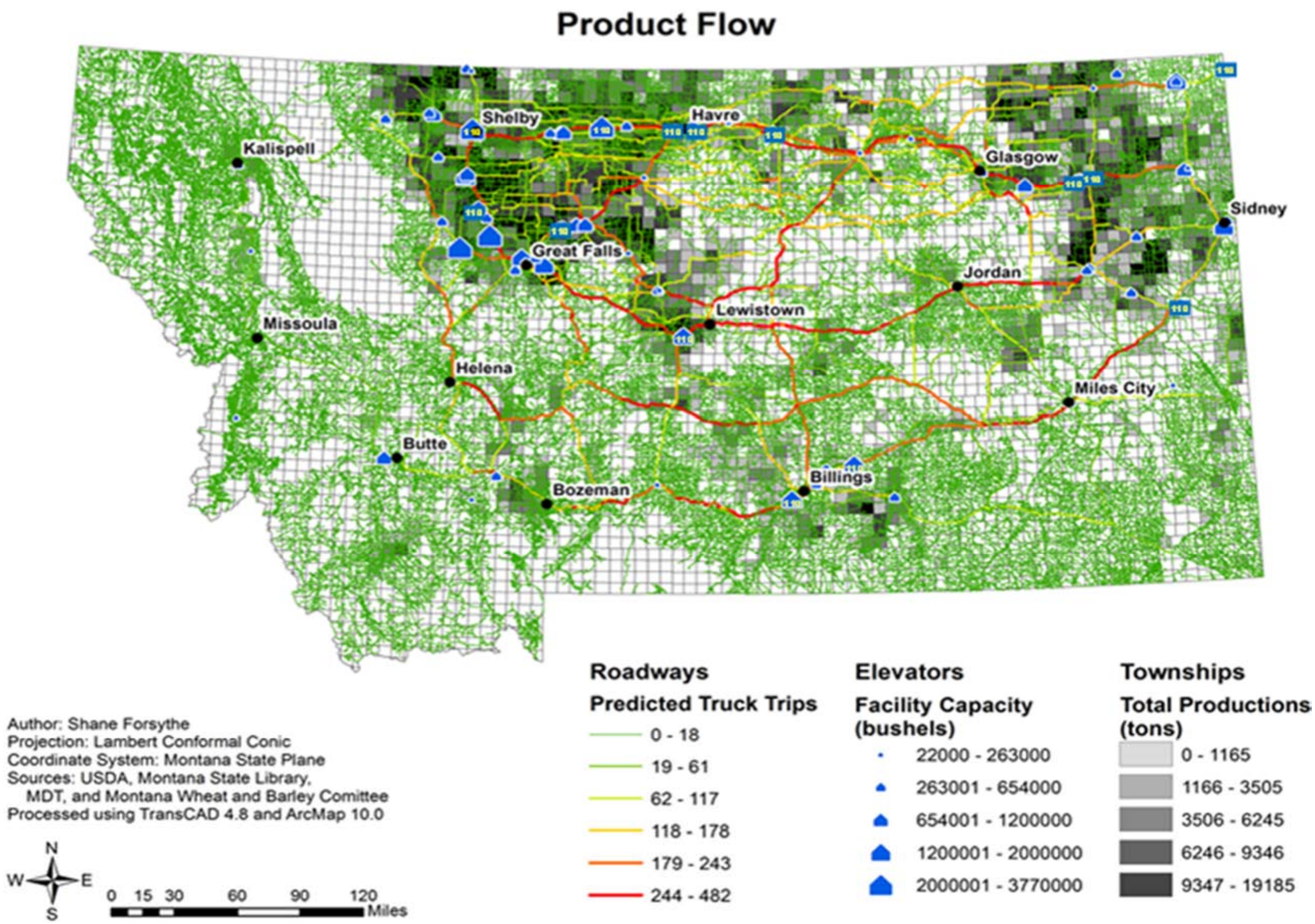


Figure 30: Estimated Daily Truck Trips, Harvest Season, Wheat and Barley (Forsythe 2014)

4.5. Summary

Capturing and detailing the nature of traffic throughout a state can be a difficult task, particularly when the state is as large and diverse as Montana. To address these issues, MDT has deployed a traffic monitoring program that consists of permanent ATR/WIM installations and short-term counts. These three counting methods are used synergistically to generate a clear view of the traffic in Montana with respect to volume, classification and weight of the vehicles using the state highway system.

The foundation of MDT's traffic data collection program are the permanent ATR/WIM sites which continuously monitor traffic operations on the state's highways. These 106 installations (64 ATR and 42 WIM sites) directly collect data on approximately 11 percent of the VMT on the state highway system, and the data they collect is critical to expanding short term traffic counts conducted at approximately 5,800 short monitoring sites around the state to provide an estimate of annual traffic flow. The ATR systems collect volume or volume and speed data (from which vehicle classification can be determined), while the WIM systems additionally collect data on axle/gross vehicle weight. The first step in processing this data is to perform extensive quality control checks of "reasonableness" relative to a) physical limits on the phenomena being measured/calculated and b) historical values determined for the same parameter. These checks are done both automatically, and through data review by experienced TDCA personnel.

The screened data are then used to determine various characteristics of the traffic operating on the state's highways, such as AADT, VMT, ESALs, etc. These traffic characteristics are determined for various aggregations of vehicle configurations (e.g., for each of the FHWA Scheme F classifications, for all commercial vehicles, for small and large trucks) over various time intervals (e.g., daily, weekly, monthly, annually). These data are used to determine traffic factors that are used to expand the results of short term traffic counts conducted for just a few days to AADT. Currently these traffic factors are generated for each traffic factor group (nine groups), by day-of-week (seven classifications) and month of year (12 months).

Traffic data dissemination is realized through a variety of publications, interactive maps and software applications, all available on the internet. The most encompassing traditional report is the TBS publication. The TBS presents the AADT for each roadway segment that is monitored as part of MDT's traffic count program. Other reports present various traffic attributes and provide some insight on the underlying data processing/analysis methods used by MDT. The "Yearly ATR/WIM Report" presents the data collected by the permanent sites though out Montana. The "Traffic Factor Tables" give the traffic factors that are applied to short-term counts.

In addition to printed media, two online interactive maps using GIS are available to the public. The first of these maps allows users to select a segment of roadway and review data including

AADT, type of count, etc. Another feature of this map is the visualization of the roadways using line weight and color to depict the range of traffic volumes in an area. The second map that is made available presents the location of all of the permanent ATR/WIM sites. This map presents much of the same information that the previous map does, with the addition to a link to the "Yearly ATR/WIM Report" tables that correspond to the selected ATR/WIM site.

MDT also uses another online system for internal, timely data sharing – TCDS, a commercial software package developed by MS2 for processing and presenting traffic data. TCDS allows those within MDT (notably including MCS enforcement) and MHP to view timely speed, volume and weight data.

Whether the data being collected capture all of the important traffic flows on the state's highways can only be fully determined if the existence of these flows (and if appropriate, their causative factors) is known. Notably, large local/regional fluctuations in traffic volumes and in the composition of the traffic stream are encountered on many of Montana's highways both temporally and spatially, as the state's economy is agriculture, natural resource extraction and tourism intensive. Efforts were made to begin documenting various temporal and areal traffic flows related to agriculture, natural resource extraction and tourism. Specifically, seasonal/regional commodity flows for wheat, barley, sugar beets, beef cattle, talc, and timber were characterized at the network level in terms of annual trips generated assuming a 25 ton payload per truck trip. Of these commodities, wheat generated significantly more trips than other commodities considered (234,000 trips assuming 25 tons of wheat per trip), although the list of commodities considered was not exhaustive. An innovative technique to further estimate traffic impacts of such commodity flows at the route level using GIS databases and analysis methodologies was investigated, with a trial application to wheat and barley movements. This analysis methodology appears promising, and may benefit from further modification/refinement in the future.

5) SURVEY OF MDT TRAFFIC DATA USERS

Working with the TDCA Section, current and potential users of TDCA Section information were identified and then contacted by the research team to learn about their use (or potential use) of the data available from the TDCA Section, as well as what new data and/or data products (i.e. aggregation/presentation schemes) they desired to better support their activities.

Thirty-three surveys were collected from various divisions, programs, bureau, and districts within MDT; local cities and MPOs; and tribes, from December of 2014 through July of 2015. The survey asked questions to better understand

1. How traffic data is being used,
2. What type of data users need,
3. The value of good data,
4. The ease of accessing data,
5. The use of the TDCA Section website, and
6. Experiences with the new TCDS.

The survey was distributed as a Word document, by phone interviews, and via SurveyMonkey. Providing potential respondents with a multitude of venues through which the survey information could be provided assisted in obtaining more user responses. This chapter presents the survey results and summarizes its overall findings.

5.1. Survey Design

The specific instrument used for this survey was designed in conjunction with the TDCA Section of MDT. The full instrument is reproduced in Appendix F. The survey began with a brief description of the overall project being conducted by MSU for MDT on the general efficacy of the traffic data collection program, followed by a brief statement on the importance of data user input as part of this review. Survey participants were then asked to provide some background information on their institutional affiliation (e.g., MDT affiliation, metropolitan planning organization, tribe, etc.). As previously mentioned, questions were then asked to better understand 1) how traffic data is being used, 2) what type of data users need, 3) the value of good data, 4) the ease of accessing data, 5) the use of the TDCA website, and 6) experiences with the new TCDS.

Following the suggestions of the TDCA Section, survey responses were solicited from 22 entities within MDT (consisting of 19 contacts at various levels within MDT's pertinent central divisions, and 5 contacts across the district offices - one in each district), the MHP, Montana's 3 MPOs, and 8 Montana tribal entities. Some input was received by cities within the State of Montana as a result of the MPO associated with that city being contacted. Specific contacts are indicated in Table 37, as are the 33 survey responses that subsequently were completed. Referring to Table 37, the survey respondents included a wide and relatively complete cross-section of traffic data users within and outside MDT. Within MDT, the specific entities contacted for the survey are indicated in Figure 31. Two MDT divisions were relatively heavily sampled, the Highways and Engineering Division, and the Rail, Transit and Planning Division. The specific MDT Bureaus within these Divisions that were contacted and that responded during the survey are further identified in Table 38.

Table 37: Summary of Survey Invitations/Respondents

	Entity Contacted	Current Significant Data User	
		Yes	No
MDT	**General Services**		
MDT	Legal Services		1
MDT	**Districts**		
MDT	Missoula District	No Response	
MDT	Butte District	No Response	
MDT	Great Falls District	1	-
MDT	Glendive District	No Response	
MDT	Billings District	1	-
MDT	**Central Divisions**		
MDT	Highways and Engineering Division	9	4
MDT	Maintenance Division	1	-
MDT	Motor Carrier Services Division	1	-
MDT	Rail, Transit & Planning Division	4	-
MHP	Montana Highway Patrol	-	1
MPOs	Billings	2	-
MPOs	Great Falls	2	-
MPOs	Missoula	1	-
Tribal	Blackfeet Nation	-	1
Tribal	Chippewa Cree Tribe	1	-
Tribal	Crow Nation	No Response	
Tribal	Confederated Salish & Kootenai Tribes	1	-
Tribal	Fort Belknap Assiniboine & Gros Ventre Tribes	No Response	
Tribal	Fort Peck Assiniboine & Sioux Tribes	No Response	
Tribal	Little Shell Chippewa Tribe	-	1
Tribal	Northern Cheyenne Tribe	-	1
SUB TOTAL		**24**	**9**
TOTAL		**33**	

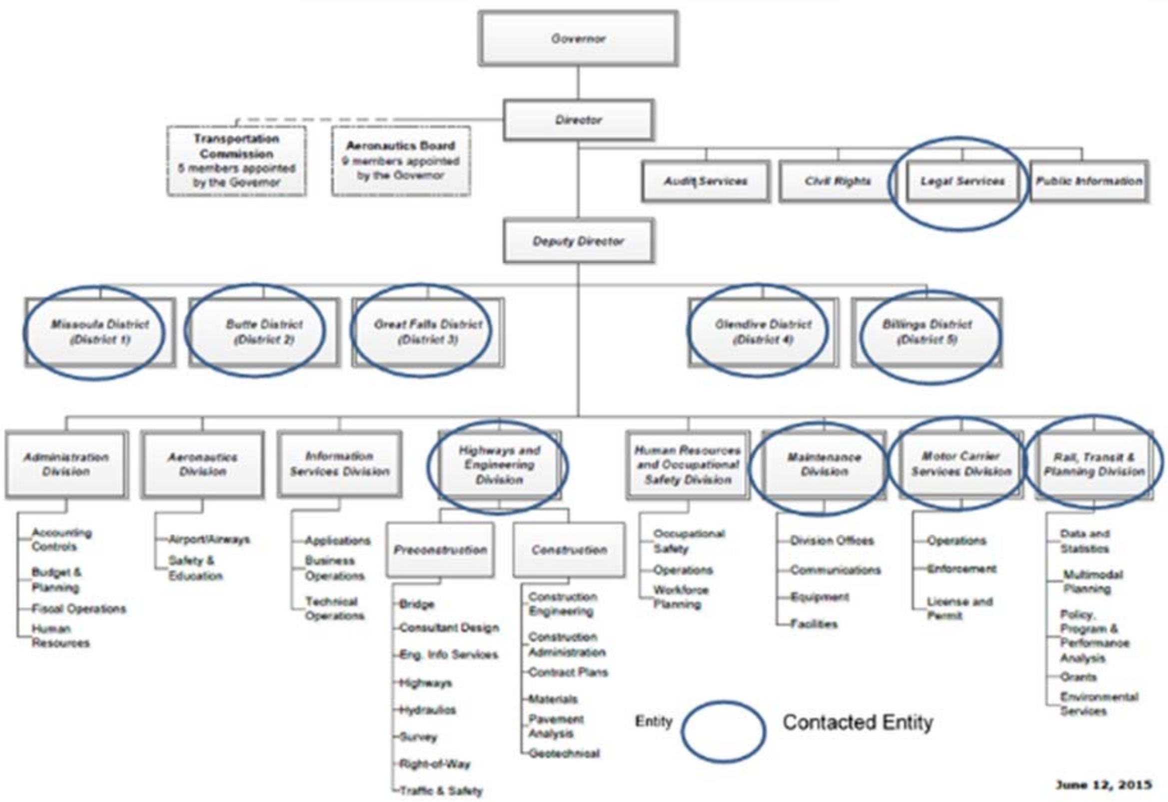


Figure 31: MDT Entities Contacted

Table 38: Summary of MDT Respondents, Highways and Engineering Division and Rail, Transit and Planning Division.

Entity Contacted		Current Significant Data User	
		Yes	No
Hwys and Eng	**Preconstruction**		
	Bridge	1	1
	Consultant Design	1	
	Right-of-Way	1	
	HIghways	1	1
	Traffic and Safety	3	
	Construction		
	Construction Engineering		1
	Construction Administration		1
	Materials	2	
Rail, Trst, Plan	**Rail,Transit and Planning**		
	Multimodal Planning	1	
	Policy, Program and Performance Analysis	1	
	Grants	1	
	Environmental Services	1	
SUB TOTAL		**13**	**4**
TOTAL		**17**	

5.2. Survey Results

The responses received to each survey question are summarized below. Of the 33 responses collected, 9 were from entities that when contacted, indicated that they were not significant users of traffic data or were only potential users, and did not further complete the survey. These respondents are indicated by organization in Table 37. For many respondents, their work is dependent upon the quality and extent of information provided by the TDCA Section; therefore, their responses provided considerable information and insight. The majority of respondents indicated the traffic data they needed was available, with several commending TDCA on its quality and accessibility.

5.2.1. Description of Tasks Requiring Traffic Data

This section discusses responses to the question, "Description of basic task that requires traffic data." Across all of the surveys collected, respondents identified a total of thirty-four data uses, almost all of which were current data uses. The majority of respondents only provided one data use; however, one respondent identified four separate data uses.

Several respondents indicated that some of the current data uses were also potential data uses. There were only three respondents who identified solely potential data uses. All three of these respondents were from tribal entities. One of the tribal respondents indicated that a potential data use was related to the construction of new roads and bridges; however, the respondent did not specify what information they specifically sought. Another tribal respondent indicated that while in the past the tribal entities primarily relied upon consultants or possibly the state to provide data related to transportation projects, they are now working to collect this information on their own. Some of the data that they need is information related to transit ridership, particularly from the perspective of age and disability. It seems that their needs and interests expand beyond the typical roadway traffic data that is collected. A third tribal respondent identified a potential data use related to all-terrain vehicles (ATVs). The respondent indicated that the tribal entities know that crashes with ATVs occur; however, because there is limited information on the level of use of ATVs at the state level, they are challenged with developing policies regarding ATV use. While the survey responses clearly identified a few potential data uses, from the researchers' experience in conducting surveys, it seems that many respondents may not have considered how existing data could be used for other purposes. Therefore, it is recommended that the TDCA Section review existing data uses and make an effort to disseminate information on other potential uses of the data. This would bring additional value to the data already collected.

The majority of current data uses identified by respondents fall into three categories: planning, design and safety. Respondents also identified two additional uses: right-of-way acquisition and weight enforcement monitoring. The following three sections discuss the aforementioned categories.

5.2.1.1. Planning

Survey respondents identified several uses of traffic data for planning purposes. One respondent indicated that the data was used in part to develop the statewide bicycle map. Bicyclists, using the information provided within this map, plan their routes to avoid roadways with high traffic volumes. In addition, the data is used in National Environmental Policy Act (NEPA) and Montana Environmental Policy Act (MEPA) analyses. The data is also used when identifying potential wildlife crossing facilities. The data was identified as being utilized for calibrating travel demand models. Finally, respondents indicated that the data was used in developing Long Range Transportation Plans (LRTPs).

5.2.1.2. Design

As identified by numerous survey respondents, traffic data is imperative for transportation design. Traffic data was identified as being used in the design of pavements and pavement treatments, particularly with respect to what material type is chosen (e.g., chip seal aggregate size, asphalt cement grade). A respondent also identified traffic data as being used to design the horizontal and vertical alignment of roadways. A respondent indicated that traffic data was used to design clear zones. Signal timing, intersection geometry, traffic control (stop sign vs. a signal light), lighting, and striping were all identified as activities that relied on traffic data as design inputs. Finally, one respondent highlighted the need for traffic data when performing traffic engineering analyses.

5.2.1.3. Safety

Several respondents cited uses of traffic data for safety analyses. Respondents indicated that the traffic data was used in 1) normalizing crash data for federal reporting, 2) evaluating railroad crossings, and 3) conducting Road Safety Audits (RSAs).

5.2.1.4. Summary

Typically, traffic data is being used for planning, design and safety purposes. There were only two uses identified by survey respondents which extended beyond these categories: weight enforcement and right-of-way acquisition. Only a few respondents provided examples of potential data uses, the majority of which were tribal entities. Therefore, if the TDCA Section can see the potential for additional uses, the researchers recommend that they reach out and inform potential users. In fact, in one of the subsequent sections, a Bureau within MDT indicated that they were interested in learning more about how they could make additional use of the currently available data. At least two of these needs are tied to federal requirements (crash data and HPMS).

5.2.2. Data Types

Survey respondents were asked to identify "Specific traffic data and related parameters used/needed" for the task that they had previously identified. Almost all users identified AADT as one type of data used in their work (55 percent of respondents that indicated they used this data). The second and third most commonly used data types, both mentioned by 24 percent of respondents, were ESAL and percentage of trucks. VMT, DHV, growth rate, and vehicle speed were identified by approximately 12, 9, 9 and 6 percent of respondents, respectively. All of the other data types identified (turning movements, axle weights by vehicle type, commercial vehicle miles traveled, bridge formula violations, commercial AADT, "motorcycle," letting date ADT, traffic counts at railroad crossings, K factor, directional factor, bike counts and pedestrian counts) were identified by only one respondent. While it makes sense that AADT (and many of its permutations) is the most commonly utilized type of traffic data, the high representation of other parameters may be a reflection of who responded to the survey instead of which ones are the most frequently used.

5.2.3. Importance of Traffic Data to Transportation Program

For each task that requires traffic data identified by survey respondents, users were asked to provide information on the importance or benefits of high quality traffic data to this work. The data provided by the TDCA Section was often characterized by respondents as "essential," with many respondents commenting on the significant impact the data has on the cost of MDT projects.

The following list highlights activities for which the traffic data provided by the TDCA Section is essential:

- imperative to safety analysis,
- defines bicyclist travel routes,
- ensures cost-effective design (pavement, traffic signal installation, etc.),
- project development,
- accurate estimate of real estate value (whose transactions are in the millions of dollars),
- weight enforcement,
- accident prevention,
- evaluation of railroad crossings,
- comparisons for data collected by local and tribal entities,
- defensible data for NEPA and MEPA litigation,
- evaluation of need for wildlife crossings,
- model calibration for future year estimates, and
- risk analyses.

Quotes that best capture the importance of the data follow:

"Our SFC [State Funded Construction] budget is about [$]10 million/year with approximately [$]9 million going to pavement preservation type projects. Traffic data is an important aspect in determining disbursement of the funds."

"…the importance of traffic data is imperative to the surface designer. Good data early on is the foundation of a good project. I have over 20 years of experience with MDT in preconstruction and we rely heavily on good data. I have seen plans need to be changed because the data was valid when collected and had changed enough with time that plans needed to be changed to accommodate the increase in traffic."

"FHWA uses the annual data submitted through the HPMS for many important functions including:

- Providing data for apportionment of federal-aid funds to states.
- Serving as a data source and primary analytical support for The Status of the Nation's Highways, Bridges and Transit in the Conditions and Performance Report (C&P Report).
- Serving as the data source for the annual congressionally mandated Highway Safety Performance Report.
- To provide justification for increases in the federal motor fuel tax to support expanded federal-aid programs that address a deteriorating highway infrastructure.
- To provide basis for policy analysis and development.
- Serving as data source for publications such as Highway Statistics, Our Nation's Highways and Selected Highway Statistics and Charts."

5.2.3.1. Summary

Survey respondents identified many benefits of high quality data. It is important to note that whenever respondents identified a data use, they also identified its value. This clearly conveys the importance of this data. Many of the benefits are tied to federal reporting, which is in turn tied to federal funding, which is of great importance to operating and maintaining a state transportation system.

5.2.4. Availability of Data

For each data use identified, the users were asked whether or not the traffic data that was needed was available. Overwhelmingly, the majority of these respondents (76%) indicated that the data they needed was available. Twelve percent of the respondents indicated that they did not have the traffic data needed; nine percent of respondents indicated that they did not know whether or not the data they needed was available. Almost all of the individuals who indicated that they did not know whether or not the data that was needed was available were from outside MDT; the one respondent who was an MDT employee was not a transportation engineer or the like. For those respondents who indicated that they do not have all of the data that is needed, the following list summarizes data that they would be interested in obtaining:

- corridor/route-specific data,
- intersection data,
- percent peak values for single and combination trucks,
- data in an alternative time frame, and
- data on tribal lands.

Regarding the intersection data, one district indicated that they were making use of Miovision to obtain intersection data. In addition, while another respondent expressed a current need for percent peak values for single and combination trucks, the respondent also highlighted that the new system, TCDS, may possibly address this need. Another respondent explained that the current timing during which the data is provided, in May, does not provide staff members with enough time to prepare the data for submission to the HPMS by the June deadline. Finally, several tribal entities indicated that they current hire consultants to collect traffic data, and they were curious whether it was possible for MDT to collect some of this data.

5.2.4.1. Summary

The results regarding availability of data indicate that the TDCA Section is generally providing the data that survey respondents need and want. Again, it should be noted that these conclusions can only be drawn based on the input from the survey responses. However, MDT may want to reassess the timing of when data is provided to its districts and divisions, in order to facilitate submissions to HPMS. In addition, MDT should investigate whether or not the TDCS can address identified data needs, such as truck data. Finally, MDT should reach out to tribal entities to discuss their data needs and identify how MDT may be able to assist them.

5.2.5. Accessing Data

The next two questions for the survey asked “What is your current/desired method of accessing this traffic data” (with some sub-questions) and “If traffic data is already being used for this task, how could this data or its presentation be improved to better support your work?” These questions are related and are addressed collectively below.

The majority of users indicated that they made direct requests for traffic data. However, almost as frequently, respondents indicated that they used the TDCA website, via maps, to obtain the information they desired. Three other identified methods of accessing the traffic data are: Safety Information Management System (SIMS), MS2, and Oracle Tables (Traffic Yearly Counts).

The majority of respondents provided high ratings (answered "Yes" or gave ratings of 5) for currently available methods of accessing data. However, feedback received regarding potential improvements includes:

- providing data on the maps portion of the web page so consultants could more efficiently gather needed data,
- "pushing" truck activity reports directly to MCS management for each weigh-in-motion (WIM)/classifier site,
- collecting district data with Miovision, provide regional estimates (there are high fluctuations on the Reservation during the summer months due to a large influx of summer vacation traffic),
- providing traffic data from a few years prior to the most current provided data,
- providing data at an earlier date to assist with timely submission of data to HPMS,
- providing classification counts,
- providing speed collection, and
- providing time stamped traffic counts.

It should be noted that while respondents identified the above recommendations for improvements, several respondents specifically commended the TDCA Section for the quality of data currently provided.

5.2.5.1. Summary

As a whole, respondents were pleased with the existing methods available to access the traffic data. However, as detailed in this section, respondents provided several recommendations regarding improvements that could be made.

5.2.6. Use of Traffic Data Collection and Analysis Website

Three of the closing survey questions asked specifically about the TDCA website.

First, respondents were asked if they had visited the website. Only about three-quarters of the thirty-three respondents (24) provided an answer. Of those responding, 61% indicated that they had visited the website, 33% indicated that they had not, and one respondent indicated that they had not recently.

For the respondents who verified that they had visited the website, the majority indicated that they were looking for AADT. Some specifically identified AADT on a particular segment as the data in which they were interested. One respondent indicated an interest in seeing what SIMS data was available to the public. Only one respondent identified a goal of looking for information related to WIM/ATR sites. Two respondents explained that they were looking for data they planned on using for comparison purposes (i.e. trends in northwestern Montana, compare with Fatality Analysis Reporting System (FARS) from state and county). Finally, two respondents indicated that they were using the data tied to ESALs.

Respondents were asked to rate the usefulness of the TDCA website. Responses ranged from average (a numerical rating of 3, in a 1 to 5 scale between Not Useful and Useful) to Useful. One critique of the data on the website was that it was "2-3 years old." Another respondent specifically identified the "interactive" feature of the traffic map as valuable, but this respondent wanted to know how to expand it to the full screen. Another respondent specifically requested more collection locations. One respondent asked that the date of collection be revised to include the month and day, rather than just the year. Another respondent indicated their preference that percent trucks, ESALs, and growth factors be provided on the map in addition to AADT. Another respondent requested more information on tribal areas; they indicated that they currently have to access this data via Bureau of Indian Affairs (BIA). One respondent recommended that the website be made more user-friendly. As an example, this respondent mentioned that the website currently uses acronyms that may not be commonly understood outside of the transportation industry. This respondent indicated that in order for some personnel to use it, she had to provide a sheet outlining what each acronym meant. Finally, one respondent requested that TDCA provide MPO specific data for Missoula, Billings, and Great Falls.

Second, respondents were asked is if they had used any of the Traffic Maps. Only 58% of respondents (i.e. 19) provided a yes or no answer. Of the survey respondents who provided input, 58% indicated that they had not used the maps and 42% indicated that they had. For those who used maps, they indicated the use of the following types: city/county, statewide, interactive traffic map, traffic count map, ATR/WIM map, and "all of them." The respondents were also asked what information they were trying to find. Respondents indicated: AADT, DHV estimates for design and nominations, ATR/WIM sites to avoid conflicts during construction, information to use for grants, information near railroad crossings, functional classifications, traffic counts, WIM, and Miovision sites. Finally, one respondent just wanted to see what information was available. All respondents indicated that the maps were "Useful" or circled a rating of a 5. (Note: It is believed that some may have thought that a 5 was the "highest" possible rating for the survey, even though "Useful" was in fact the highest.) Another sub-question asked what features of the maps the respondent may recommend adding or deleting. DHV and small and large truck volume and percentage were requested to be added to the maps. Three other maps were recommended: bicycle and pedestrian maps, MPO-specific maps, and hourly variation in traffic at sites.

The final question asked whether the respondent used any of the monthly or annual traffic reports from the website. Only one indicated the affirmative. They used the "Traffic By Urban Areas" map to obtain VMT and said that it was useful. Therefore, the TDCA Section may want to consider the future of the monthly and annual traffic reports.

5.2.6.1. Summary

Respondents that have used the TCDS website found it to be very helpful. However, based on their feedback, certain portions of the website may have more value than others, and there is the potential that some time currently spent generating monthly and annual maps, which were rarely accessed, could be redirected to providing other information that was requested.

5.2.7. Use of Traffic Count Database System

Several of the preceding sections provide indications that some of the survey respondents made use of the new online TCDS on the MS2 website. When asked specifically if they had, 64% of the respondents provided an answer. Of those providing an answer, the majority (81%) said no, they had not used TCDS. Only four of those responding to this question indicated that they had used TCDS. Three of these four respondents indicated that they were trying to upload data; the fourth respondent indicated that he/she was testing out the capabilities of TCDS. Three of the four respondents indicated that the system was useful; the fourth respondent indicated finding TCDS less user-friendly than the previous system. However, this respondent anticipated growing accustomed to the new system over time.

5.2.8. Comments

The final question for survey respondents solicited general comments. Only a few were received, and as such, are provided below:

- "MCS needs to work closely with TDCA Section to determine placement of future WIM locations. In addition, MCS may request wireless connectivity capability to the WIM system installation. The wireless connectivity will allow MCS enforcement to use the WIM information when conducting special operations with portable Virtual Weigh Station trailers."
- "Please keep it simple, if it isn't broke, don't fix it, thank you."
- "I have also used traffic data available in our Pavement Management System "Agile Assets." Network level traffic data can be viewed, which paints a traffic picture for a route segment over a period of time. I have used this when in a hurry, or when I just need a rough guess on traffic demand."
- "We may benefit from some training on all the Traffic Data tools available. Thank you for this opportunity to provide input."
- "The state will come and do a traffic study if we need it, but sometimes we need it in 3 days instead of 2 weeks."

- "Marie and Peder are awesome."
- "Have not really started using it yet."
- "Appreciate the availability."

5.3. Summary

The feedback provided by the thirty-three respondents to the traffic data users survey was overwhelmingly positive, and some very useful recommendations were received.

Most of the respondents identified current data uses. Respondents indicated that data was primarily used for planning, design and safety analysis purposes. The most frequently used traffic data by survey respondents, in descending order, was AADT, ESAL, and percentage of trucks. The data was described as vitally important, supporting for example, numerous federal reporting requirements, which are directly tied to the funding a state department of transportation receives. However, in one important piece of feedback, a respondent said that data is not currently provided at an optimal time for submitting some federal reports. Therefore, the TDCA Section should consider if the data collection and distribution can be modified to better accommodate these requirements.

There seems to be little understanding of how the data can potentially be used for other purposes. However, one MDT unit and several Tribal entities indicated a willingness to better understand additional opportunities for use of the data. Therefore, it is recommended that the TDCA Section reach out internally, as appropriate, and externally, notably to tribal entities to see if they can provide information on additional data uses.

Some types of data were identified as needed but not currently collected, including ATV, pedestrian and transit data. In addition, respondents requested more recent data. Finally, when considering existing data that may be underutilized, a large portion of respondents indicated they did not use monthly and annual traffic reports. MDT personnel primarily reported having the data they needed; it was typically responses received from individuals outside of MDT that identified additional data needs. The TDCA Section needs to consider whether the additional data needs are feasible.

Approximately sixty percent of respondents currently made use of the website. Those that used it found it valuable, but they had a few recommendations for improvements. Two examples are more up-to-date information and improving the existing full screen feature.

The data collected by respondents for this study show that few have tried out the new TCDS. It is unclear whether there are actually few users, or whether those surveyed have not made use of the new system. Therefore, MDT may want to consider trying to promote this new tool to potential and current data users.

6) REVIEW OF TRAFFIC FACTOR GROUPS

Traffic factor groupings are an important aspect of the overall traffic data collection and analysis process. In light of resource constraints, continuous traffic monitoring is only done at a limited number of sites on the highway system, with short term counts - often conducted for only a few days per year - done at the majority of data collection locations. The results of short term counts, which generally do not encompass all of the temporal variations in traffic flow during the year, can subsequently be used to estimate traffic over longer and/or different time intervals using adjustment factors. These factors are developed from the traffic data continuously collected at a group of permanent sites that experience similar traffic activity – such a group of sites is referred to as a "traffic factor group." Traffic factor groupings must be appropriately constituted if they are to accurately characterize traffic operations in a given area and over a particular period of time. In this regard, a) the selected groupings must adequately represent all the various distinct traffic patterns of interest, b) each permanent monitoring site must be appropriately assigned to a traffic factor group, and c) sufficient monitoring sites must be available in each group to support the accuracy desired in projecting traffic activity. Changes in traffic patterns (resulting for example from changes in regional economic activity) can render obsolete once useful traffic factor groupings. Therefore, it is desirable to periodically review the traffic factor groupings being used, and to consider any potential improvements in traffic information that might be realized if new groupings were adopted.

In this study, three alternative schemes for traffic factor groupings were investigated for possible use by MDT. The current traffic factor groupings are based on the nature of a route's use, as categorized primarily by highway functional classification. The prospective alternative approaches are based on a) vehicle type - i.e., commercial versus non-commercial and functional classification b) area of the state and its dominant economic activity, rural or urban setting, and functional classification, and c) a simplified functional classification scheme, i.e., interstate versus non-interstate with subcategories of rural and urban. For each alternative grouping, the resulting traffic factors were generated and analyzed.

6.1. Traffic Factor Groupings

To provide the reader some perspective on the alternative traffic factor groupings considered in this investigation, presented below is general background information on traffic factor groupings and their derivation, a description of the current traffic factor grouping scheme used by MDT, and a description of the distribution of WIM/ATR sites across the state relative to supporting generation of traffic adjustment factors by traffic factor group.

6.1.1. Background

As previously mentioned, one of the important uses of the continuous traffic data collected by permanent WIM and ATR installations is to provide the data necessary to adjust traffic data collected from short term monitoring events to obtain reasonable estimates of AADT or forecast the average daily traffic for any other time during the year. Such adjustments are necessary since short term traffic counts (conducted in Montana typically for a minimum period of 48-hours) generally cannot simply be factored up based on their duration to obtain usable estimates of AADT, as such an approach does not account for temporal variations in traffic flow during the year. The general pattern of traffic throughout the year can be characterized using traffic data continuously collected from permanent monitoring sites. The results of a short term traffic count can then be temporally matched against the annual pattern determined for routes carrying similar traffic - i.e., the appropriate traffic factor group - to obtain a useful estimate of AADT at the short term monitoring location. Further, average daily traffic for other months and days of the year can be obtained for the short term site using daily and monthly adjustment factors available for the traffic factor group to which it is assigned.

The TMG presents two approaches for determining factors to adjust short term traffic counts to obtain estimates of AADT, namely, roadway-specific factors and traffic factor groups (FHWA 2013). Following the roadway-specific approach to traffic factors (as developed by the Virginia Department of Transportation), a short-term count collected at a given location is adjusted to generate an AADT estimate based on the nearest permanent recorder on the same route. This approach is relatively simple and direct in its application, but also requires monitoring to be done on every route, often at relatively frequent intervals.

The second approach presented in the TMG for adjusting short-term traffic counts to obtain estimates of annual traffic volumes is the “traditional” or traffic group factor method. Following this approach,

1. Seasonal adjustment factors are calculated from each permanent recorder.
2. The permanent recorders are grouped based on similarities in traffic patterns as determined by their seasonal adjustment factors.
3. The factors determined from each site within a group are averaged.
4. All road/road segments in the state highway network are assigned to a group.
5. Short term traffic counts obtained for a specific road/road segment are adjusted to obtain annual estimates using the seasonal adjustment factors for the traffic grouping to which the segment is assigned.

Two major challenges in using the traffic group factor method are determining the nature/number of groups to be used and appropriately assigning road/road segments to a group.

In establishing traffic factor groups there is a tradeoff between having enough groups to accurately represent all traffic patterns, and having reasonable number of permanent traffic recorders to support each group. To some extent, this issue can be addressed by comparing the adjustment factors from different permanent recorders when assigning them to a traffic factor group, as well as assessing the variability in the adjustment factors across the recorders within a group. In the latter case, for example, if the variability in the adjustment factors within a group is too high, there can be uncertainties in assigning a particular road/road segment to a specific group.

In developing adjustment factors to address these seasonal and daily impacts, several variables must be considered. Variables to consider include the route (functional classification), the location (urban versus rural), economic activities in the area, vehicle classifications (commercial versus passenger vehicles), and coverage area (e.g. an adequate number of stations in an area to ensure complete capture of trends). All of these variables play a direct role in the traffic monitored at a permanent site and the resulting adjustment factors derived for that site. As a result, they warrant consideration when looking at different approaches to the traffic factor grouping schemes used in developing adjustment factors. Further, in evaluating load related demands on highway infrastructure, the characteristic operating weights of the vehicles that use it are of interest (particularly the commercial vehicles). These characteristic operating weights by vehicle configuration can vary across the system, based on the same factors that affect traffic factor groupings, i.e., route functional classification, location – urban versus rural, nature of economic activity, etc. Thus, in addition to traffic factor groupings, weight groupings are considered in assessing load related infrastructure issues. MDT's weight groups are based on highway functional classification and are not further subdivided by geographic region or other vehicle weight related discriminators. This is the first and most fundamental structure for such groupings.

The TMG offers three analysis approaches for establishing traffic factor groups, namely, traditional, cluster and volume analysis. Following the traditional analysis approach, professional knowledge of traffic patterns is used subjectively to establish traffic factor groups typically acting on the various factors described above. Cluster analysis uses statistical methods to identify similarities and differences in the data collected from various sites to suggest traffic factor groups. Volume analysis acknowledges the "national emphasis and high usage levels" of the interstate system, and thus calls for maintaining separate traffic factor groups for interstate routes. Following the former two analysis approaches (traditional and cluster), often traffic factor groups at least initially are formulated consistent with highway functional classifications. Following the former analysis approach (volume), at a minimum traffic factor groups are established for rural and urban interstates, rural and urban other roadways, and recreation routes. The TMG cites various advantages and disadvantages of all three approaches, and does not advocate any one approach as necessarily superior to the others.

6.1.2. Current MDT Traffic Factor Groupings

Generally following the "traditional" traffic group factor approach, Montana currently uses nine traffic factor groups (as previously introduced), largely consistent with the primary functional classifications mandated in the Federal HPMS (FHWA 2014). These groups are:

1. Rural Interstate,
2. Urban Interstate,
3. Principal Arterial – Rural,
4. Principal Arterial – Urban,
5. Minor Arterial – Rural,
6. Major Collector – Rural,
7. Minor Arterial – Urban,
8. Collector – Urban, and
9. Recreational.

All traffic flows on Montana's highways are viewed as represented by one of the nine traffic patterns embodied by these groups. While these groups obviously reflect the functional classifications used to categorize the state's highways, functional classifications were not intended to indicate the specific pattern of traffic on a roadway, but rather the general nature of its use. Thus, while functional classifications enter into the identification of appropriate traffic factor groups, vehicle configuration, economic activity, and seasonal traffic flow should also be considered.

MDT calculates adjustment factors for each traffic group and each day of the week. Sample adjustment factors for the rural interstate group as developed by MDT are presented in Table 39. The weekday adjustment factors in this table are plotted by month for an entire year for each traffic factor group in Figure 32. Referring to Figure 32, these adjustment factors clearly reflect seasonal trends in traffic operations across all traffic factor groups (and referring to Table 39, on all days-of-the-week), consisting of a decrease in daily traffic in the winter compared to summer months. As might be expected, the most pronounced seasonal variation is on recreation routes, with summer traffic exceeding winter traffic by approximately 300 percent (i.e., adjustment factors of approximately 0.5 in July compared to 2.0 in January). The seasonal adjustment factors on routes in all other traffic factor groups typically show summer traffic exceeding winter traffic by approximately 20 to 70 percent. A more complete discussion of the current MDT adjustment factors is presented later in this report.

Table 39: Example of MDT Adjustment Factors

Edit Seasonal Factor

Group: RI

From Year: 2015 To Year: 2015

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan	1.503	1.533	1.463	1.394	1.410	1.202	1.354
Feb	1.364	1.354	1.391	1.354	1.214	1.083	1.274
Mar	1.081	1.239	1.217	1.184	1.079	0.955	1.062
Apr	1.037	1.089	1.117	1.064	0.981	0.873	1.033
May	0.970	0.988	1.058	1.016	0.941	0.834	0.975
Jun	0.784	0.888	0.910	0.879	0.824	0.749	0.857
Jul	0.710	0.794	0.838	0.792	0.726	0.682	0.834
Aug	0.744	0.844	0.847	0.818	0.780	0.712	0.767
Sep	0.934	0.944	1.013	0.975	0.908	0.800	0.932
Oct	0.999	1.065	1.095	1.034	0.952	0.859	1.036
Nov	1.049	1.220	1.230	1.169	1.247	1.083	1.103
Dec	1.282	1.380	1.341	1.267	1.332	1.337	1.232

Edit Axle Factor

AF Group: RI

From Year: 2015 To Year: 2015

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan	0.733	0.698	0.658	0.652	0.691	0.737	0.726
Feb	0.742	0.715	0.668	0.658	0.688	0.736	0.727
Mar	0.769	0.716	0.674	0.667	0.702	0.750	0.749
Apr	0.780	0.734	0.684	0.683	0.714	0.752	0.748
May	0.792	0.764	0.712	0.699	0.728	0.770	0.765
Jun	0.816	0.770	0.734	0.729	0.755	0.792	0.784
Jul	0.843	0.800	0.756	0.757	0.787	0.813	0.802
Aug	0.830	0.783	0.749	0.747	0.770	0.799	0.806
Sep	0.797	0.769	0.717	0.708	0.736	0.782	0.772
Oct	0.786	0.739	0.697	0.698	0.724	0.766	0.751
Nov	0.780	0.727	0.695	0.698	0.707	0.755	0.751
Dec	0.750	0.721	0.683	0.693	0.707	0.723	0.743

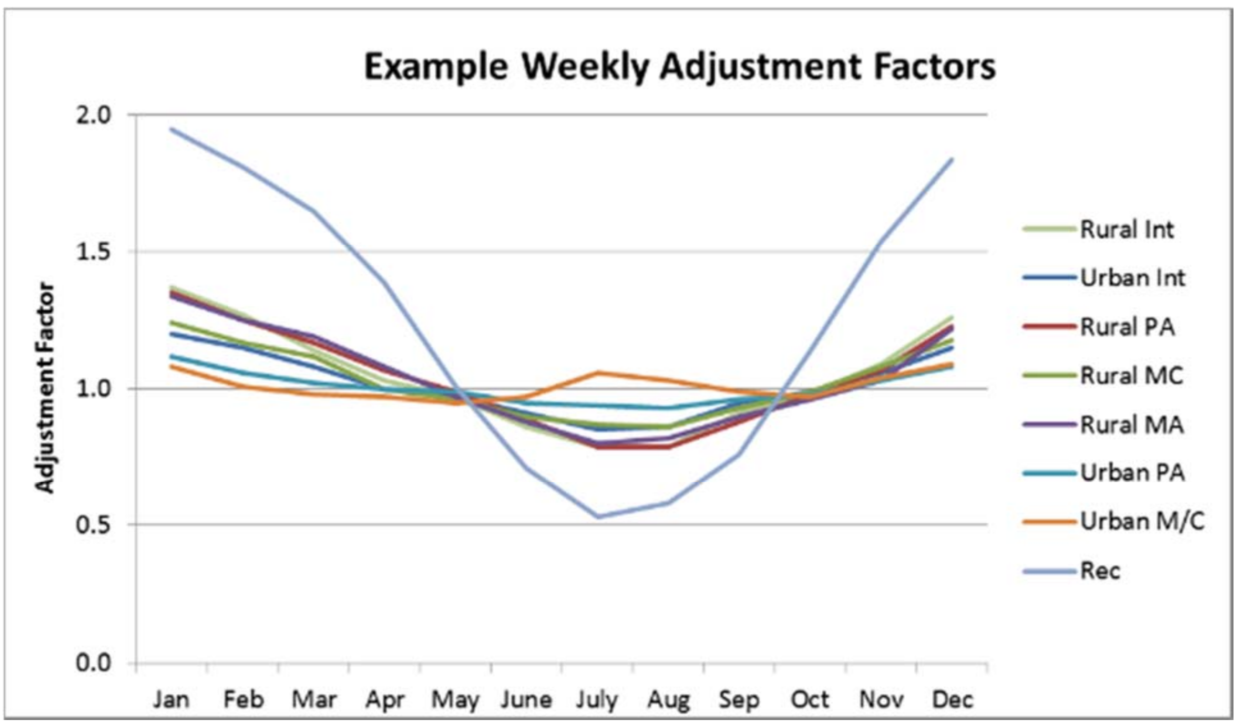


Figure 32: Example of Weekday Adjustment Factors by Month

6.1.3. Current MDT Traffic Data Collection Program

The traffic data collection program in the state of Montana consists of permanent stations and short-term traffic count sites. At the time of this analysis (primarily 2014), 99 permanent stations (i.e. continuous count sites) were collecting traffic data on a daily basis throughout the state, consisting of 62 ATR and 37 WIM sites. The analysis in this chapter therefore pertains to these 99 stations, and not the 2016 number of 106 stations. These 99 stations are shown in Figure 33 with the intent of providing a sense of their general distribution across the state's on-system highway network. Additionally, MDT collects traffic data at approximately 5,800 active short-term traffic count sites statewide. These counts, also known as coverage counts, make up the bulk of the MDT's traffic count program.

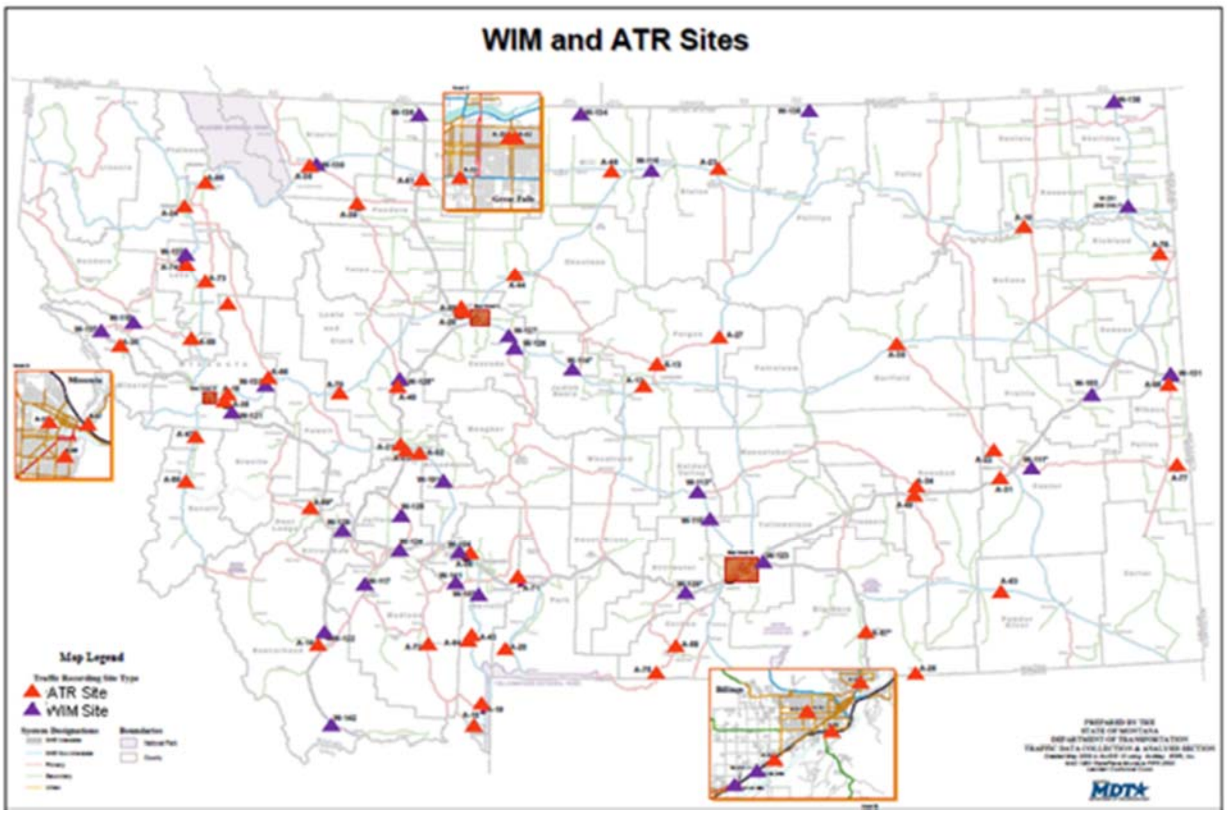


Figure 33: WIM and ATR Sites (MDT 2012)

Table 40 presents descriptions of the location of each ATR and WIM site used in the analyses conducted in this investigation. The reader is encouraged to use this table as a cross-reference when examining the various figures presenting adjustment factors later in this report. The site numbers have been assigned chronologically as sites have been added to the system, with a prefix "A" or "W" corresponding to if the site is an ATR or WIM system. The functional classification of the segment of highway each site is located on is indicated on Table 40. This functional classification, in most cases, corresponds to the traffic factor group to which each site is assigned.

Specifically, a limited number of sites (station names marked with an asterisk) are grouped together in a separate traffic factor grouping called "recreational." These stations are treated differently because traffic patterns at those sites are more influenced by seasonal tourist traffic than by its functional class.

Table 40: WIM and ATR Site Location Descriptions

Site	Route	Location
	Urban Interstate	
A-003	I-15	0.5 miles south of Helena
A-059	I-90	East of south Billings Blvd Int.
W-129	I-15 / I-90	Butte / Rocker
	Urban Principal Arterial	
A-021	US-12	On MT. Ave btwn Blgs St/Msla St, Helena
A-033	US-89, (10th Ave S)	Between 9th St/10th St,Great Falls
A-037	U-8107	East end of Orange St Bridge in Missoula
A-050	US-87, (Main St)	Between Milton Rd/Hansen Ln, Billings
A-051	U-1006, (Broadwater Ave)	Between 22nd St/Gay Pl, Billings
	Urban Minor Arterial	
A-032	U-5217, (25th St North)	Between 4th Ave/5th Ave,Great Falls
A-042	U-5226, (26th St N)	Between 4th Ave/5th Ave, Great Falls
A-067	U-8115, (Van Buren St)	North of Poplar St, Missoula
	Urban Collector	
A-054	L-56-2410, (19th St W.)	Between Wy. St/Ylstn. St, Billings
A-068	U-8116, (Beckwith Ave)	East of Hilda St, Missoula
	Rural Interstate	
A-009	I-15	7 miles west of Great Falls
A-017	I-15	6.8 miles north of Lima
A-031	I-94	8 miles west of Miles City
A-057	I-90	South side of Lodge Grass Int
A-061	I-15	North side of Marias Int
A-071	I-90	Bozeman Hill
W-103	I-94	Near Bad Route
W-120	I-90	Near Columbus
W-121	I-90	Near Turah
W-122	I-15	Near Dillon
W-123	I-90	Near Pinehill
W-124	I-90	Near Cardwell
W-131	I-94	0.6 miles east of Wibaux
W-136	I-15	2 mi NW of Sunburst Int.
W-137	I-90	1 mi W of MT-135 in ST Regis
W-142	I-15	South of Lima
W-203	I-90	Near Mossmain

Site	Route	Location
Rural Principal Arterial		
A-002	US-287/US-12	Near Claysoil, 9 miles east of Helena
A-008	US 93	0.5 miles south of Ravalli
A-010	US-2	2 miles east of Wolf Point
A-012	US-87/MT-200	6 miles west of Lewistown
A-013	Brooks US-191	7 miles north of Lewistown
A-015	MT-200	4 miles northeast of Bonner
A-018*	US-20	5 miles west of US 191 West Yellowstone
A-019*	US-191/US-287	7.7 miles north of West Yellowstone
A-020*	US-89	17 miles north of Gardiner
A-022	MT-59	20 miles north of Miles City
A-024	US-2	1.3 miles west of Kalispell
A-027	US-191	3 miles north of US-191/MT-19 junction
A-036*	US-2	2.3 miles west of Browning
A-038	MT-200	1 mile west of Jordan
A-043	US-191	1.5 miles north of MT-64 Big Sky
A-047	US-93	1 mile south of Florence
A-056	US-93	1.5 miles north of Hamilton
A-060*	US-2	1.5 miles north of Columbia Falls
A-063	US-212	13 miles east of Ashland
A-070	MT-200	East of Lincoln
A-074	US 93	South of MT 28
W-101	US-12	Near Townsend
W-107	US-191	Near Gallatin N-50
W-110	MT-3	Near Broadview
W-113	US-12	Near Ryegate
W-114	US-87	Near Stanford
W-115	US-87	Near Fort Benton
W-117	MT-41	Near Twin Bridges
W-126	US-89	East Armington
W-130*	US 2	Browning East
W-132	MT-200	SW of Clearwater Jct.
W-133	US-93	0.8 miles North of Elmo,
W-135	US-191	Port of Morgan

Site	Route	Location
	Rural Minor Arterial	
A-005	MT-7	1 mile south of Wibaux
A-014	S-278	7 miles southwest of Dillon
A-029	State Highway X-56683	6 miles west of Billings
A-034	US-12	5 miles northwest of Forsyth
A-039*	US-89	5 miles north of Dupuyer
A-049	MT-39	0.5 miles south of 1-94
A-058	US-212	1.8 miles north of Red Lodge
A-066*	MT-83	1 mile north of MT-200
A-072*	US-287	South of Ennis
A-073	MT 35	2.8 Mi East of US 93
A-077	US-12	RP 88.5, 1.3 mi E of RR tracks
W-111	US-12	Near Miles City
W-118	MT-200	Near Paradise
W-128	MT 69	Boulder South
W-141	MT-84	7.5 MI W. of S-288
	Rural Major Collector	
A-006	S-288	South of the I-90 interchange
A-023	S-241	2.5 miles north of Harlem
A-026	S-314	Near Decker
A-028	State Highway X-07611	7 miles west of Great Falls
A-035	S-210	3 miles southeast of Turah
A-040*	State Highway X-81003	2.5 miles north of Wolf Creek
A-064	State Highway X-81064	West of US-191, Meadow Village
A-069	S-273	1 mile north of MT-48
W-134	S-232	Port of Wild Horse

6.2. Proposed Alternative Grouping Schemes

To better understand if changes are warranted in MDT's current traffic factor groups, a number of prospective grouping schemes were examined. Work specifically focused on three such schemes, namely, grouping by: 1) vehicle type (commercial vehicles versus all vehicles) and functional classification, 2) geographical area/dominant economic activity and functional classification, and 3) simplified functional classification (interstate and non-interstate, rural and urban). The following sections provide a detailed overview of these hypothesized traffic factor grouping schemes, including the rationale behind them and the specific manner in which they were formulated.

6.2.1. Grouping by Vehicle Type

The first alternative grouping scheme examined in this study was a grouping by vehicle type and existing functional classification. In this grouping scheme, adjustment factors for commercial vehicles (trucks and other heavy vehicles) were compared to adjustment factors developed for total vehicles (passenger and commercial vehicles combined). The hypothesis behind this grouping scheme was that the temporal variation in commercial vehicle traffic, which varies by activity, location and season, is likely to be different from that of smaller vehicles, mainly passenger cars. Such a difference would be expected, as the trip purpose of commercial vehicles is different from that of passenger vehicles. As a result, the traffic adjustment factors resulting from the traditional grouping approach may not be representative of the actual trends in truck and freight traffic. The TMG acknowledges that a) development and application of traffic groups and adjustment factors by vehicle class is relatively new and not significantly explored by many states, b) the parameters that influence this process can be complex, and c) available data may only support this process for relatively broad aggregations of vehicle classes. In light of these observations, as introduced above, only two broad vehicle classes –commercial trucks and other vehicles – were considered herein. Similarly, the Ohio Department of Transportation, for example, determines seasonal adjustment factors for all vehicles, trucks and passenger vehicles (Ohio Department of Transportation undated).

6.2.1.1. Rationale

As stated, it is well known that the trip purposes of commercial vehicles are different from those of passenger vehicles individually as well as all vehicles considered collectively as a group. As such, the temporal variation in heavy vehicle traffic by day of week and season may be substantially different from that of the majority smaller vehicles, including passenger cars. Aggregating all vehicles in deriving adjustment factors may add approximation to those factors overall, and may critically affect heavy vehicle traffic estimation from short-term count stations.

6.2.1.2. Proposed Grouping Scheme

In order to evaluate this proposed grouping scheme, adjustment factors determined for commercial vehicles were compared to those for total vehicles. Total vehicles for a count station were, as the name indicates, all vehicles that were tallied as passing that count station. Commercial vehicles were considered to be all vehicles in FHWA categories 5 through 13. This designation differs slightly from the typical categorization of heavy vehicles as being FHWA categories 8 through 13, but it was believed that the smaller commercial vehicles categorized as classes 5 through 7 should be grouped together with heavy vehicles, as these vehicles would exhibit similar trip patterns in many respects to heavy vehicles. In a similar fashion, the Ohio Department of Transportation aggregates vehicle classes 4-13 in their “truck” traffic factor group.

In these analyses, adjustment factors for commercial vehicles were compared with those for all vehicles. A more precise approach would be to compare the adjustment factors for commercial vehicles to those of smaller vehicles. However, to limit the analysis to a reasonable scope, it was decided to compare commercial vehicles to all vehicles. Note that the factors for smaller vehicles are expected to be largely similar to those of all vehicles, as smaller vehicles constitute the vast majority of vehicles. Information specifically on commercial vehicles was not available at all stations, and therefore the comparisons discussed in this investigation are based on a subset of the total ATR and WIM stations. Based on the data provided by MDT, a total of 40 stations did not have commercial vehicle counts delineated separately, and no data was provided for an additional 10 sites. Of these sites collectively, 40 were located along rural routes; 10, on urban routes.

6.2.2. Grouping by Areas and Regions

A second hypothesis regarding traffic factor groupings and adjustment factors was that different areas and regions of the state would exhibit different traffic patterns based on their geographic characteristics and economic activity. For example, certain areas of the state have significant agriculture activity, and the traffic patterns related to this activity were likely to differ from other regions of the state that have significant tourism/recreation activity. In light of this, traffic adjustment factors for different areas and regions of the state were examined to determine if any differences could be observed. Following this same general premise, Oregon for example, generates traffic adjustment factors for eleven traffic factor groups, from interstate urban, to agriculture, to recreational winter (Oregon Department of Transportation, undated).

6.2.2.1. Rationale

As stated, the rationale for this grouping strategy was that different areas and regions of the state have different dominant geographical characteristics and economic activities, which are then reflected in distinct traffic patterns in each region. These differences can be seasonal in nature; for example, farm harvest activities (agriculture) occur for the most part in the fall while recreational activities occur primarily during the summer, and part of the winter season for some areas in the state. These regional and temporal differences in traffic operations would therefore have an impact on the grouping of WIM and ATR sites (current and future) that are needed to characterize them. For example, the measurement of traffic on routes serving recreation activities would likely differ from that of areas predominated by agricultural activity. As a result, the data was examined to determine whether a locational grouping strategy was needed.

6.2.2.2. Proposed Grouping Scheme

To develop the grouping scheme, the researchers identified the different economic activities that are predominant within the state by examining the Montana Department of Commerce's "Real Gross Domestic Product" (GDP) data (MDC, undated). This data provided an indication of the value of goods and services produced in Montana by a particular industry (or industry group) that require goods movement or generate vehicle traffic in one manner or another. From a transportation perspective, the industries identified as being predominant in the state were agriculture, recreation/tourism, manufacturing and natural resource extraction.

Once primary industry groups were identified, the researchers examined the distribution of WIM and ATR sites throughout the state and selected individual sites for inclusion within one of four groups: agriculture/farming, recreation/tourism, urban (to cover traffic patterns associated with socio-economic activities generally found in more populated areas, including manufacturing) and rural (to cover traffic patterns associated with socio-economic activities generally found in less populated areas, including remaining agriculture and natural resource extraction activities). The selection of geographic areas where these activities were predominant was based on past research experience and familiarity with the economic activities of the different areas within the state. For example, areas of southwest Montana, such as Gallatin, Park and Sweet Grass counties, as well as northwestern counties near Glacier National Park were identified as having recreation/tourism as the predominant industry, and WIM and ATR sites within these regions (excluding sites within urban areas such as Bozeman and Kalispell) were selected for inclusion in the recreation/tourism group. Similarly, count sites within counties in the central and eastern portions of the state (excluding urban areas such as Great Falls and Billings) were typically included in the agriculture group based on the predominance of farming activity in these areas. Count stations within urban areas such as Billings and Great Falls were categorized together to capture manufacturing and other urbanized traffic flows, while remaining counties and sites that had no clear dominant economic activity were grouped into the remaining rural category, which captured activities that included natural resource extraction (minerals, oil and gas, forest products, etc.) and some agriculture. Besides the aforementioned groups, all WIM and ATR stations on interstate highways were assigned a separate group called "interstate." This is due to the fact that a significant component of the traffic on interstate highways is through traffic, which is nominally affected by local economic activities, and thus distinct traffic patterns by day, month and season are expected for data collected from these stations. The specific sites assigned to each category are listed in Table 41 and shown in Figure 34.

Table 41: WIM and ATR Sites by Area/ Region Grouping

Group	Sites
Urban	A-003, A-021, A-024, A-032, A-033, A-037, A-042, A-050, A-051, A-054, A-059, A-067, A-068
Interstate	A-009, A-057, A-59, A-061, A-071, W-103, W-120, W-121, W-122, W-123, W-124, W-129, W-131, W-136, W-137, W-142, W-203
Agriculture	A-012, A-013, A-023, A-027, A-038, A-063, W-113, W-114, W-126
Recreation/Tourism	A-008, A-018, A-019, A-020, A-036, A-039, A-043, A-058, A-060, A-064, A-072, A-073, A-074, W-107, W-130
Rural/Other	A-002, A-005, A-006, A-010, A-014, A-015, A-017, A-022, A-028, A-029, A-031, A-034, A-035, A-040, A-047, A-049, A-056, A-069, A-070, A-077, W-101, W-110, W-111, W-115, W-117, W-118

Notes: Prefix "A" denotes ATR sites; "W" denotes WIM sites

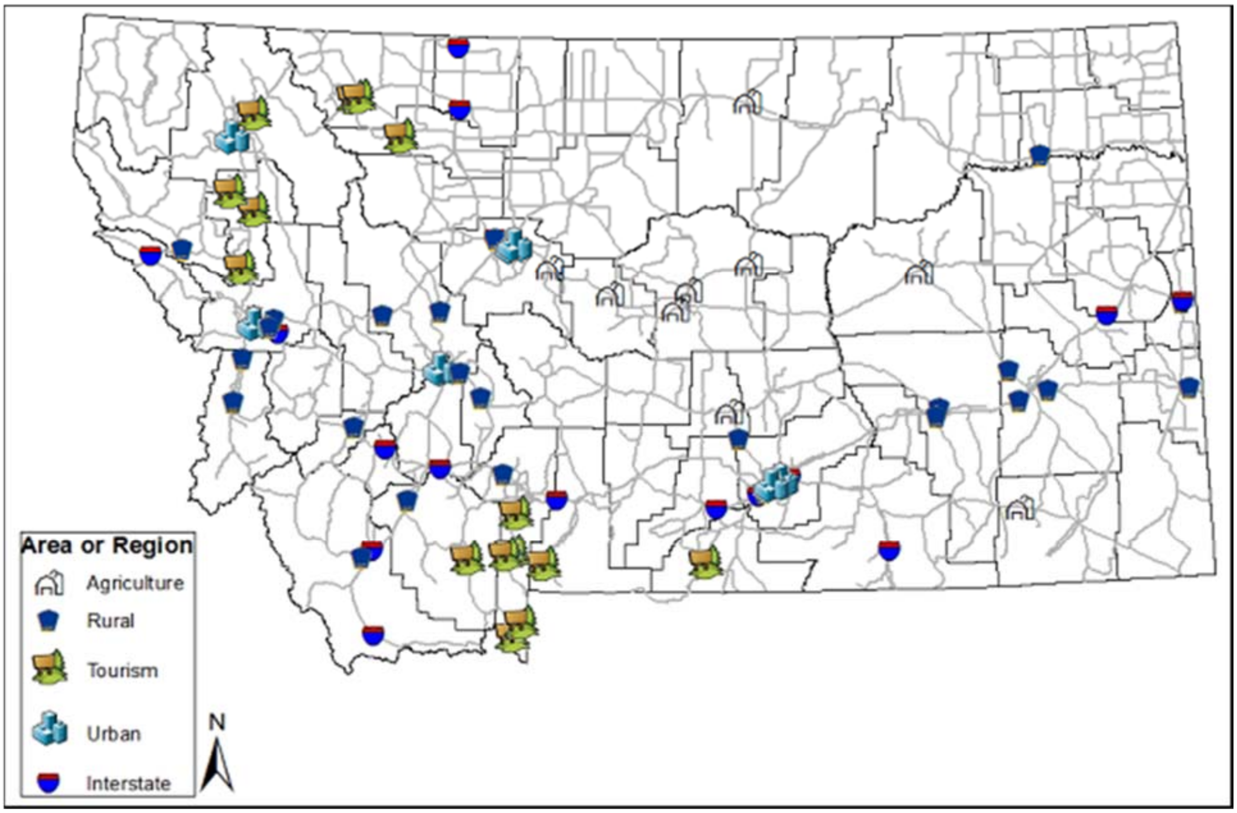


Figure 34: WIM and ATR Sites by Area/Region Grouping

6.2.3. Grouping by Modified Functional Classification Scheme

The final grouping scheme considered in this study, presented in Table 42, was a simplification of the functional classification grouping scheme currently in use by MDT and consistent with the minimum number of traffic factor groups that is suggested by the TMG. The modified scheme called for treating interstate highways as one group and all roadways, i.e. other arterials, collectors, and local highways, in another group, with subcategories of rural and urban within these classifications. Further, the modified scheme retained WIM and ATR stations on recreation routes in a separate group. Should this modified scheme be proven reasonable and appropriate, it could greatly simplify the use of adjustment factors in practice. The Indiana DOT uses a similar simplified traffic factor grouping scheme, with five traffic factor groups, namely, two urban groups – interstate and non-interstate, and three rural groups, one for interstate and two for non-interstate routes (Indiana Department of Transportation, undated).

Table 42: Modified Traffic Factor Groups

Modified Functional Class Scheme	Groups used in Montana
Interstate Rural	Rural Interstate
Other Rural	Rural Principal Arterial
	Rural Minor Arterial
	Rural Major Collector
Interstate Urban	Urban Interstate
Other Urban	Urban Principal Arterial
	Urban Minor Arterial
	Urban Collector
Recreational	Recreational

6.2.3.1. Rationale

The rationale for this approach to grouping was the hypothesis that interstate highways are unique and they tend to notably differ from the rest of the road network in terms of the traffic they carry. This situation is largely due to the fact that, unlike other highways in the state, Montana's interstates tend to carry considerable through traffic as opposed to local traffic. The basic makeup and temporal variations in through traffic could be similar on all interstates, but distinctly different from those observed in local traffic operating on all other highways. Correspondingly, the characteristics of the predominantly local traffic carried by all non-interstate highways may be similar across all classifications. If the aforementioned was proven to be the case, the highway classifications being used could simply be reduced to interstate and non-interstate.

6.2.3.2. Proposed Grouping Scheme

Counts from interstate WIM and ATR sites were assigned as urban or rural following existing route classifications. Similarly, data from sites on rural and urban principal arterials, minor arterials, and collectors were grouped to form the traffic factor groups of other rural and other urban categories. Additionally, all WIM and ATR stations on recreation routes were assigned to one group, regardless of highway functional class.

6.3. Data Collection and Analysis

With the different traffic grouping schemes of interest established, the next step in this project was data collection and analysis. Specific analyses and results for each of the grouping schemes being considered are presented in the following sections.

6.3.1. Data Collection

Extensive traffic count data was obtained from MDT's Traffic Data Collection and Analysis Section to support the examination of the different grouping schemes proposed in the previous section. Data for each of the state's 37 WIM and 62 ATR sites (2014 numbers) was provided in spreadsheet format for 2011, 2012 and 2013. Complete hourly counts by direction and total daily vehicle counts for each year were provided in individual, yearly files. Additionally, individual commercial vehicle counts for each site were provided in separate files.

TDCA staff had previously completed quality control checks to ensure the count data generated at each site was accurate. However, as one could expect, some days of data were missing from stations due to maintenance activities and other causes of downtime. Given the total body of count data available from each site, and the sparseness of these gaps, they were not considered to have a significant impact on the analysis.

6.3.1.1. WIM and ATR Stations

As indicated, the data came from MDT's 37 WIM and 62 ATR sites (2014 numbers) distributed throughout the state. These sites are located on a variety of routes relative to functional classification and region of the state, and were judged to provide adequate data in support of the various research hypotheses outlined in prior sections.

6.3.1.2. Analysis Period

The data selected for analysis was from 2011, 2012 and 2013. These were the most recent years for which complete, quality control checked data was available, and as such provided the most current traffic trends experienced throughout the state. This data captures reasonably current travel patterns, which if expected to continue into the foreseeable future, provided an acceptable basis for evaluating current and future traffic factor groupings.

6.3.2. Data Analysis

The data obtained from MDT was reformatted into Excel spreadsheets which consisted of total counts by day as well as commercial vehicle counts to facilitate research-specific analysis activities. First, ADT figures were calculated by day of week and month of year for each count station. This data was then used to calculate site-specific traffic adjustment factors for the years 2011, 2012, and 2013 individually. The adjustment factors were then averaged to develop a single set of adjustment factors for the three year period at each WIM and ATR site. The same process was also performed using commercial vehicle counts in developing adjustment factors for commercial vehicles to support the evaluation of the commercial vehicle grouping scheme.

Once site-specific adjustment factors for all traffic and commercial vehicles were available, examination of the various hypotheses outlined in earlier sections of this text was completed using the different proposed grouping schemes. As suggested by the TMG, the schemes were evaluated both graphically and using selected statistical measures. The results of these evaluations are presented in the following sections.

6.3.2.1. Grouping by Vehicle Type

Recall that the hypothesis behind this grouping scheme was that the trip purposes of commercial vehicles are different from those of passenger vehicles individually, as well as all vehicles considered collectively. In light of this premise, comparisons were made between various commercial and total adjustment factors by highway type and locale (urban and rural). These comparisons are presented in the following paragraphs. Note that the results presented for total vehicles in the evaluation of the first grouping scheme hypothesis (grouping by vehicle type) are directly representative of the current traffic grouping scheme and associated adjustment factors used by MDT, as they were derived using the same basic data, groupings and processing approach.

Total adjustment factors for all traffic (passenger and commercial vehicles combined) were compared to commercial vehicle adjustment factors for weekdays (Monday – Thursday), Fridays, Saturdays and Sundays respectively for each functional class. This comparison is shown for rural interstate highways in Figure 35. Referring to Figure 35, two important trends in adjustment factors can readily be discerned. First, the adjustment factors for commercial vehicles are in general larger in value that their counterparts for total traffic, perhaps with the exception of weekdays where the aforementioned trend is reversed between all vehicles and commercial vehicles. The difference in adjustment factors would be expected to be even greater were the comparison to be made between commercial vehicles and passenger cars (FHWA vehicle classes 1 to 4). Second, commercial vehicle traffic factors exhibit less variation across the months of the year compared to those for total vehicles. Another important observation is that Fridays were associated with the highest traffic level among other weekdays throughout the year for total traffic, while weekdays witnessed highest traffic levels for commercial vehicles.

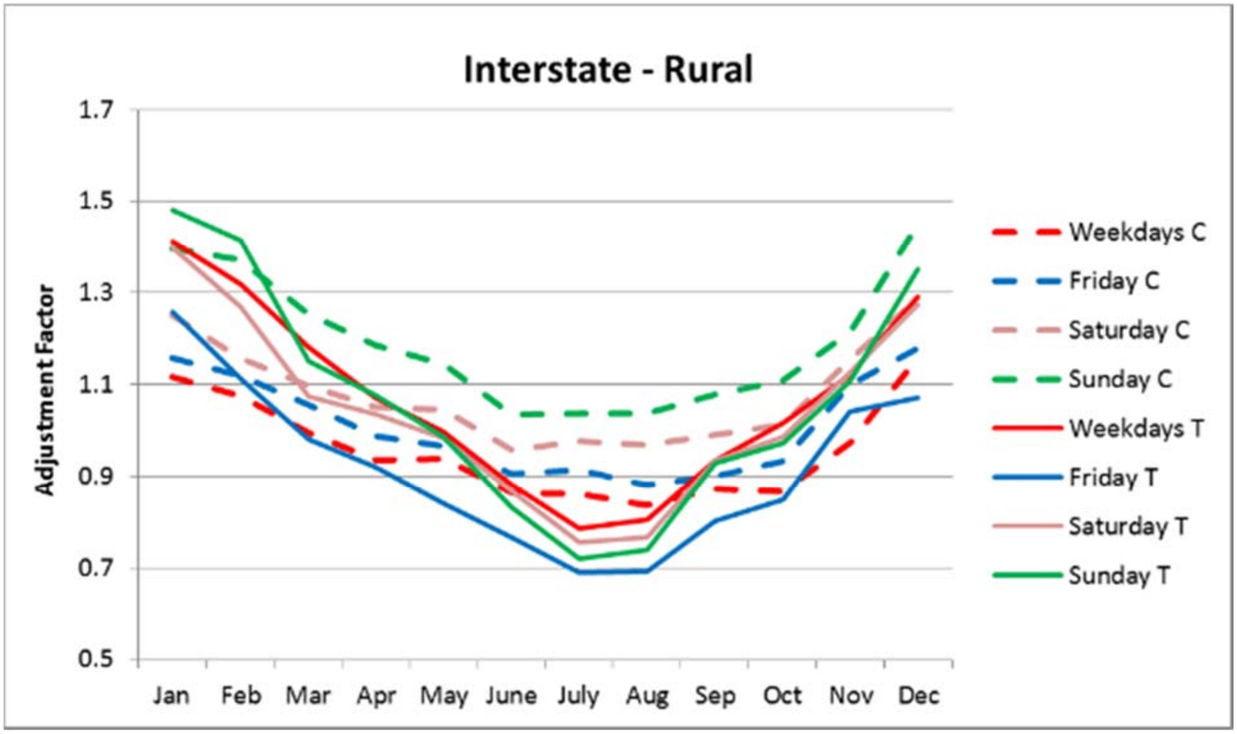


Figure 35: Rural Interstate Adjustment Factor Comparison, Total Vehicles Versus Commercial

A comparison of urban interstate adjustment factors between total and commercial vehicles is presented in Figure 36. The adjustment factors for weekdays for both total and commercial vehicles were relatively similar both in trend and value. Commercial factors for Saturdays and Sundays showed the greatest deviation from these general trends, with Sunday factors being much higher throughout the year. This was attributed to less commercial traffic operating on weekends in general and on Sundays in particular. A similar pattern was observed with total vehicle factors showing less traffic on Saturdays and Sundays. Overall, the trend lines observed for urban interstates match expectations, with adjustment factors being lower during the summer months when traffic is highest and higher during the winter, spring and fall when traffic volumes drop off.

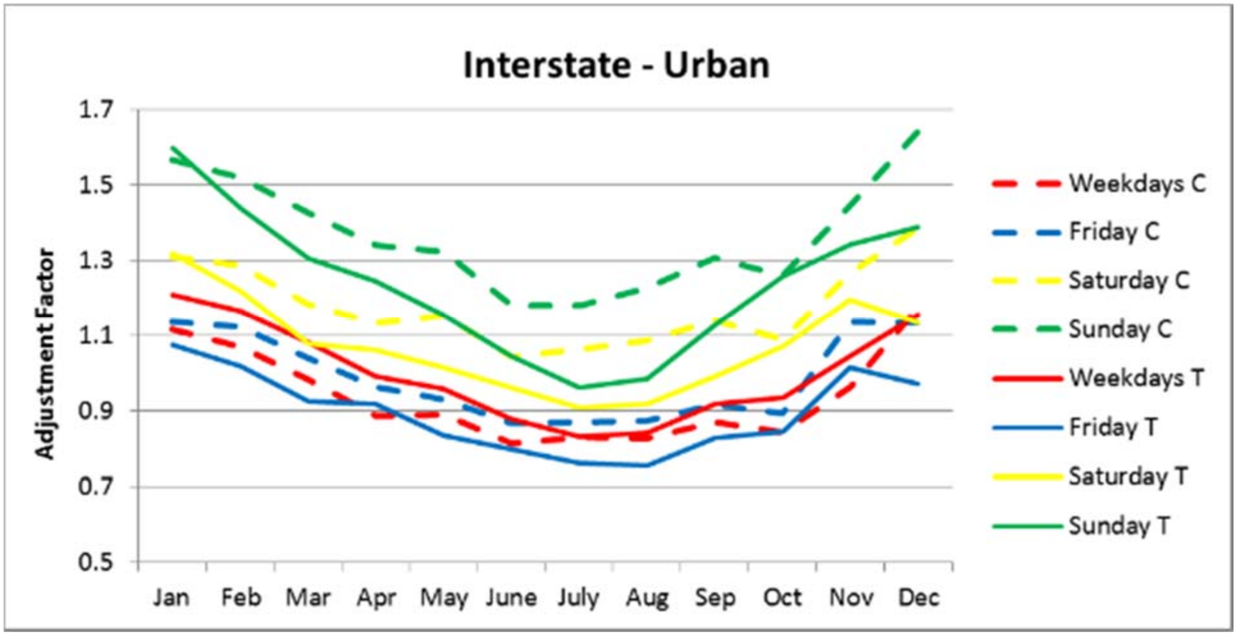


Figure 36: Urban Interstate Adjustment Factor Comparison, Total Vehicles Versus Commercial

For rural principal arterials, presented in Figure 37, traffic patterns for total vehicles are relatively similar for all days of the week throughout the year, compared to the more significant temporal variations in traffic seen on the interstate system (both rural and urban). For commercial vehicles, the trends for weekdays and Fridays were somewhat different from those of total vehicles, generally exhibiting lower variation in average daily traffic over the year (factors vary over a smaller range). However, commercial vehicle factors were considerably different for Saturdays and Sundays, i.e. significantly higher adjustment factors and more variation in magnitude throughout the year.

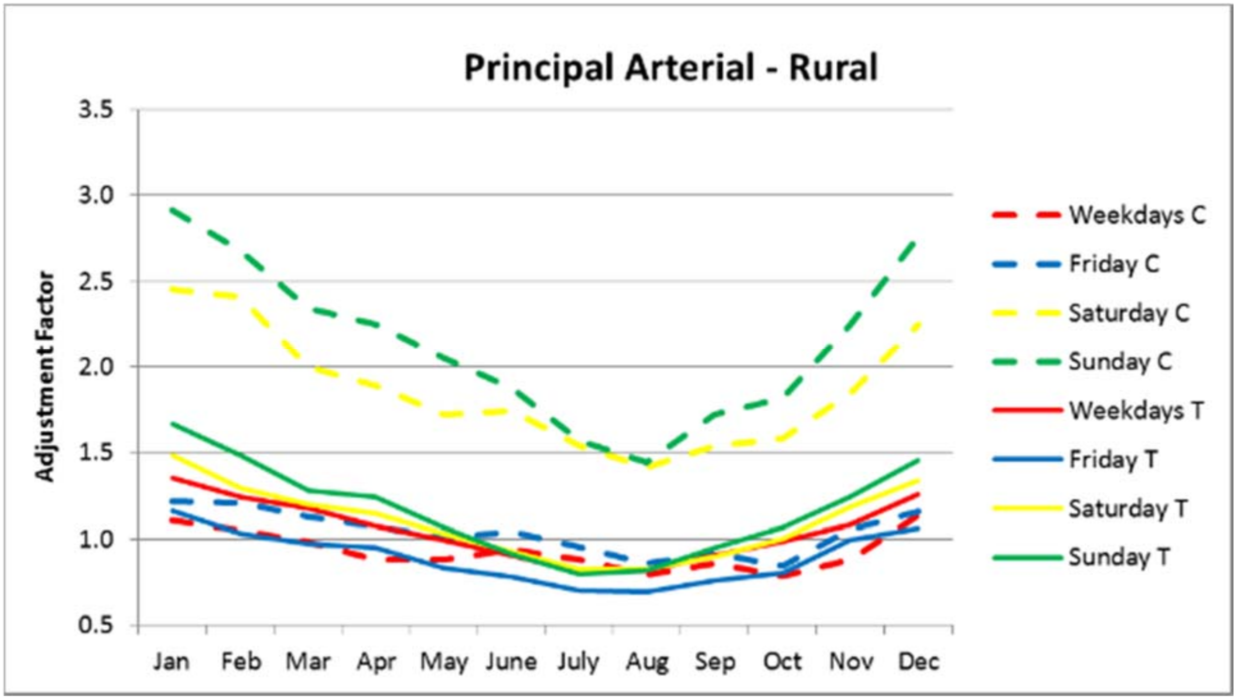


Figure 37: Rural Principal Arterial Adjustment Factor Comparison, Total Vehicles Versus Commercial

Rural minor arterial adjustment factors for commercial and total vehicles are presented in Figure 38. This figure once again illustrates that patterns in commercial vehicle operations on Saturdays and Sundays are significantly different from those of total vehicles on these routes. Specifically, adjustment factors for commercial vehicles are notably higher on weekend days than those for all vehicles, particularly during the non-summer months. Factors undergo a steep decline during the spring and begin to climb in the fall. This indicates very low volumes of commercial vehicles using those relatively less important rural routes in the winter season. These trends illustrate that commercial vehicle traffic is potentially being overestimated on these days of the week using the current MDT factor grouping scheme. Unlike Saturday and Sunday, Weekday and Friday adjustment factors for commercial vehicles are somewhat comparable in magnitude to those of total traffic. However, as was observed with the rural principal arterials, the commercial adjustment factors on rural minor arterials exhibit less variation in average daily traffic throughout the year when compared to total traffic.

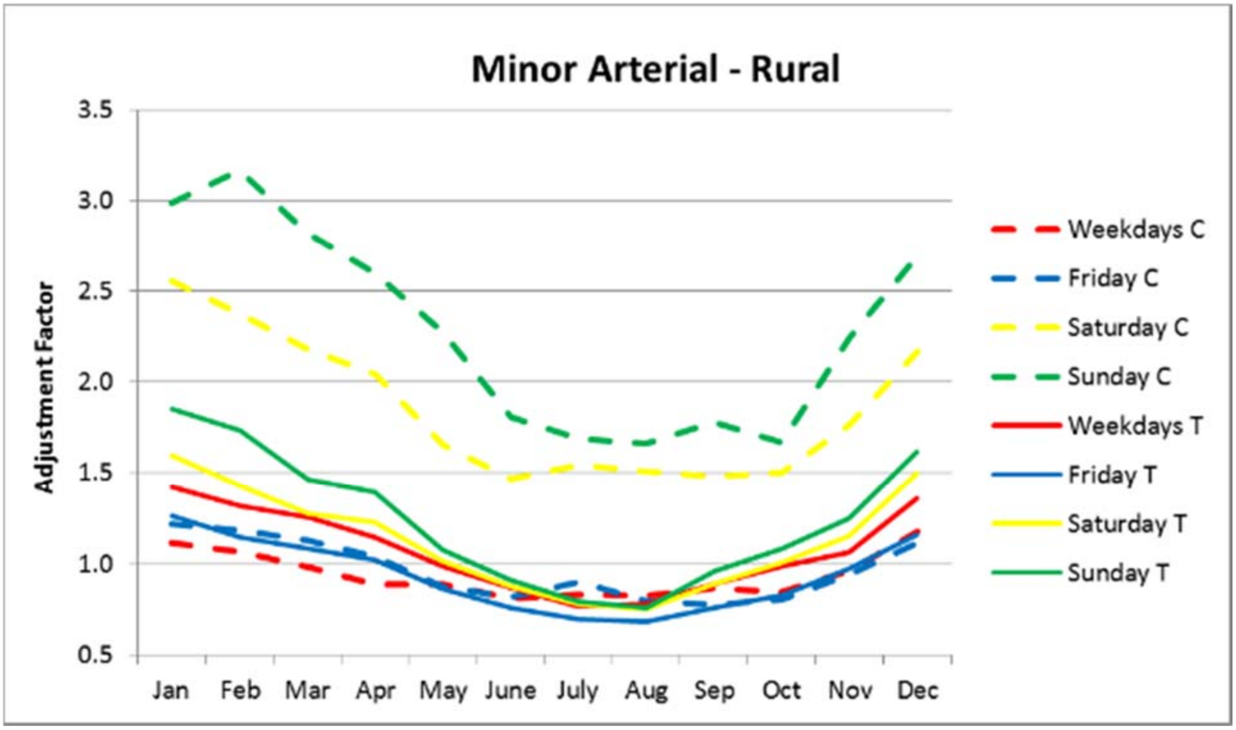


Figure 38: Rural Minor Arterial Adjustment Factor Comparison, Total Vehicles Versus Commercial

Adjustment factors for commercial and total traffic on rural major collectors are shown in Figure 39. Weekday and Friday commercial vehicle adjustment factors and trend lines were once again very similar to those of total vehicle factors. On the other hand, Saturday and Sunday adjustment factors for commercial vehicles are far higher than those for all vehicles, particularly during the non-summer months. Similar to rural minor arterials, the commercial vehicle factors undergo an even steeper decline during the spring and climb to higher values in the fall. Compared to rural minor arterials, lower volumes of commercial vehicles use these less important rural routes in the winter season. These various observations continue to suggest that separate adjustment factors may be appropriate for commercial vehicles.

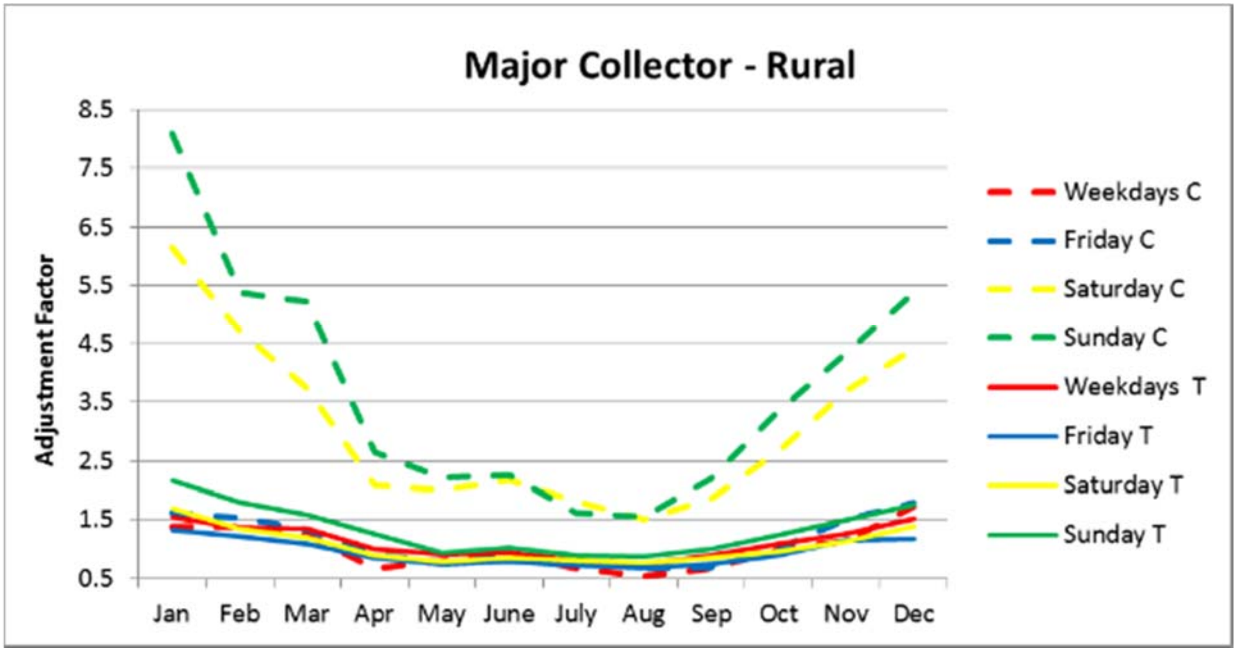


Figure 39: Rural Major Collector Adjustment Factor Comparison, Total Vehicles Versus Commercial

In general and referring to Figure 37, Figure 38 and Figure 39, the distribution across the year of commercial vehicle adjustment factors for weekend days (Saturday and Sunday) steadily sharpened and deepened, moving across non-interstate rural systems from major to minor collector, with corresponding adjustment factors increasing in the winter months from 2.5 to 3, to 5.5 to 8.

In summary, the evidence from the evaluation of the commercial vehicle hypothesis is that adjustment factors for weekdays and Fridays are generally similar between total and commercial vehicles for the majority of routes. Commercial vehicles, however, exhibit distinctive traffic patterns on Saturdays and Sundays, particularly as the route classification moves from arterial to collector. The difference in adjustment factors over the year for commercial vehicles on all routes was significantly higher than those of the total vehicle factors. This indicates that traditional adjustment factors may not be accurately accounting for the presence of commercial traffic, which could have potential impacts when using factors in pavement designs, etc. In general, the pattern in terms of decreasing adjustment factors in the spring and increasing factors in the fall remained consistent between both the commercial vehicle and total vehicle groupings, which was the expected trend.

To better understand the variation in the traffic patterns between data collection sites included in each traffic factor group, the standard deviations in the adjustment factors calculated for the sites in each group were determined. These standard deviations were calculated for the adjustment factors determined by month-of-year and day–of-week. Standard deviations for total and commercial traffic are presented in Table 43 and Table 44, respectively. The standard deviations between 0.2 and less than 0.3 are shown in yellow, between 0.3 and less than 0.4 in orange, and above 0.4 are shown in red. As illustrated, the least variation is exhibited by the group of stations located on urban and rural interstate highways. This is consistent throughout total and commercial traffic adjustment factors. For other non-interstate categories, adjustment factors exhibited significantly higher variation both for total as well as commercial vehicles, with more variation being associated with commercial vehicle adjustment factors. Specifically, higher variations for non-interstate categories occurred mainly between the months of November and April for total vehicles, while for commercial vehicles, they generally occurred on Saturday and Sunday, and between June and September on all days on rural principal arterials only. Collectively, the variation associated with these rural routes was expected, given that they are serving different commercial traffic volumes and patterns compared to interstates. Overall, the commercial vehicle grouping alone did not consistently show less variability compared to the current MDT grouping. This was particularly illustrated where the commercial vehicle grouping showed more variability on rural principal arterials, while the grouping showed less variability for minor arterials and collectors.

Table 43: Standard Deviations for Factors for Grouping by Current MDT Classification

Rural Interstate

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.16	0.14	0.11	0.14	0.04	0.04	0.06	0.06	0.05	0.06	0.07	0.17
Friday	0.14	0.10	0.09	0.09	0.05	0.06	0.07	0.06	0.06	0.04	0.07	0.13
Saturday	0.10	0.09	0.05	0.10	0.08	0.12	0.13	0.11	0.09	0.06	0.09	0.14
Sunday	0.13	0.10	0.10	0.11	0.09	0.14	0.13	0.12	0.12	0.09	0.11	0.17

Rural Major Arterial

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.35	0.31	0.30	0.23	0.08	0.10	0.12	0.11	0.07	0.13	0.30	0.35
Friday	0.34	0.33	0.31	0.24	0.08	0.11	0.12	0.11	0.07	0.12	0.30	0.38
Saturday	0.36	0.31	0.30	0.22	0.08	0.09	0.13	0.10	0.07	0.13	0.27	0.37
Sunday	0.34	0.29	0.26	0.22	0.08	0.08	0.12	0.10	0.06	0.12	0.31	0.31

Rural Minor Arterial

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.32	0.30	0.24	0.19	0.11	0.07	0.12	0.10	0.09	0.13	0.20	0.28
Friday	0.21	0.20	0.17	0.17	0.08	0.06	0.14	0.11	0.07	0.09	0.19	0.22
Saturday	0.41	0.36	0.25	0.22	0.13	0.12	0.24	0.19	0.16	0.12	0.22	0.30
Sunday	0.43	0.41	0.32	0.28	0.14	0.19	0.27	0.24	0.25	0.16	0.29	0.36

Rural Major Collector

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.61	0.62	0.38	0.17	0.17	0.08	0.10	0.08	0.06	0.16	0.38	0.63
Friday	0.52	0.47	0.23	0.11	0.20	0.10	0.14	0.12	0.07	0.11	0.30	0.48
Saturday	0.34	0.29	0.13	0.17	0.45	0.22	0.22	0.21	0.19	0.25	0.27	0.35
Sunday	0.47	0.37	0.25	0.18	0.46	0.27	0.26	0.25	0.24	0.33	0.29	0.41

Urban Interstate

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.12	0.08	0.08	0.05	0.01	0.01	0.04	0.01	0.01	0.03	0.06	0.10
Friday	0.09	0.05	0.02	0.03	0.02	0.04	0.06	0.05	0.01	0.01	0.03	0.05
Saturday	0.02	0.09	0.04	0.02	0.07	0.09	0.14	0.12	0.06	0.04	0.06	0.07
Sunday	0.07	0.04	0.07	0.08	0.11	0.16	0.18	0.15	0.11	0.01	0.07	0.09

Urban Principal Arterial

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.06	0.05	0.05	0.04	0.06	0.02	0.04	0.03	0.06	0.04	0.06	0.05
Friday	0.03	0.02	0.01	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Saturday	0.11	0.10	0.09	0.08	0.05	0.09	0.07	0.08	0.08	0.07	0.10	0.12
Sunday	0.11	0.10	0.09	0.09	0.12	0.11	0.12	0.12	0.11	0.11	0.09	0.13

Urban Minor Arterial

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.03	0.03	0.03	0.04	0.05	0.03	0.04	0.03	0.05	0.03	0.04	0.04
Friday	0.04	0.01	0.01	0.01	0.00	0.03	0.06	0.03	0.02	0.02	0.01	0.01
Saturday	0.07	0.07	0.06	0.07	0.07	0.05	0.03	0.03	0.06	0.09	0.09	0.05
Sunday	0.14	0.14	0.14	0.11	0.12	0.09	0.09	0.09	0.09	0.18	0.16	0.14

Urban Major Collector

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.05	0.11	0.10	0.06	0.07	0.10	0.13	0.06	0.14	0.16	0.10	0.05
Friday	0.09	0.07	0.04	0.01	0.02	0.18	0.19	0.08	0.09	0.08	0.03	0.06
Saturday	0.24	0.07	0.08	0.09	0.14	0.44	0.57	0.18	0.05	0.05	0.03	0.24
Sunday	0.28	0.03	0.06	0.02	0.12	0.43	0.51	0.11	0.07	0.03	0.10	0.19

Table 44: Standard Deviations for Factors for Grouping by Vehicle Type Scheme - Commercial Vehicles

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Interstate Urban												
Monday	0.08	0.08	0.07	0.06	0.04	0.06	0.01	0.06	0.04	0.07	0.09	0.20
Tuesday	0.04	0.00	0.03	0.04	0.03	0.02	0.01	0.02	0.04	0.02	0.06	0.13
Wednesday	0.06	0.03	0.05	0.03	0.03	0.02	0.01	0.04	0.02	0.03	0.06	0.12
Thursday	0.04	0.02	0.02	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.05	0.07
Friday	0.02	0.04	0.02	0.03	0.01	0.02	0.02	0.02	0.04	0.03	0.04	0.03
Saturday	0.12	0.09	0.11	0.12	0.14	0.12	0.16	0.16	0.16	0.15	0.09	0.14
Sunday	0.09	0.08	0.09	0.12	0.15	0.14	0.18	0.18	0.16	0.16	0.07	0.08
Interstate Rural												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.15	0.15	0.16	0.16	0.12	0.08	0.08	0.08	0.08	0.08	0.13	0.21
Tuesday	0.10	0.09	0.10	0.10	0.08	0.06	0.06	0.07	0.06	0.07	0.10	0.20
Wednesday	0.10	0.09	0.09	0.08	0.07	0.06	0.10	0.07	0.08	0.08	0.11	0.22
Thursday	0.09	0.10	0.09	0.09	0.07	0.06	0.08	0.07	0.07	0.08	0.11	0.10
Friday	0.09	0.09	0.11	0.11	0.08	0.06	0.11	0.10	0.09	0.09	0.12	0.15
Saturday	0.15	0.16	0.14	0.12	0.12	0.13	0.15	0.19	0.16	0.17	0.17	0.20
Sunday	0.16	0.15	0.14	0.12	0.16	0.12	0.17	0.18	0.18	0.18	0.18	0.22
Principal Arterial Rural												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.17	0.14	0.24	0.14	0.12	0.59	0.58	0.52	0.56	0.17	0.12	0.25
Tuesday	0.15	0.15	0.11	0.10	0.12	0.52	0.50	0.39	0.52	0.21	0.13	0.20
Wednesday	0.12	0.13	0.14	0.10	0.08	0.52	0.38	0.38	0.37	0.10	0.14	0.17
Thursday	0.13	0.09	0.24	0.16	0.17	0.55	0.43	0.32	0.38	0.10	0.13	0.15
Friday	0.23	0.25	0.38	0.26	0.26	0.53	0.48	0.39	0.53	0.13	0.14	0.14
Saturday	0.92	0.86	0.60	0.59	0.41	0.55	0.47	0.44	0.42	0.61	0.59	0.61
Sunday	1.08	1.01	0.95	0.93	0.82	0.74	0.58	0.54	0.57	0.80	1.07	1.17
Minor Arterial Rural												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.20	0.13	0.21	0.12	0.09	0.11	0.13	0.09	0.08	0.12	0.09	0.14
Tuesday	0.18	0.09	0.07	0.08	0.12	0.07	0.10	0.06	0.08	0.11	0.06	0.17
Wednesday	0.12	0.11	0.14	0.13	0.07	0.04	0.16	0.05	0.05	0.08	0.09	0.18
Thursday	0.13	0.13	0.09	0.10	0.11	0.10	0.13	0.10	0.10	0.11	0.06	0.14
Friday	0.20	0.18	0.10	0.15	0.15	0.14	0.17	0.11	0.12	0.12	0.14	0.15
Saturday	0.73	0.66	0.67	0.60	0.41	0.33	0.27	0.27	0.30	0.52	0.56	0.65
Sunday	0.84	1.07	0.90	0.97	0.68	0.49	0.51	0.49	0.39	0.66	0.81	0.73
Major Collector Rural												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.26	0.06	0.23	0.15	0.12	0.21	0.08	0.08	0.10	0.21	0.16	0.29
Tuesday	0.12	0.01	0.12	0.12	0.36	0.45	0.05	0.05	0.05	0.26	0.16	0.05
Wednesday	0.17	0.06	0.13	0.11	0.23	0.53	0.05	0.05	0.12	0.12	0.06	0.01
Thursday	0.11	0.04	0.08	0.04	0.31	0.23	0.06	0.02	0.17	0.10	0.22	0.08
Friday	0.14	0.15	0.05	0.09	0.14	0.25	0.03	0.19	0.18	0.04	0.24	0.14
Saturday	1.69	0.30	0.57	0.55	0.25	0.06	0.72	0.80	0.97	0.18	0.16	0.27
Sunday	2.31	0.31	0.97	0.82	0.73	0.50	0.79	0.93	1.18	1.11	0.61	0.07

6.3.2.2. Grouping by Areas and Regions

The hypothesis behind this grouping scheme was that different areas and regions of the state are host to different economic activities, such as agriculture, tourism/recreation, manufacturing, etc.

throughout the year. As such, these different regions may merit different adjustment factors based on this criteria. To test this hypothesis, different adjustment factors were developed for various areas and regions. The results of this grouping scheme are discussed in this section specifically as it was implemented using the categories of urban, interstate, agriculture, and rural/other. Recall that a summary of the stations assigned to each respective category was presented in Table 41.

Adjustment factors developed from WIM and ATR sites in urban areas of the state, namely, Billings, Great Falls, Missoula, Helena, and Kalispell, are presented in Figure 40, Figure 41, Figure 42 and Figure 43 for weekdays, Fridays, Saturdays and Sundays, respectively. Thirteen stations were identified as being located in urban areas of the state and were included in this group. These sites were established as being associated with general urban activities (e.g. service industries, health care centers, colleges, manufacturing, etc.). Referring to Figure 40 and Figure 41, the adjustment factors developed in urban areas for weekdays, including Fridays, are tightly grouped throughout the year. The exceptions are sites A-054 (19th St. in Billings) and A-068 (Beckworth Ave. in Missoula), where fluctuations were observed, particularly in the summer months, but also in the spring and fall for site A-054. The reasons behind the small spikes observed at site A-054 are not immediately clear, as the location is not near any major traffic generator or attraction, such as a school, tourist destination, etc. MDT has consistently observed a dip in July and rise in August-September in the traffic at site A-054. It should be noted that during 2013, the site was offline from June 17th thru August 23rd due to construction, while nearby work on Broadwater Avenue also affected traffic at the site beyond the end of the year. Site A-068 is located near the University of Montana campus, and the observed fluctuations correspond to the academic term calendar.

In examining weekend trends, all sites generated adjustment factors above 1.0, which was expected. Weekend traffic in urban areas can be high, with residents running errands, visitors shopping and attending various events, etc. However, the traffic level particularly on Sundays would still be, in most cases, less than that of a weekday with commuter/business traffic.

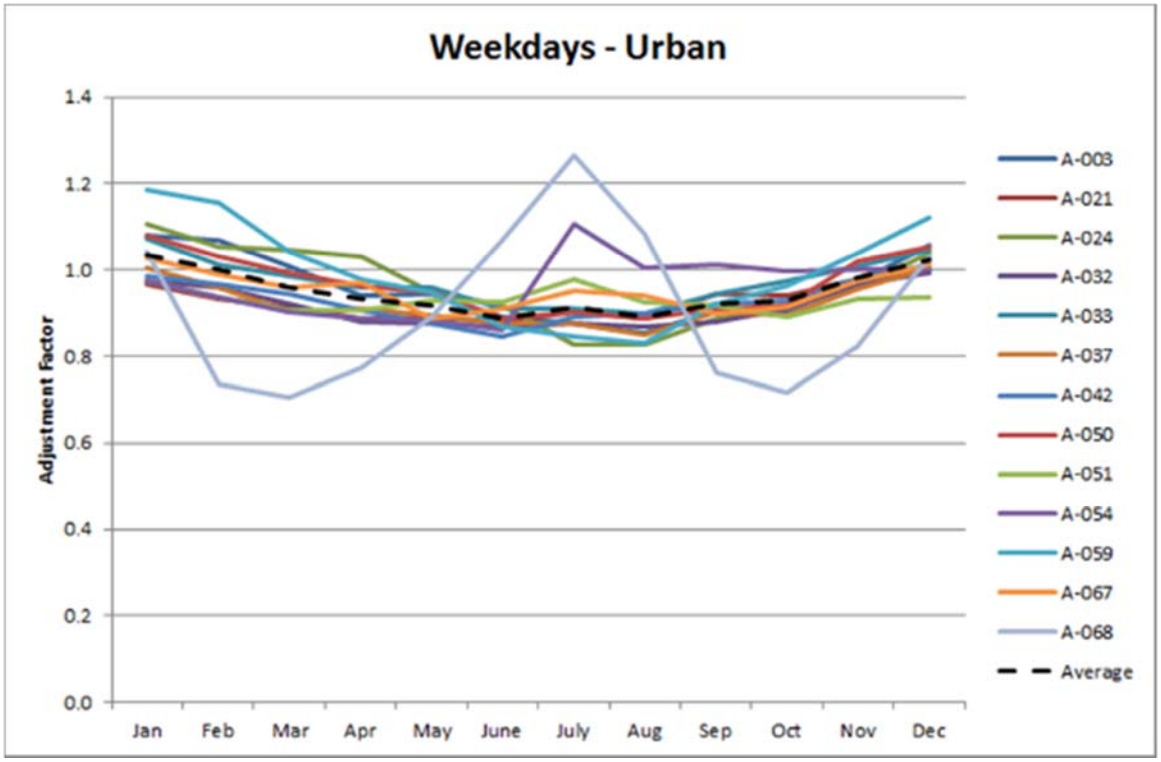


Figure 40: Urban Count Station Adjustment Factors, Weekdays

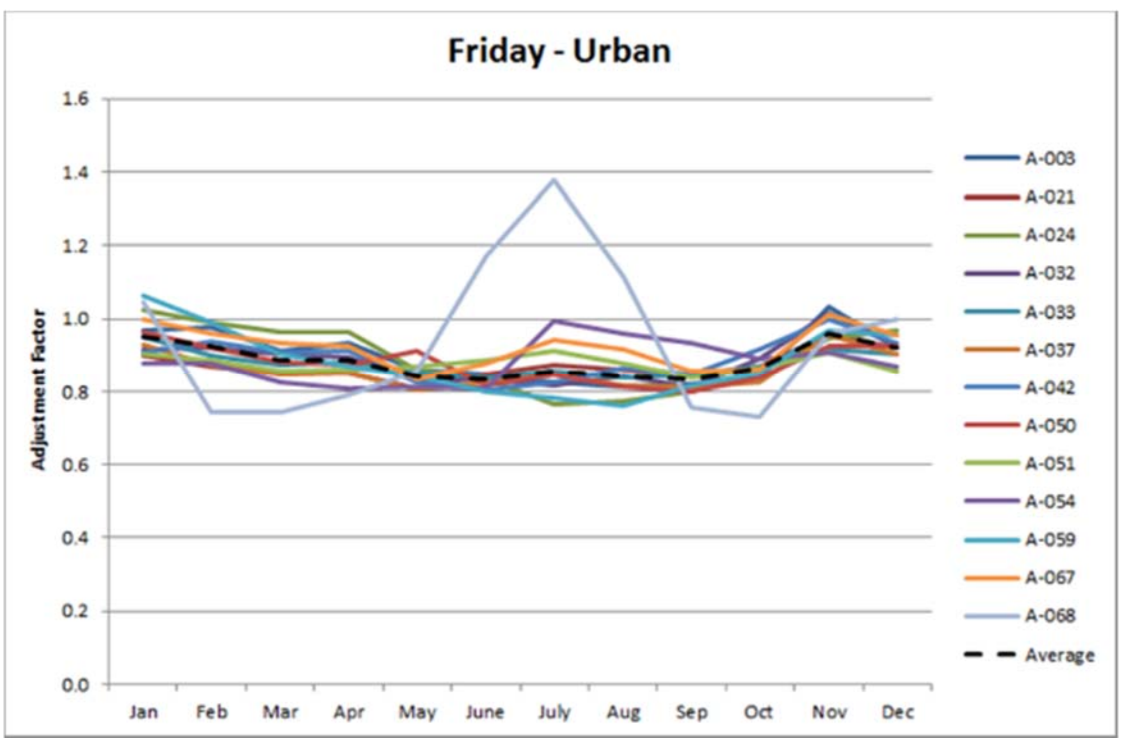


Figure 41: Urban Count Station Adjustment Factors, Friday

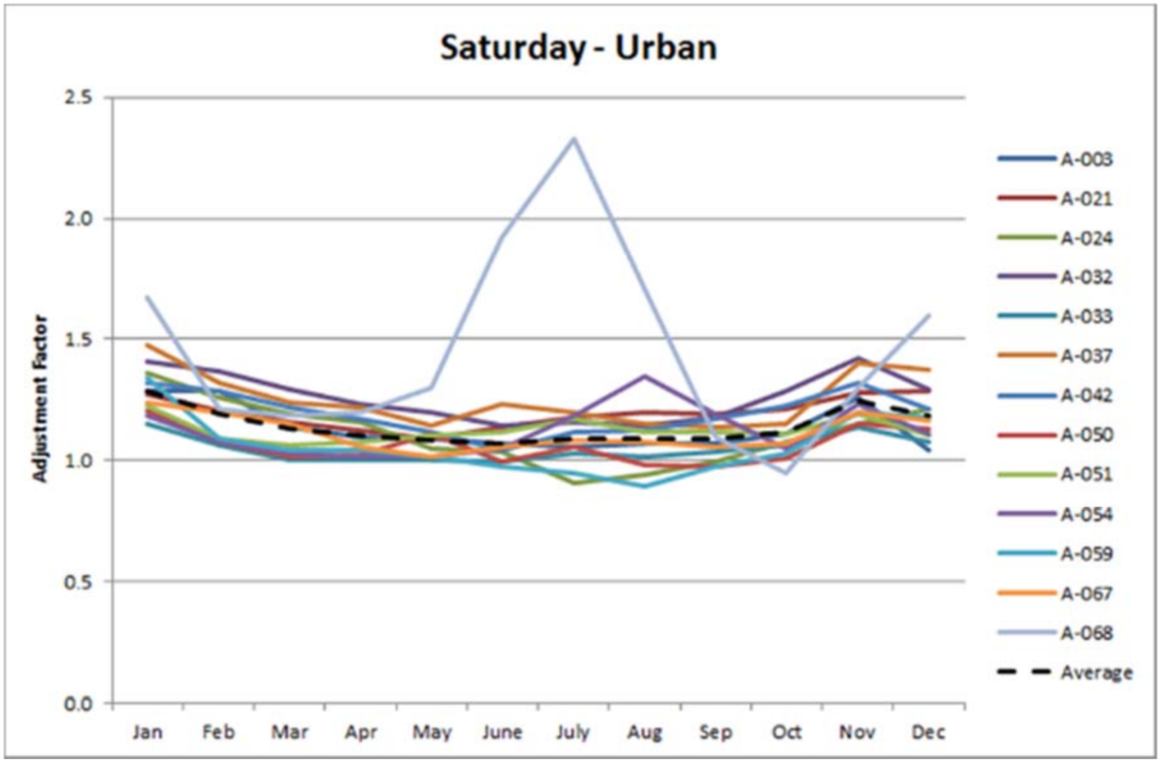


Figure 42: Urban Count Station Adjustment Factors, Saturday

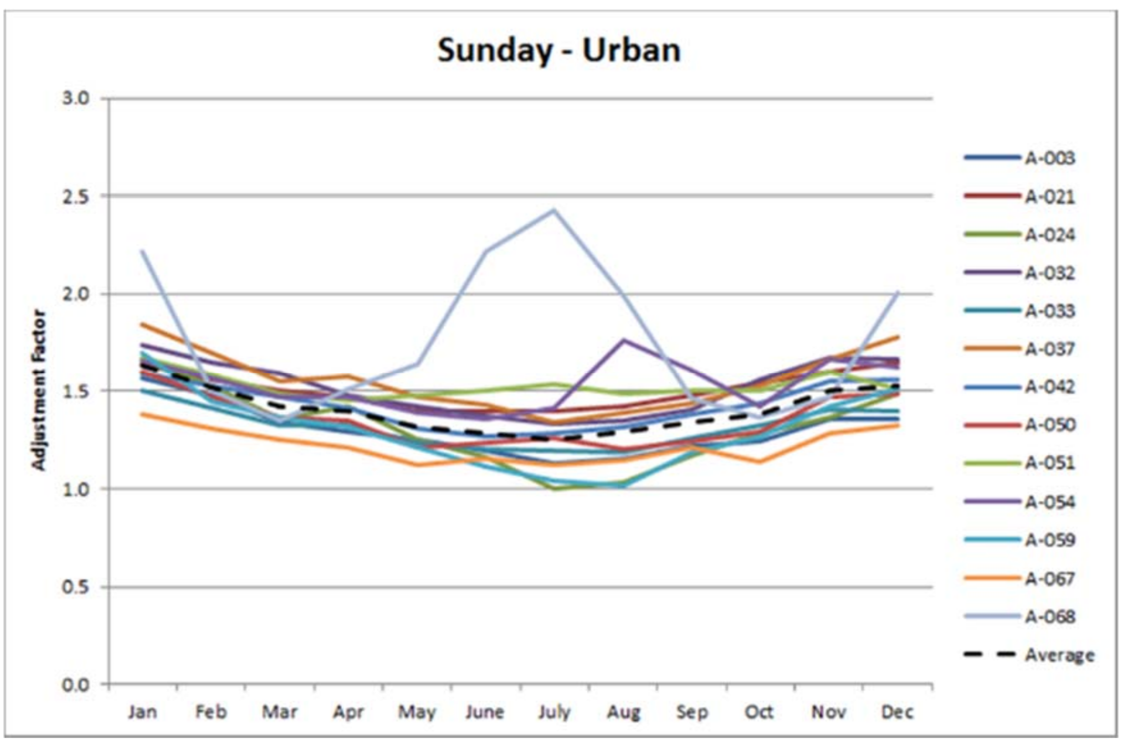


Figure 43: Urban Count Station Adjustment Factors, Sunday

The second group of area factors developed was for interstate routes. Based on the different travel patterns that these routes serve, notably through passenger and commercial traffic, it was decided that these routes would comprise their own area group. The results of the analysis are presented in Figure 44, Figure 45, Figure 46 and Figure 47 for weekdays, Fridays, Saturdays, and Sundays, respectively. For weekdays, including Fridays, the observed trends matched what was expected. That is, adjustment factors were lower during the summer months and higher in the spring, fall and winter, reflecting the general decreased mobility and reduction in activity in northern climates during the colder months of the year. Also as was expected, factors varied somewhat between sites in response to the underlying variations in the basic travel demands served by different highway segments around the state. Site W-137, located on I-90 west of St. Regis did generate discernibly lower adjustment factors than other sites between May and September, which may be the result of particularly high tourist travel on this route during this period of the year.

Weekend traffic adjustment factors exhibited expected trends as well; in this case factors were generally higher and above 1.0 during the winter months and lower and below 1.0 during the summer months. Three sites in the Sunday factor group (Figure 15) are distinctly different from the rest of the group. Three of these sites are contiguous on I-15 - A-009 (I-15 at Vaughn), A-061 (I-15 at Shelby), and W-136 (I-15 at Sweetgrass), and the other site is W-203 (I-90 at Mossmain, westbound and eastbound directions respectively). All sites generated higher adjustment factors compared to other interstate sites between May and September-October. It is likely that these differences are attributable to tourism traffic, but it is interesting that these differences occurred on Sundays and were not so clearly evident on any other day of the week.

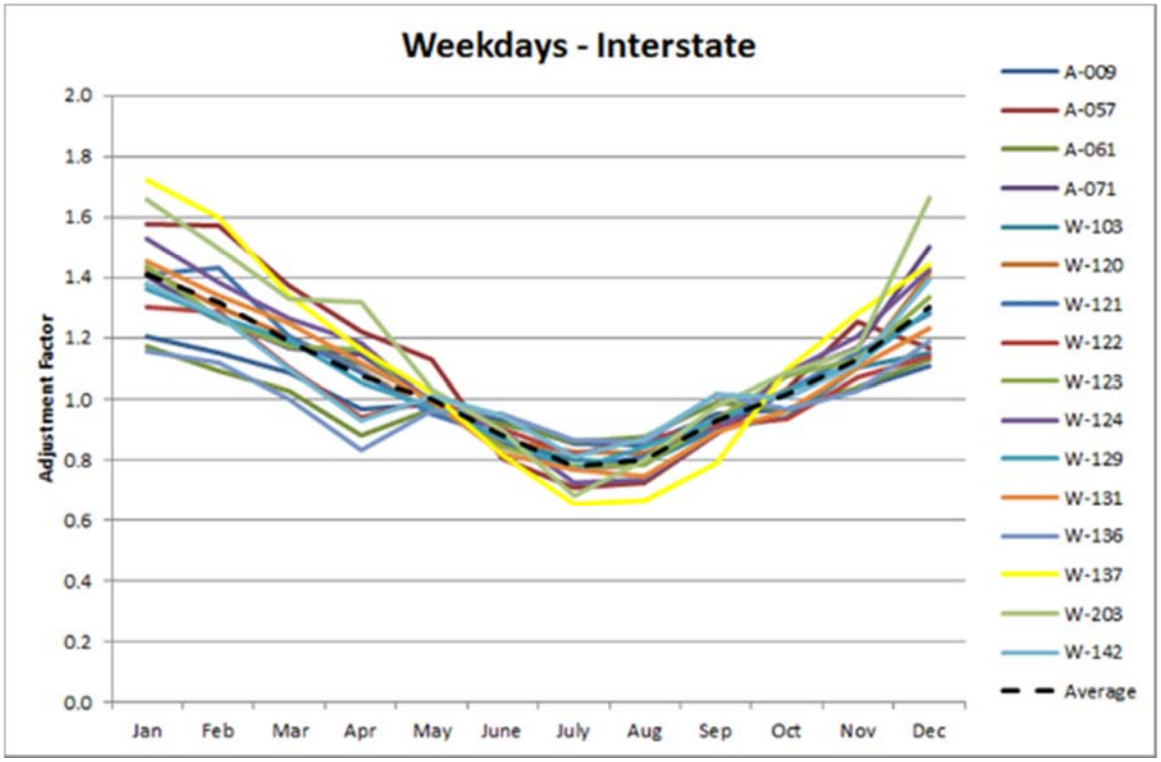


Figure 44: Interstate Count Station Adjustment Factors, Weekdays

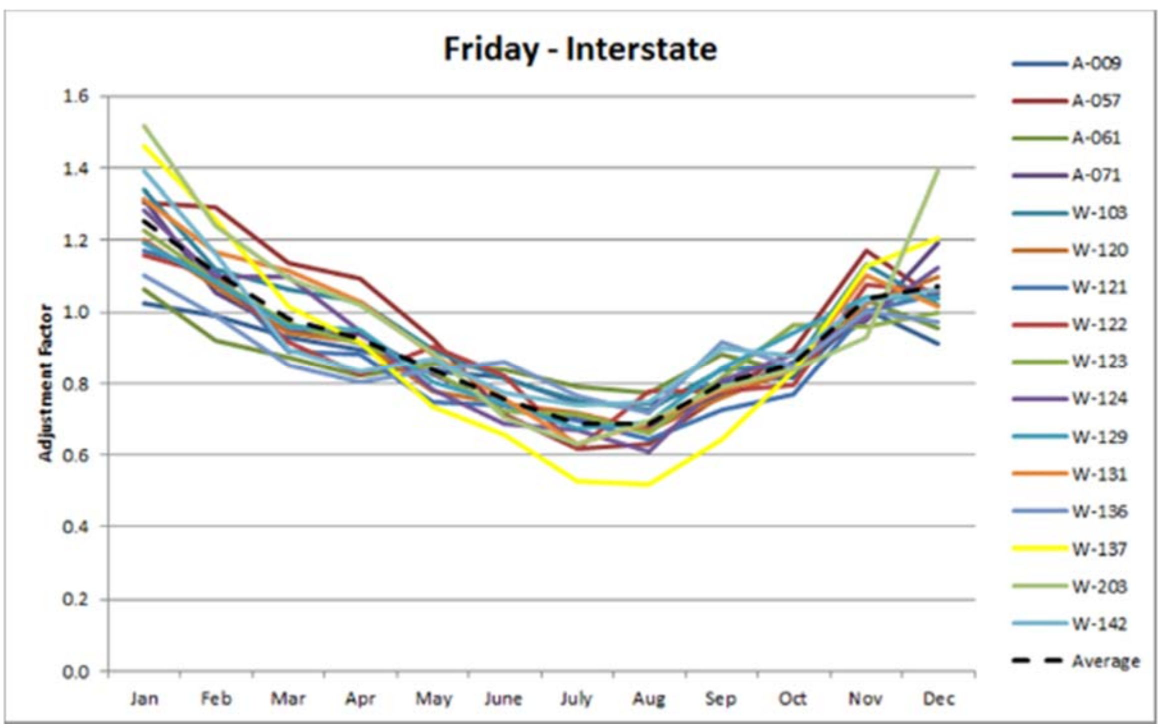


Figure 45: Interstate Count Station Adjustment Factors, Friday

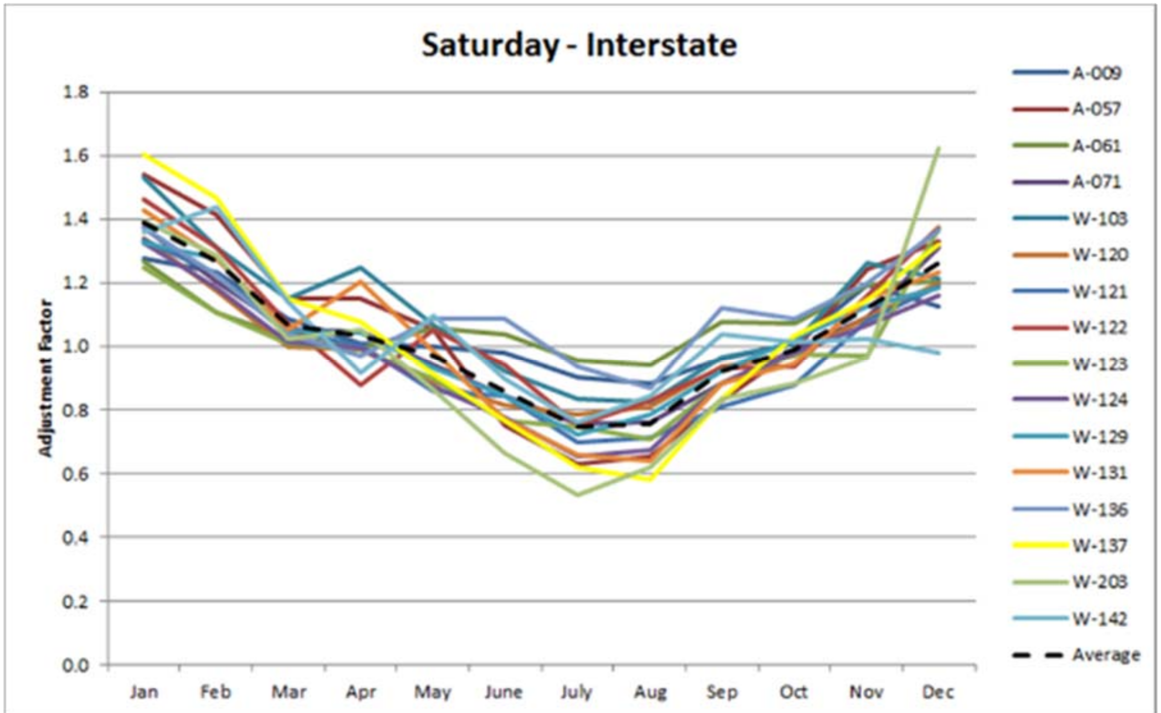


Figure 46: Interstate Count Station Adjustment Factors, Saturday

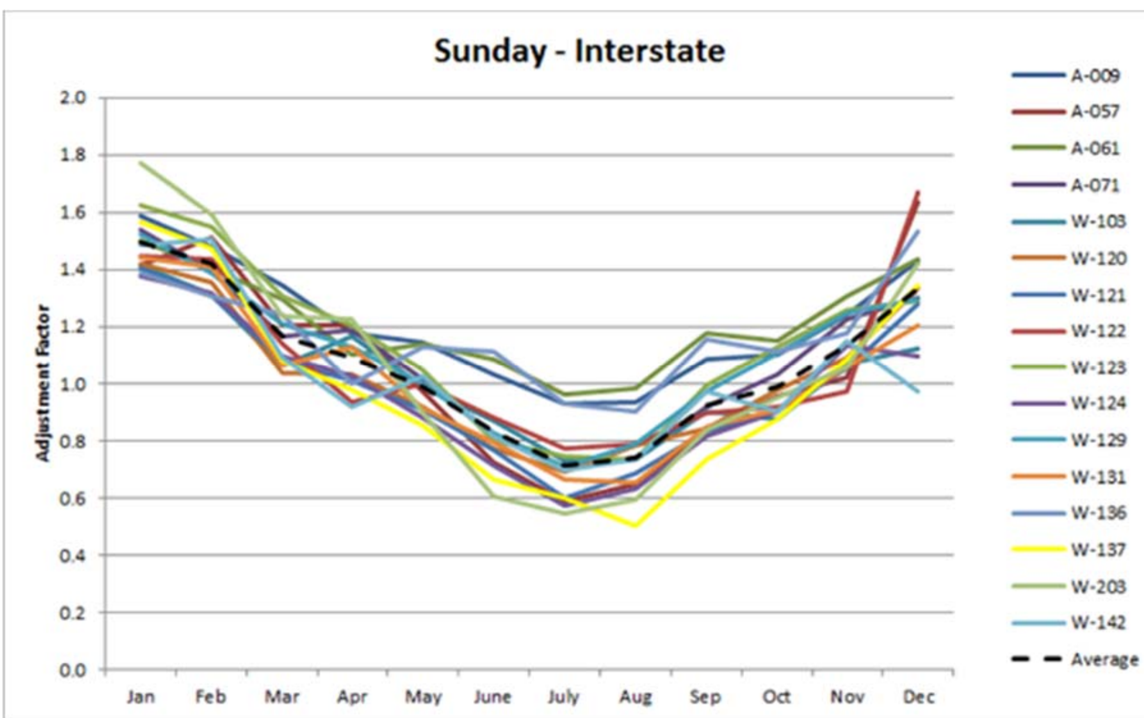


Figure 47: Interstate Count Station Adjustment Factors, Sunday

The next regional adjustment factor group evaluated was agricultural areas. The adjustment factor trends at these sites, shown in Figure 48, Figure 49, Figure 50 and Figure 51, were as expected; notably, for weekdays, higher factors were observed during the relatively dormant months of late fall and winter, and lower factors during the active months of spring, summer and early fall. There is more variability among adjustment factors during fall and winter months (November – April) compared to spring and summer months. While various sites had higher and lower factors at various times throughout the year, the overall trend between sites was consistent. Factors for Fridays were generally lower in value than those of weekdays. Factors for Saturdays and Sundays are different from weekdays and Fridays in that they show much more variation between seasons at any given station and, similar to weekdays, more variation between stations during fall and winter months.

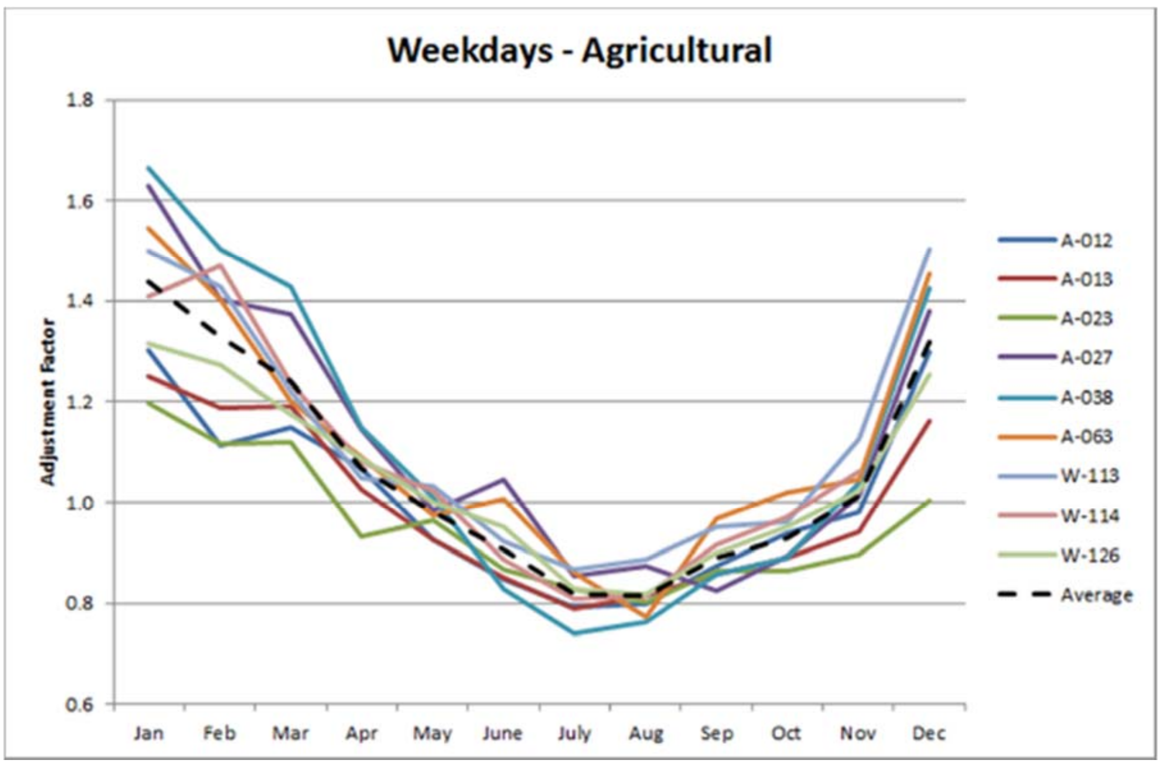


Figure 48: Agriculture Count Station Adjustment Factors, Weekdays

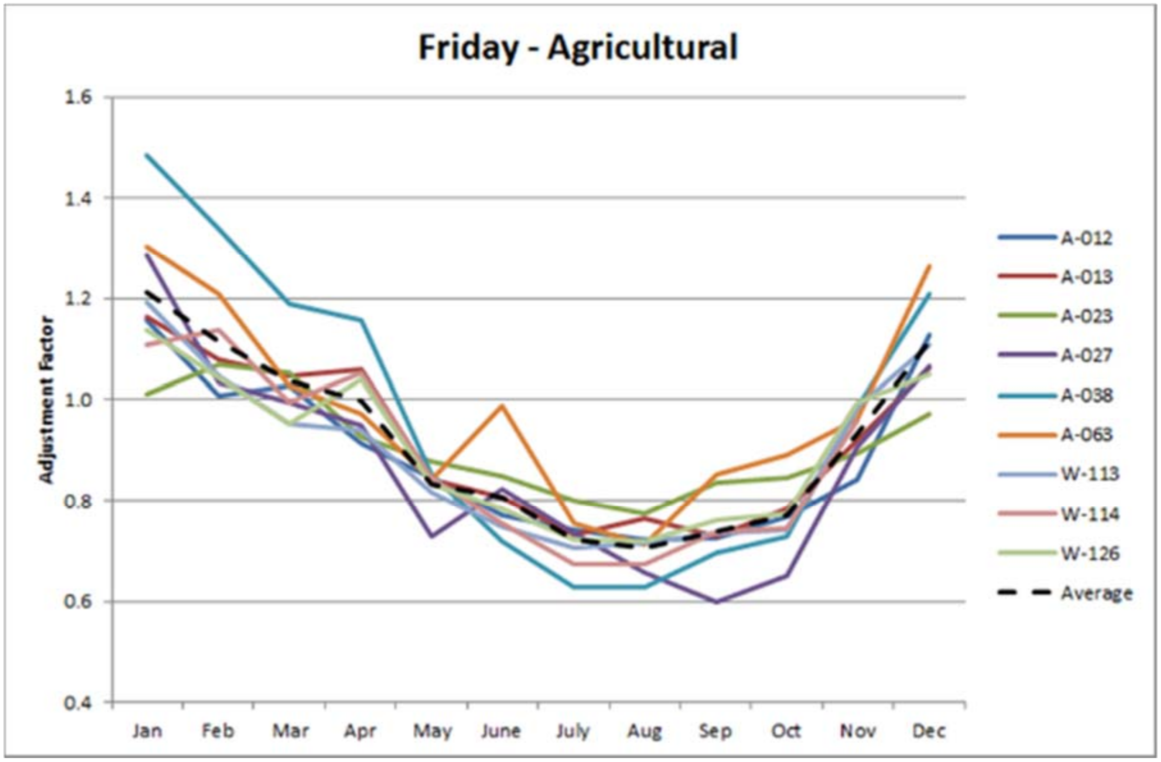


Figure 49: Agriculture Count Station Adjustment Factors, Friday

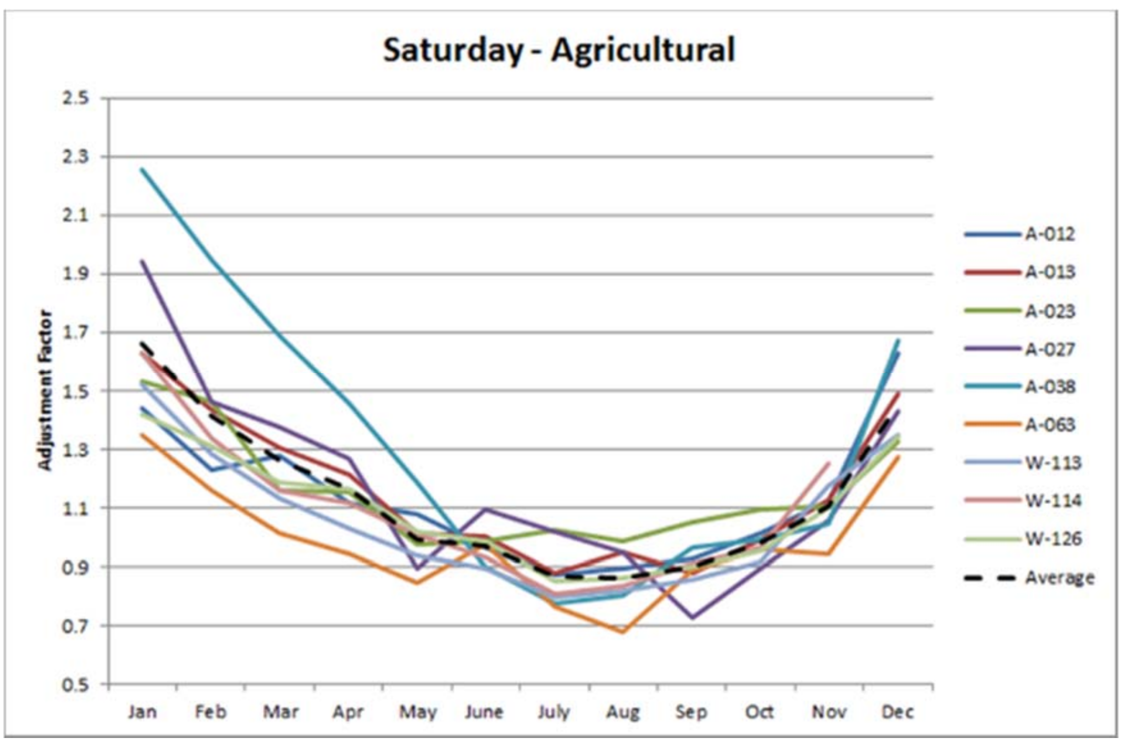


Figure 50: Agriculture Count Station Adjustment Factors, Saturday

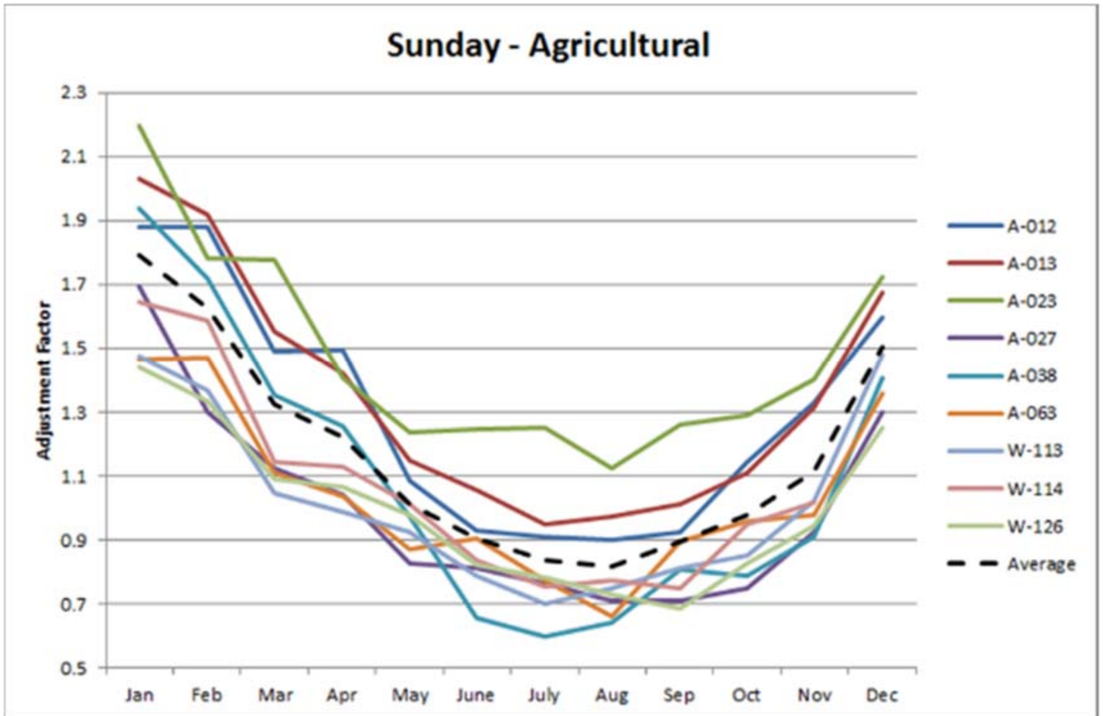


Figure 51: Agriculture Count Station Adjustment Factors, Sunday

The next regional adjustment factor group was generated for sites on recreation and tourism routes. These were routes that serviced areas near ski resorts, national parks, etc. As Figure 52, Figure 53, Figure 54, and Figure 55 show, varying traffic patterns were observed on these routes by day-of-week and time-of-year. Overall, these figures show that the adjustment factors during the summer tourist season are notably low (lower than all previous factors discussed), with little variation among stations in this group. For the rest of the year (i.e., outside the summer season), large differences are observed in adjustment factors between stations, larger than seen in any other grouping. Specifically, stations in regions that have a single tourism season during the year (typically summer) display the largest variation in adjustment factors over the year, while as would be expected, stations in regions that also experience recreational traffic during the winter (due to nearby ski resorts) have much lower variation in adjustment factors over the year. For the latter group of stations, there is a spike in adjustment factors between the tourism seasons, i.e. around April-May in the spring and October-November in the fall, particularly on Fridays, Saturdays and Sundays. For example, site A-018, located on U.S. 20 west of the town of West Yellowstone, exhibited relatively pronounced recreation oriented traffic patterns, as this route leads to a key entrance to the Yellowstone Park and is affected by seasonality (this entrance is closed to vehicle traffic late fall thru spring). On the other hand, station A-064 located on MT 64 near Big Sky, exhibited low adjustment factors during the summer and winter seasons with spikes in adjustment factors during the spring and fall transitional periods. This trend is largely related to the presence of the Big Sky resort, which attracts ski traffic in the winter and general tourism in the summer.

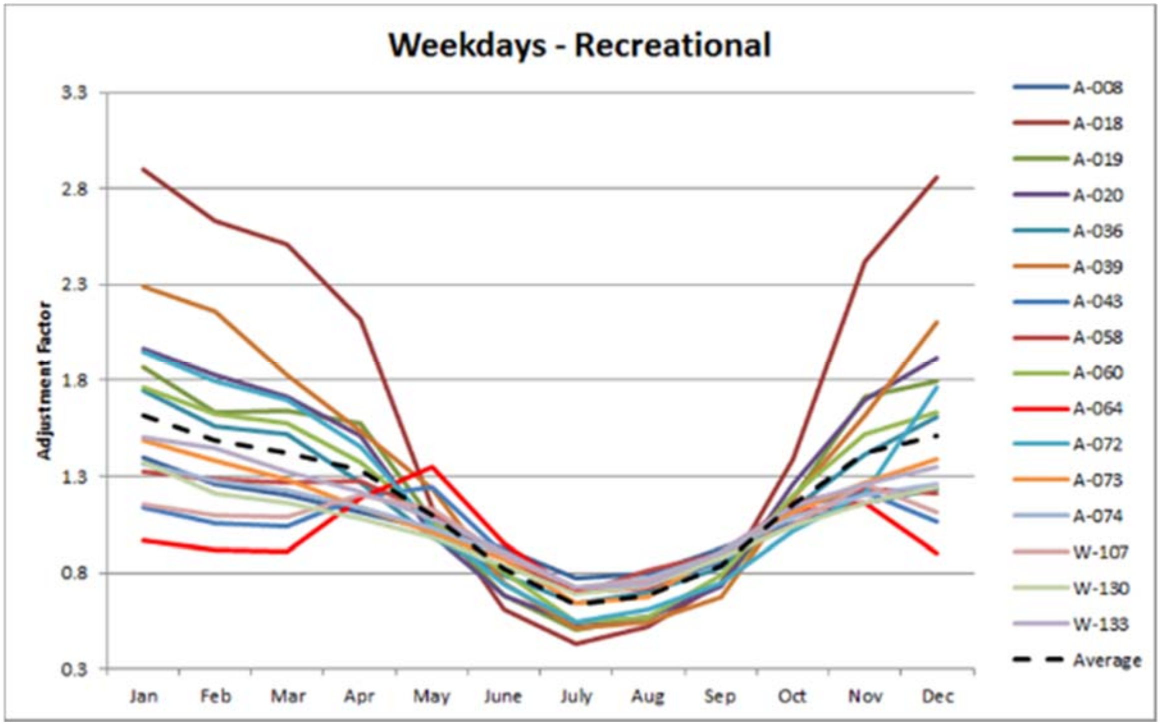


Figure 52: Recreation Count Station Adjustment Factors, Weekdays

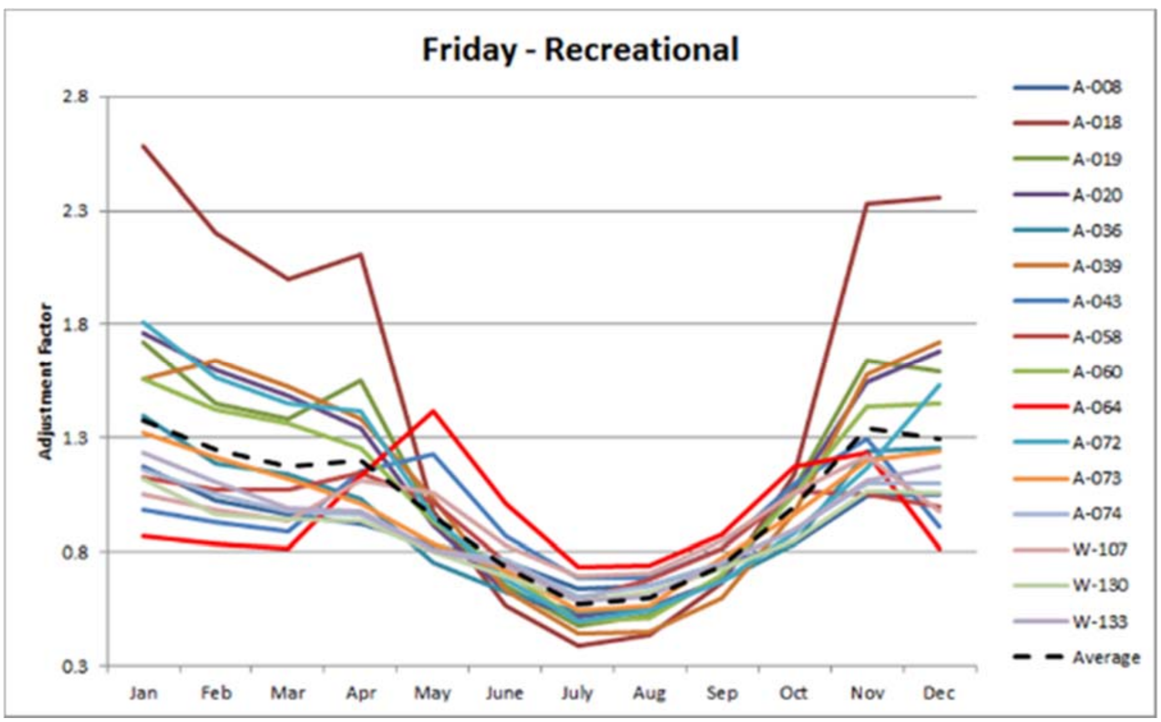


Figure 53: Recreation Count Station Adjustment Factors, Friday

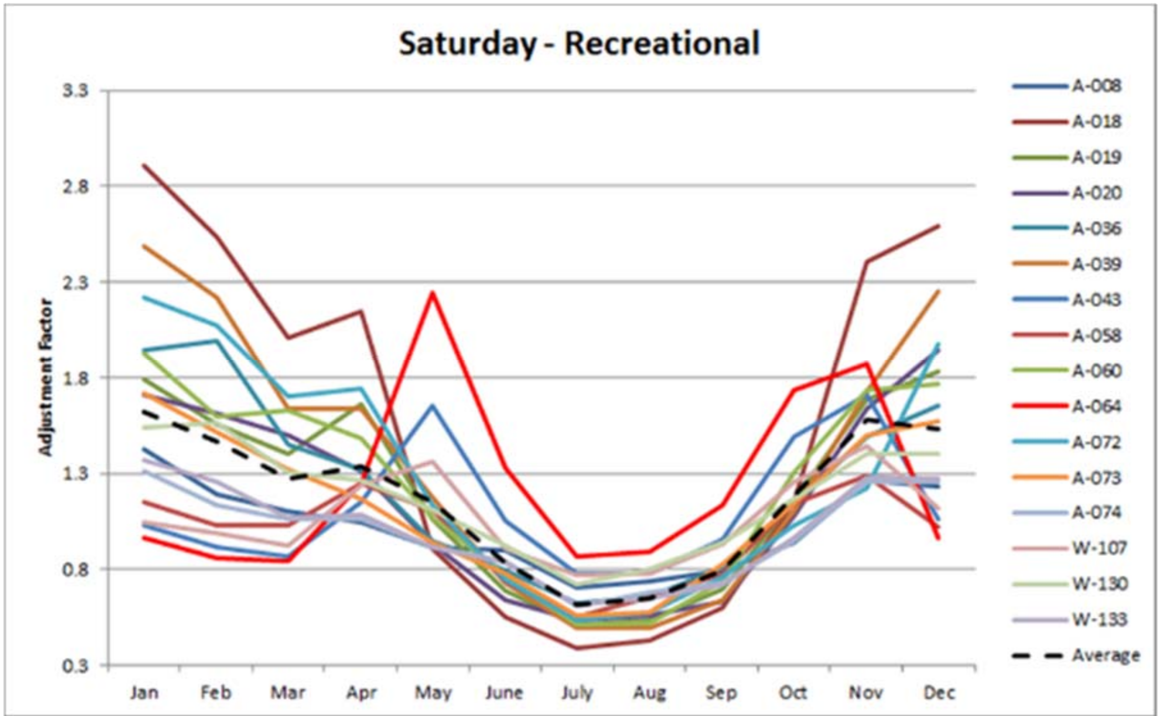


Figure 54: Recreation Count Station Adjustment Factors, Saturday

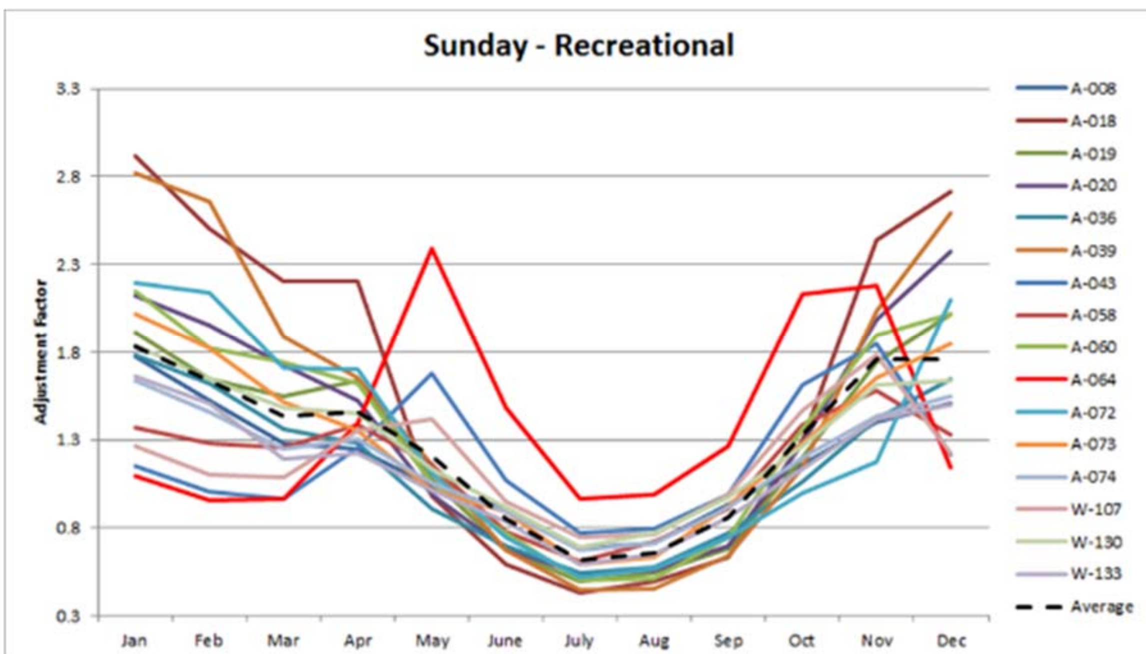


Figure 55: Recreation Count Station Adjustment Factors, Sunday

The last group of stations in this grouping scheme was “Rural/Other”. This group included all stations in rural areas that were not readily identified as being part of any of the previous groups.

Figure 56, Figure 57, Figure 58 and Figure 59 show the adjustment factors for all stations in this group for various days of week over the year. As shown, the adjustment factors exhibited fairly consistent patterns at all stations on weekdays and Fridays (except for A-40) but much more variation in patterns on Saturdays and Sundays. The similarity in patterns between these stations on weekdays and Fridays was somewhat unexpected given that they may not have had many things in common other than not being affiliated with any of the previous groups. Station A-40, which is located on a major rural collector 2.5 miles north of Wolf Creek, was particularly divergent from the other stations in this group. This location experiences significant tourist traffic in the summer season, yet it was not placed in that category as it is not located in a major tourist region. This situation demonstrates one of the potential issues with this grouping scheme, namely, appropriately assigning various stations to each established group.

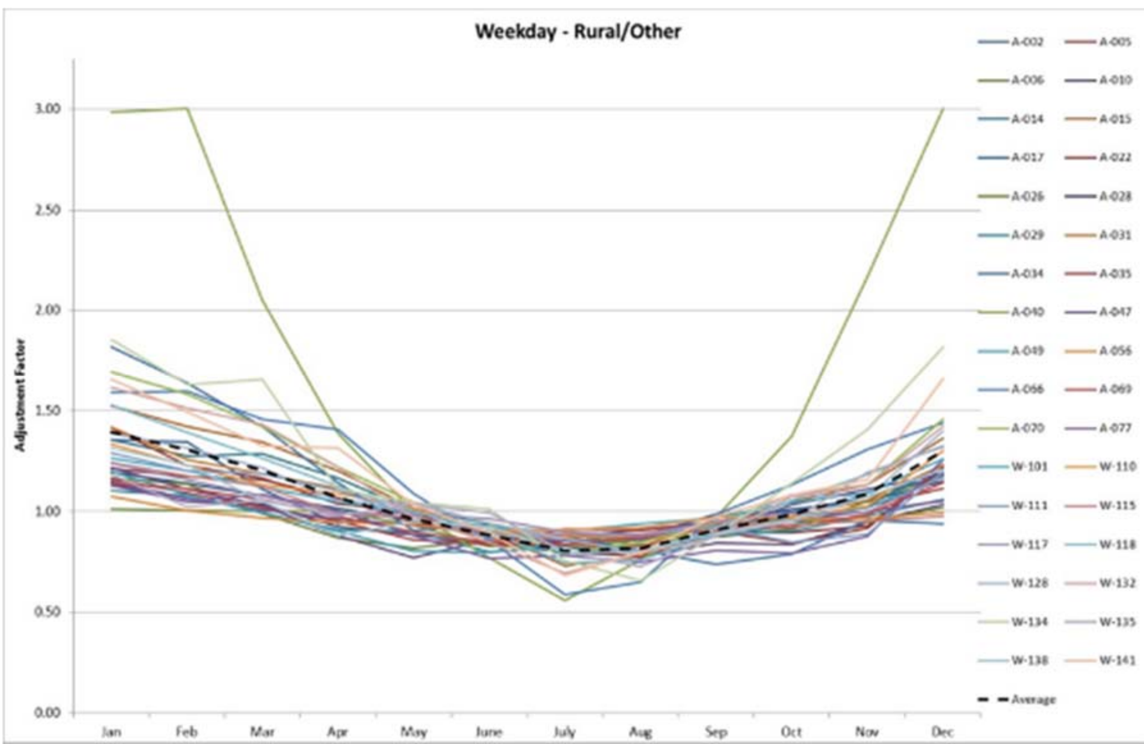


Figure 56: Rural/Other Count Station Adjustment Factors, Weekdays

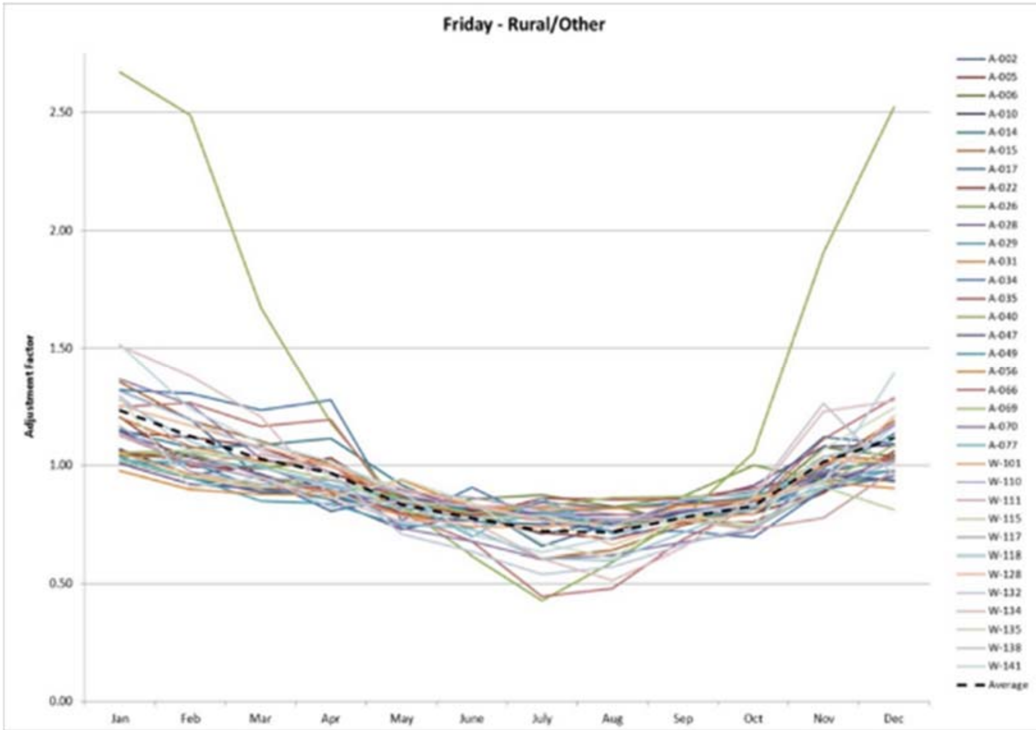


Figure 57: Rural/Other Count Station Adjustment Factors, Friday

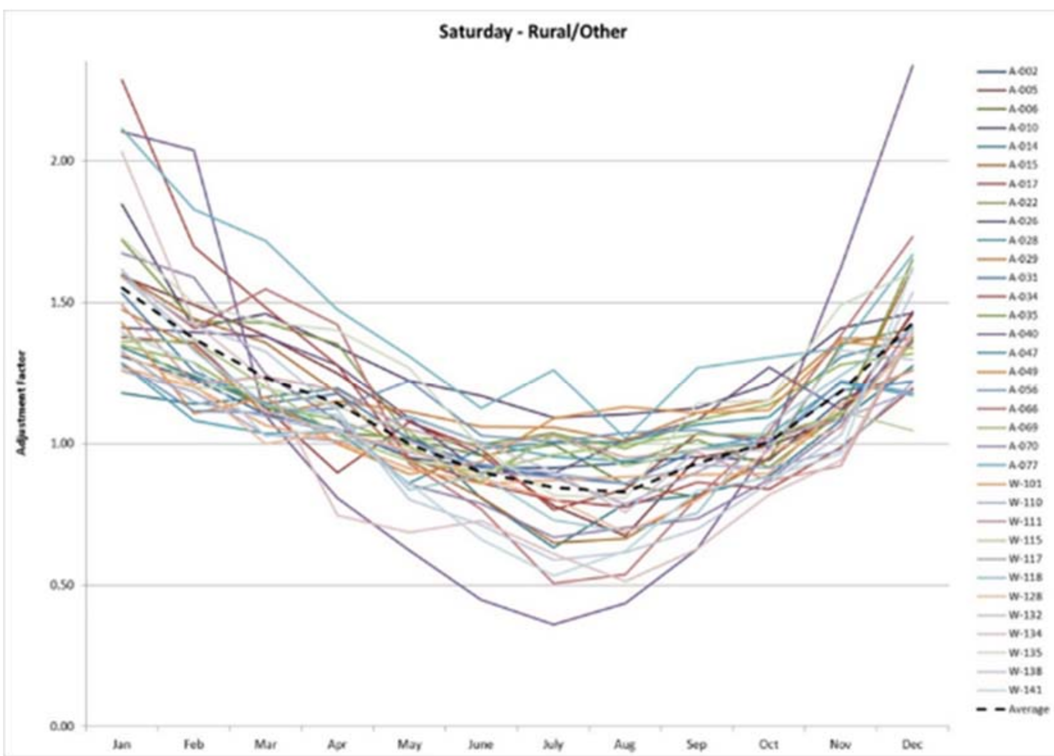


Figure 58: Rural/Other Count Station Adjustment Factors, Saturday

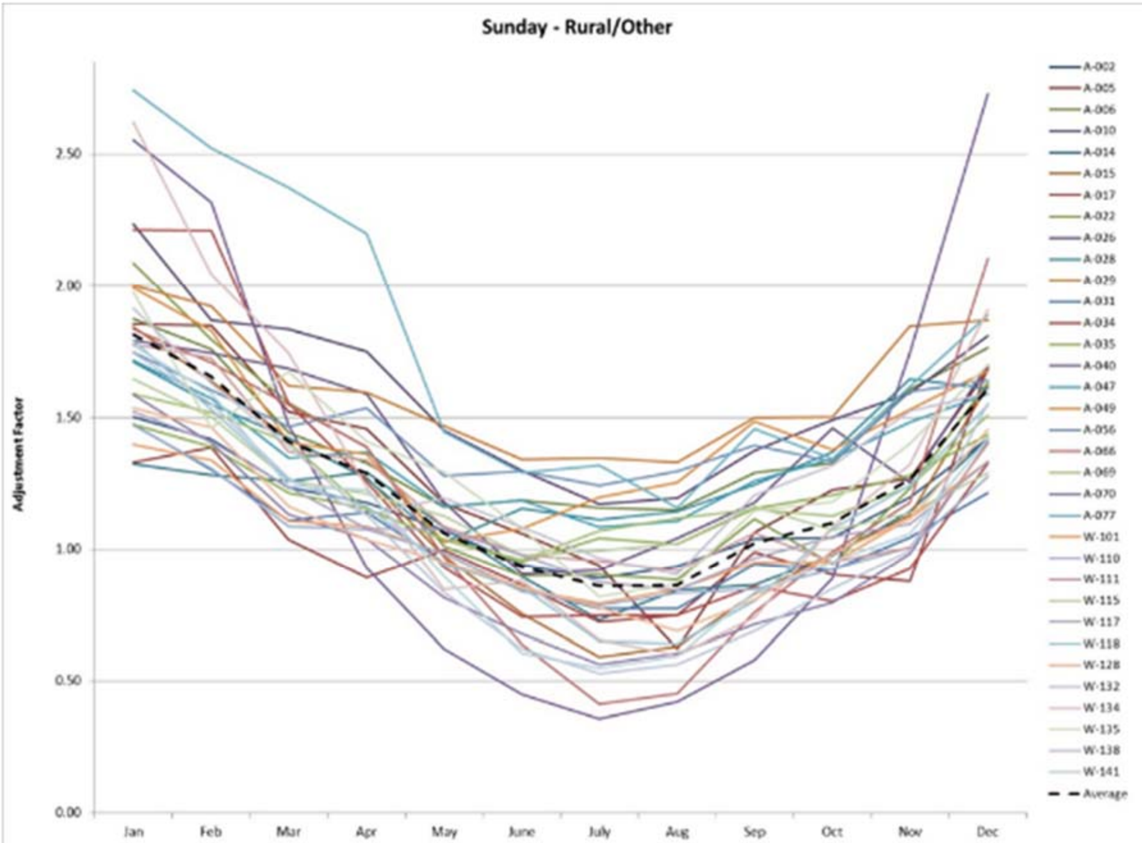


Figure 59: Rural/Other Count Station Adjustment Factors, Sunday

In summary, the trends observed when developing traffic adjustment factors by geographic characteristics and economic activity of an area yielded results that were generally as expected. Urban sites generated consistent adjustment factors throughout the year for all days of the week. Interstate adjustment factors exhibited the trends expected to accompany seasonal goods flow throughout the year depending on the day of the week. Late spring, summer and early fall produced lower adjustment factors than those of the late fall, winter and early spring. Similarly, adjustment factors for agricultural areas reflected the seasonality of agriculture operations, although Sundays displayed some variability. Recreation sites exhibited more variation in adjustment factors across the year, underscoring the seasonal nature of different tourism and recreation activities, such as skiing in the winter and parks visits in the summer. Table 45 presents the standard deviation in the adjustment factors for this grouping scheme by month of year and day of week. As before, standard deviations between 0.2 and less than 0.3 are shown in yellow, between 0.3 and 0.4 are shown in orange, and above 0.4 are shown in red. As can be readily observed, the least variation is exhibited by the group of stations located on interstate highways. Highest variation in adjustment factors is associated with the stations that are located in regions that see tourism/recreation traffic. The rural/other group also exhibited high variability in adjustment factors among stations, which was somewhat expected. Considering the variability within groups for the first and second grouping schemes (Table 43 and Table 45, respectively), a general observation would be that the second grouping scheme (by geographic area/economic activity) exhibits in a very general sense more variability between sites in some groups in winter months, while the first grouping scheme (by functional classification) exhibits more variability within some groups in summer months.

Table 45: Standard Deviations for Factors for Grouping by Area Scheme

Urban												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.07	0.10	0.09	0.06	0.02	0.05	0.15	0.08	0.06	0.09	0.05	0.06
Tuesday	0.06	0.09	0.09	0.06	0.04	0.05	0.10	0.06	0.06	0.06	0.05	0.04
Wednesday	0.07	0.10	0.08	0.06	0.04	0.06	0.12	0.07	0.05	0.06	0.04	0.05
Thursday	0.06	0.09	0.07	0.06	0.03	0.05	0.11	0.07	0.05	0.06	0.06	0.04
Friday	0.06	0.06	0.05	0.05	0.03	0.09	0.15	0.09	0.04	0.04	0.04	0.04
Saturday	0.13	0.10	0.09	0.08	0.08	0.24	0.34	0.20	0.08	0.09	0.09	0.14
Sunday	0.19	0.10	0.10	0.10	0.14	0.27	0.35	0.27	0.14	0.13	0.13	0.18

Interstate												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.16	0.13	0.11	0.16	0.06	0.04	0.06	0.06	0.06	0.08	0.10	0.12
Tuesday	0.17	0.16	0.11	0.14	0.06	0.05	0.06	0.07	0.06	0.05	0.08	0.18
Wednesday	0.16	0.16	0.12	0.13	0.04	0.05	0.07	0.05	0.05	0.05	0.06	0.23
Thursday	0.15	0.13	0.10	0.11	0.03	0.04	0.07	0.06	0.06	0.08	0.08	0.15
Friday	0.13	0.10	0.09	0.08	0.05	0.06	0.07	0.06	0.06	0.05	0.07	0.11
Saturday	0.10	0.10	0.05	0.09	0.08	0.11	0.11	0.10	0.09	0.06	0.09	0.14
Sunday	0.10	0.09	0.09	0.10	0.09	0.14	0.13	0.12	0.12	0.10	0.10	0.18

Agricultural												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.18	0.16	0.11	0.06	0.05	0.08	0.04	0.04	0.07	0.08	0.10	0.16
Tuesday	0.18	0.19	0.14	0.10	0.07	0.09	0.04	0.06	0.06	0.07	0.10	0.18
Wednesday	0.19	0.17	0.12	0.09	0.06	0.08	0.06	0.04	0.05	0.02	0.04	0.26
Thursday	0.16	0.12	0.08	0.06	0.04	0.07	0.04	0.05	0.05	0.03	0.08	0.14
Friday	0.13	0.10	0.07	0.08	0.04	0.08	0.05	0.05	0.07	0.07	0.05	0.09
Saturday	0.28	0.23	0.19	0.15	0.10	0.06	0.10	0.09	0.09	0.06	0.09	0.14
Sunday	0.25	0.22	0.25	0.19	0.13	0.17	0.19	0.16	0.17	0.18	0.19	0.15

Recreational												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.47	0.45	0.40	0.26	0.14	0.10	0.11	0.10	0.10	0.09	0.35	0.50
Tuesday	0.49	0.45	0.41	0.28	0.09	0.11	0.10	0.10	0.08	0.09	0.34	0.51
Wednesday	0.50	0.43	0.40	0.25	0.09	0.10	0.10	0.09	0.08	0.10	0.29	0.49
Thursday	0.48	0.40	0.34	0.26	0.10	0.09	0.10	0.09	0.07	0.08	0.35	0.43
Friday	0.41	0.35	0.31	0.30	0.17	0.11	0.09	0.09	0.07	0.11	0.33	0.39
Saturday	0.53	0.47	0.32	0.28	0.35	0.18	0.13	0.13	0.14	0.20	0.29	0.46
Sunday	0.52	0.47	0.34	0.24	0.37	0.21	0.14	0.14	0.16	0.25	0.30	0.48

Rural/Other												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monday	0.33	0.33	0.27	0.16	0.06	0.07	0.10	0.09	0.08	0.12	0.22	0.32
Tuesday	0.38	0.35	0.26	0.16	0.11	0.08	0.08	0.07	0.08	0.12	0.23	0.37
Wednesday	0.36	0.35	0.23	0.15	0.09	0.07	0.09	0.07	0.07	0.12	0.21	0.37
Thursday	0.35	0.38	0.20	0.14	0.08	0.05	0.10	0.08	0.06	0.10	0.21	0.36
Friday	0.30	0.27	0.16	0.13	0.06	0.06	0.12	0.10	0.06	0.07	0.18	0.28
Saturday	0.29	0.23	0.18	0.19	0.14	0.13	0.20	0.17	0.15	0.12	0.16	0.24
Sunday	0.35	0.30	0.26	0.25	0.18	0.21	0.25	0.24	0.25	0.21	0.25	0.29

6.3.2.3. Grouping by Modified Functional Classification Scheme

The final grouping scheme evaluated was based on a modification of the conventional functional classification groupings currently used by MDT. Recall that counts from WIM and ATR sites were grouped together in urban and rural sets by the functional classification of the roadway. The classifications examined for rural areas consisted of interstates, principal arterials, minor arterials and collectors. Urban categories consisted of interstates, principal arterials and minor arterials/collectors (combined). In the modified grouping scheme, adjustment factors for rural and urban routes respectively were each averaged into two categories. Interstates served as one category, and all remaining roads were combined into the second category. A summary of the findings for this classification scheme is presented in the following section. First, a presentation and discussion of the average adjustment factors under MDT's current grouping scheme) is provided, followed by presentation and discussion of the combined category approach.

Adjustment factors for the rural highway groups currently used by MDT are presented in Figure 60, Figure 61, Figure 62 and Figure 63, respectively, for weekdays, Friday, Saturday and Sunday. In examining trends in these factors, they are as would be expected. That is, weekday and Friday trends showed factors above 1.0 in the winter through late spring (reflecting relatively low traffic), below 1.0 and generally at or above 0.80 during the summer and early fall months (reflecting relatively high traffic), and back above 1.0 during the late fall and winter (reflecting a return to relatively low traffic in the colder months of the year). In regards to day-of-week, weekdays exhibited less variation in adjustment factors over the year compared with Friday and weekends. As for highway class, rural major collectors showed nominally less variation in adjustment factors across the year compared to other rural highway classes. Considered collectively, the four rural functional classes were fairly similar in terms of adjustment factor trends over the course of a year.

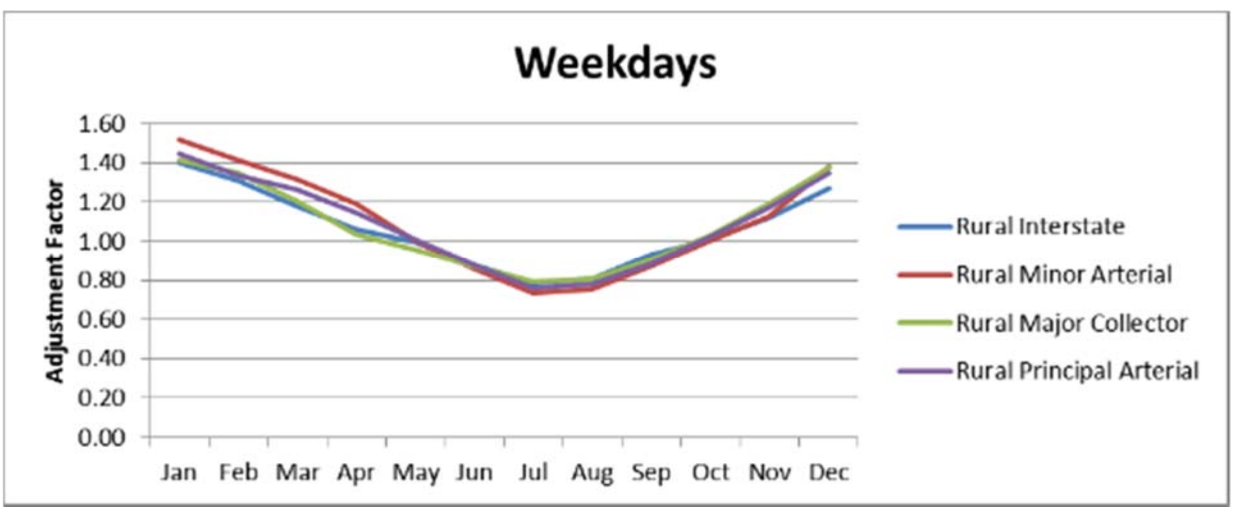


Figure 60: Rural Route Classification Count Station Adjustment Factors, Weekdays

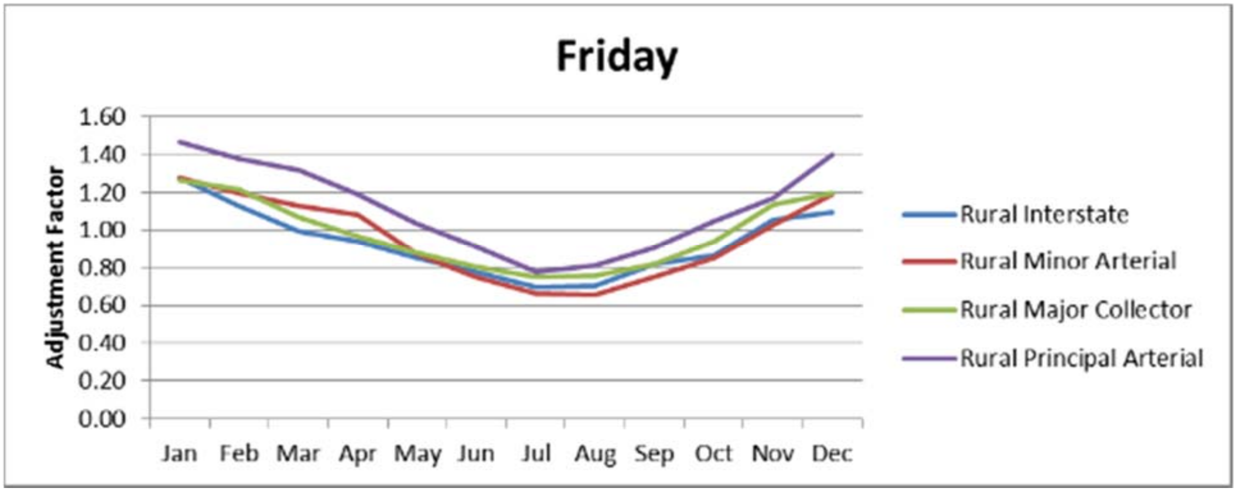


Figure 61: Rural Route Classification Count Station Adjustment Factors, Friday

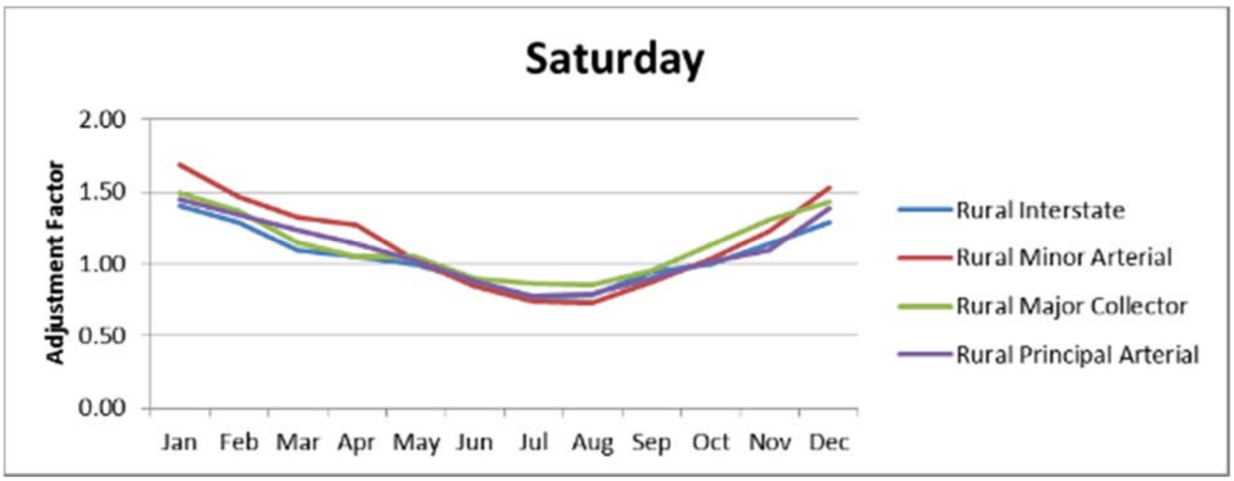


Figure 62: Rural Route Classification Count Station Adjustment Factors, Saturday

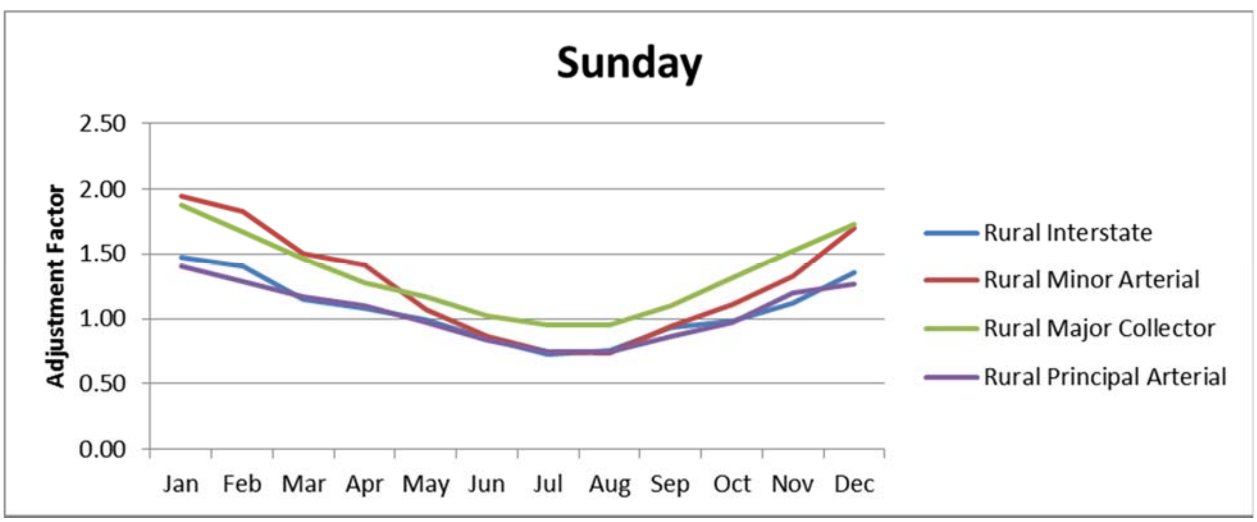


Figure 63: Rural Route Classification Count Station Adjustment Factors, Sunday

Adjustment factors for the urban highway groups currently used by MDT are presented in Figure 64, Figure 65, Figure 66, and Figure 67, respectively, for weekdays, Fridays, Saturdays and Sundays. Note that in this analysis collector routes have been combined with urban minor arterials as a result of the sparseness in associated data collection sites. Overall, it is evident that the change in magnitude of adjustment factors for urban highways across the year is notably smaller than that of rural highways. This may largely be attributed to commuter traffic in urban areas that occurs throughout the year. People travel to and from work during the week on a regular basis generally independent of time-of-year, and so volume on urban routes remains relatively stable. Nominally, the least variation in adjustment factors was associated with weekdays followed by Saturday, Friday and Sunday, respectively. In regards to the functional class, urban interstate consistently showed greater variation in average daily traffic over the year compared to other urban functional classes. This could be related to the increase in tourism-related traffic that occurs during the summer season; tourists may disproportionately travel on interstates relative to local roads in traveling to their destinations. In a departure from previous observations on rural highways, not all categories produced factors below 1.0 during the summer months. In the case of urban minor/collector routes, a factor above 1.0 was observed in July and August. While the exact reason for this is unclear, the low number of sites (n = 5) in this group may have played a role. One possibility behind the trends of some of this group is reduced school traffic on these routes during summer. Once again, lower factors were produced for the months of April through September, highlighting the peak travel period in the state for seasonal commercial travel (i.e., agriculture), as well as tourism.

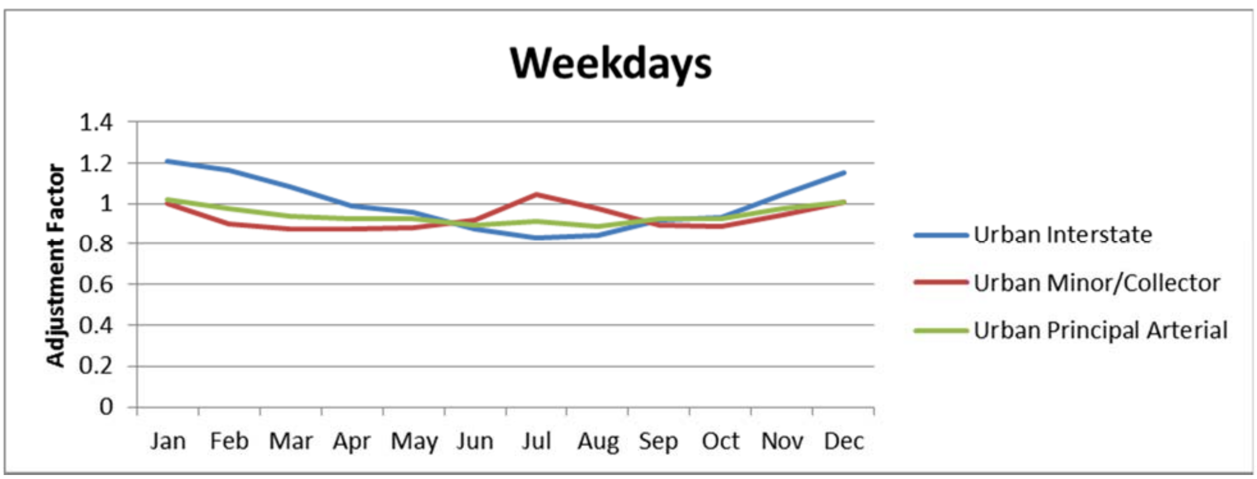


Figure 64: Urban Route Classification Count Station Adjustment Factors, Weekdays

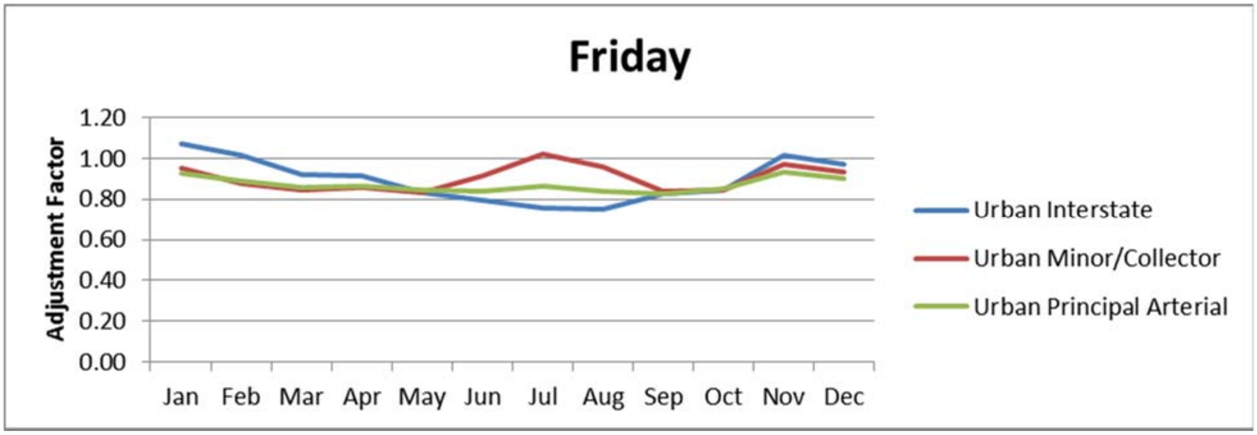


Figure 65: Urban Route Classification Count Station Adjustment Factors, Friday

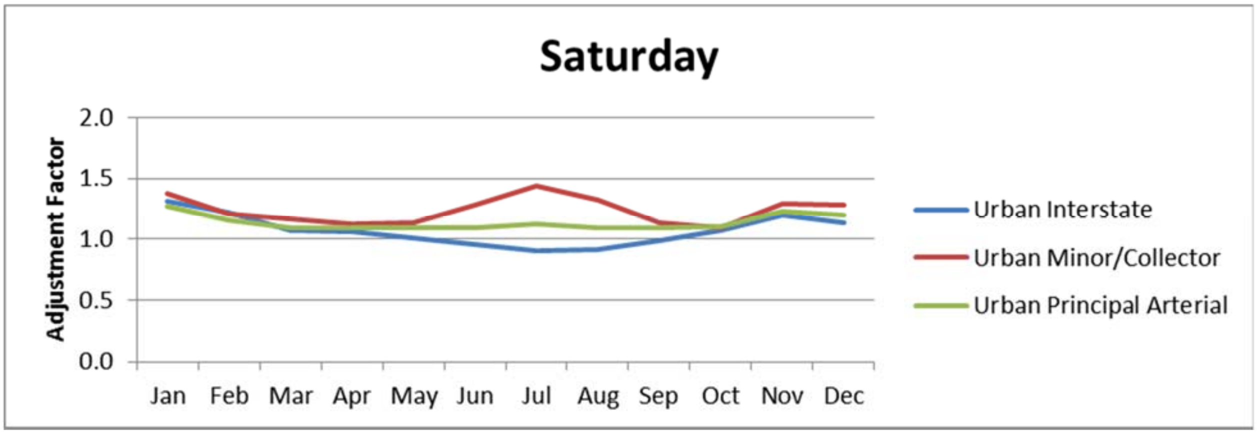


Figure 66: Urban Route Classification Count Station Adjustment Factors, Saturday

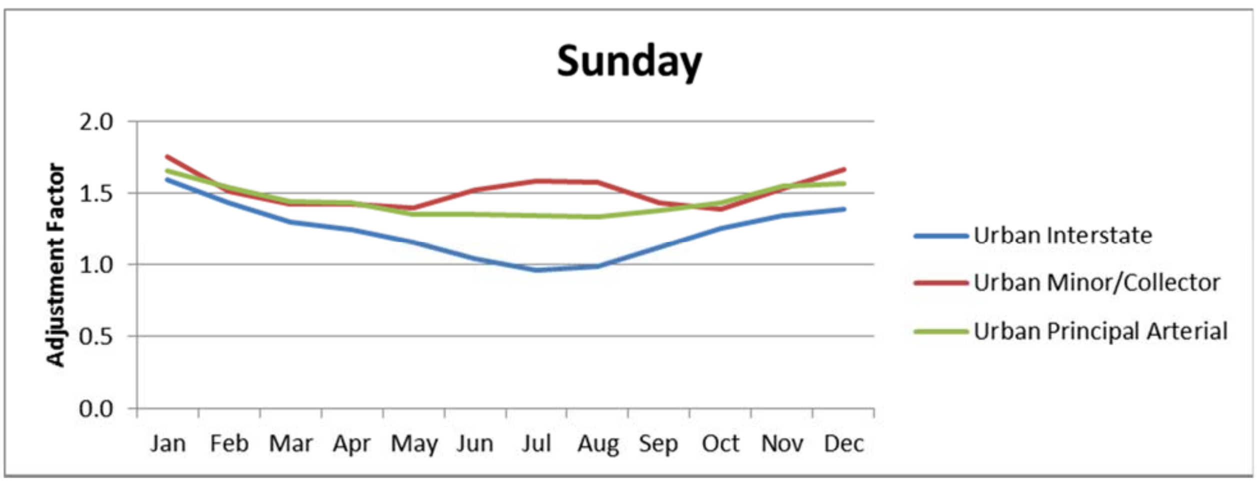


Figure 67: Urban Route Classification Count Station Adjustment Factors, Sunday

The simplified/condensed grouping scheme investigated herein consisted of combining all non-interstate classes into one group (still maintaining rural and urban distinctions). Based on observations made when evaluating rural and urban routes by functional class, it was evident that traffic patterns on interstates were different from those on non-interstates, particularly in the urban environment. In light of this, two categories were used in the final analysis: interstates compared to all remaining routes, further differentiated by urban and rural.

Adjustment factors for the traffic factor groups of rural interstate and all other rural roadways are presented in Figure 68, Figure 69, Figure 70 and Figure 71, for weekdays, Fridays, Saturdays and Sundays, respectively. Referring to these figures, traffic on rural interstates and all other rural routes is similar. Collectively, the adjustment factors for both types of routes underscored that in rural areas the greatest travel activity occurs in late spring through early fall, which can be attributed to tourism, agriculture and other seasonal activities. In regards to day of week, Fridays and Sundays showed nominally more variation in adjustment factors over the year, when compared to weekdays and Saturdays.

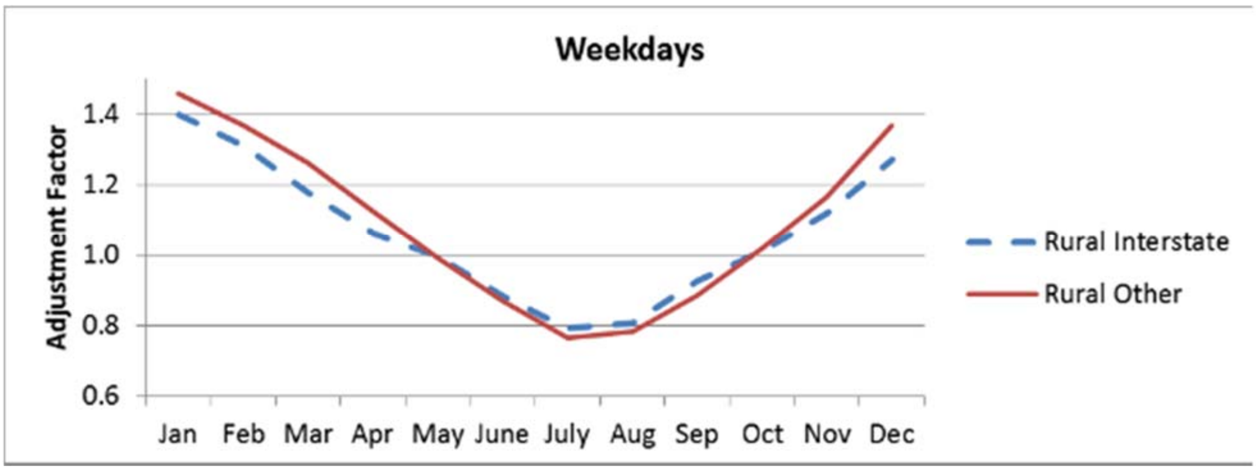


Figure 68: Rural Interstate and All Other Route Adjustment Factors, Weekdays

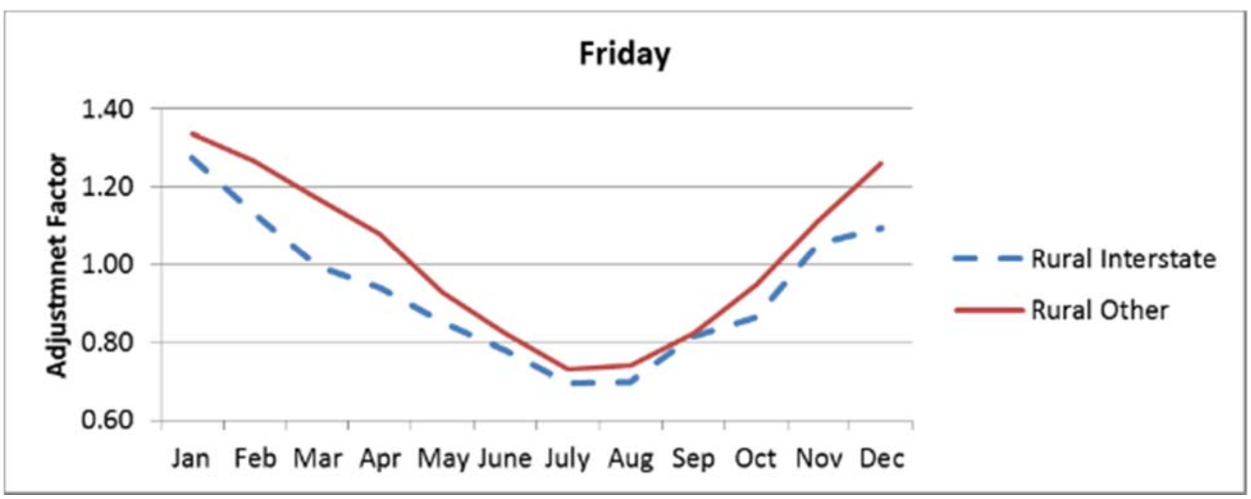


Figure 69: Rural Interstate and All Other Route Adjustment Factors, Friday

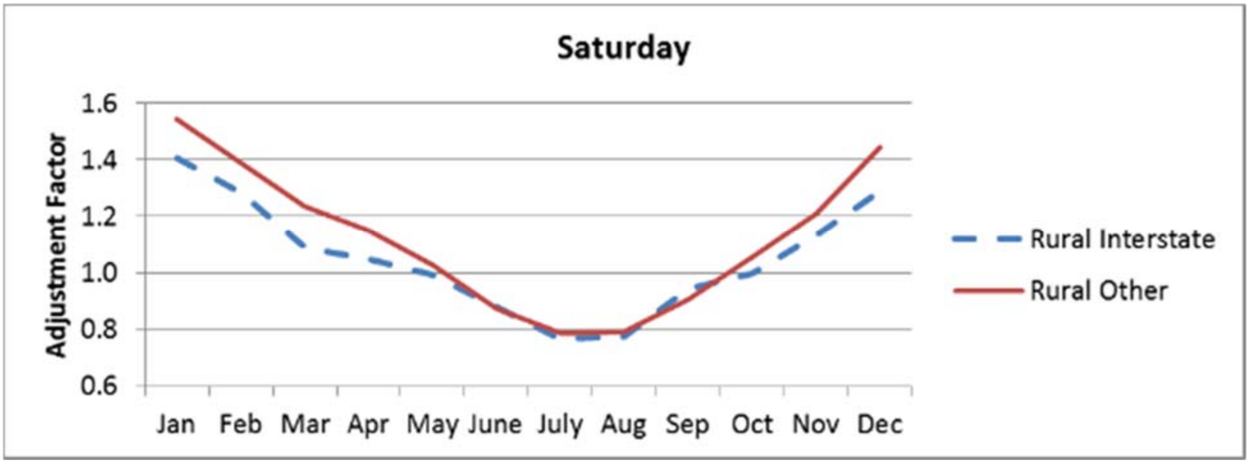


Figure 70: Rural Interstate and All Other Route Adjustment Factors, Saturday

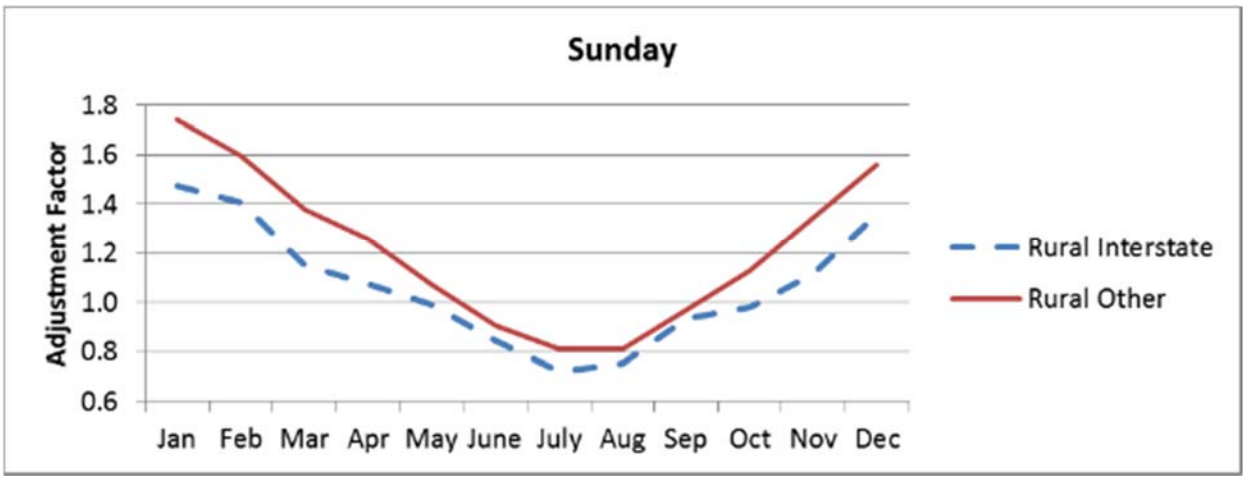


Figure 71: Rural Interstate and All Other Route Adjustment Factors, Sunday

Similar to rural routes, two categories were used for urban routes, interstates compared to all remaining routes. The adjustment factors determined for these two traffic factor groups are presented in Figure 72, Figure 73, Figure 74 and Figure 75, respectively, for weekdays, Fridays, Saturdays and Sundays. Referring to these figures, unlike the situation for rural routes, these two traffic factor groups have distinctly different traffic patterns over the year. Urban interstates show much higher variation in average daily traffic over the year compared with all other urban routes. The greater variation in the interstate category is somewhat expected given the significant increase in traffic (assumed not to be local) associated with tourism during the summer season. In regards to day of week, the two traffic factor groups showed only little variation between days, with Fridays and Sundays showing slightly more variation than weekdays and Saturdays.

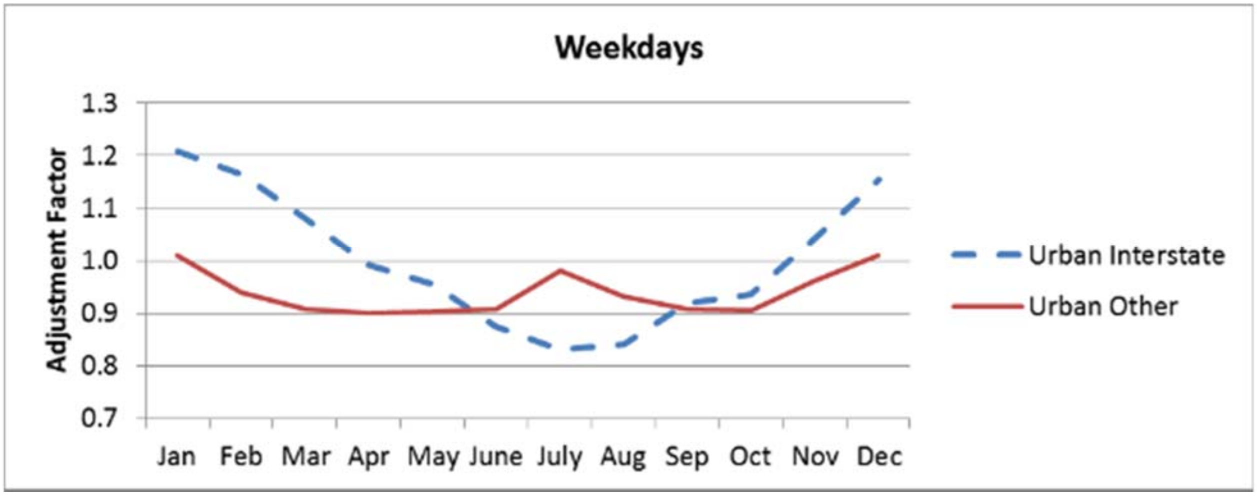


Figure 72: Urban Interstate and All Other Route Adjustment Factors, Weekdays

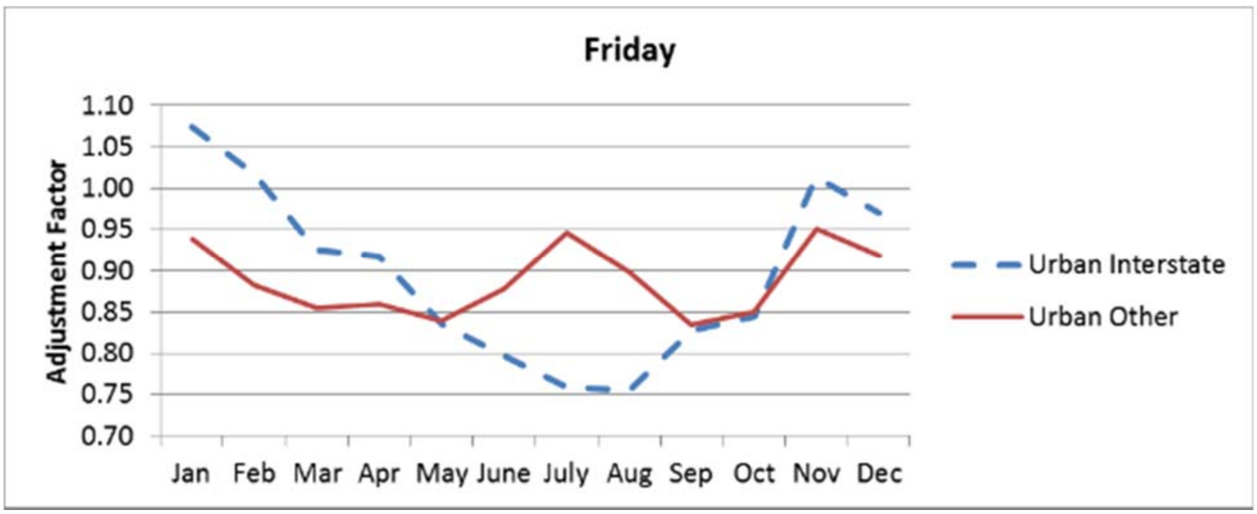


Figure 73: Urban Interstate and All Other Route Adjustment Factors, Friday

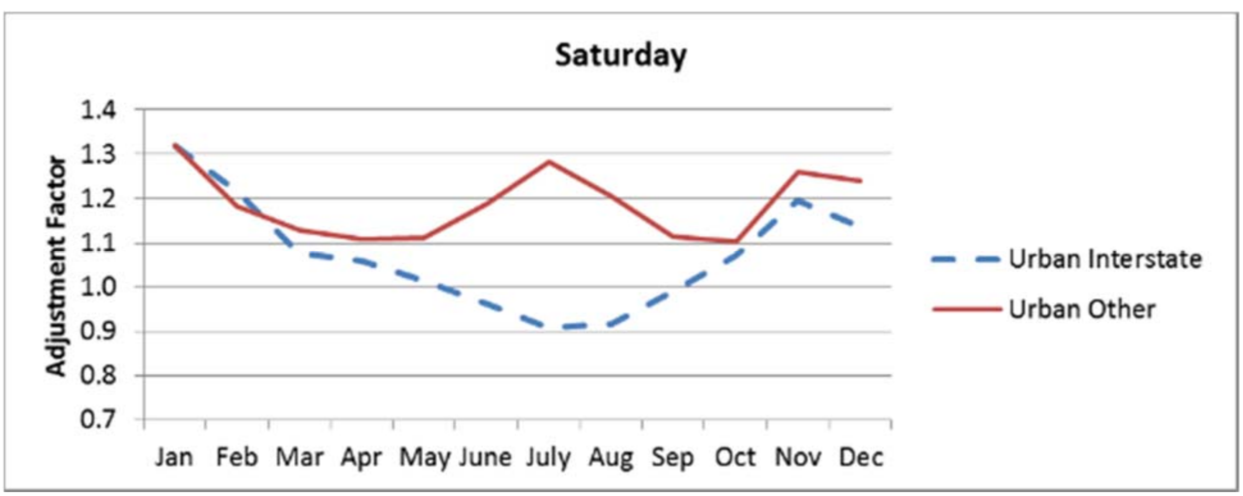


Figure 74: Urban Interstate and All Other Route Adjustment Factors, Saturday

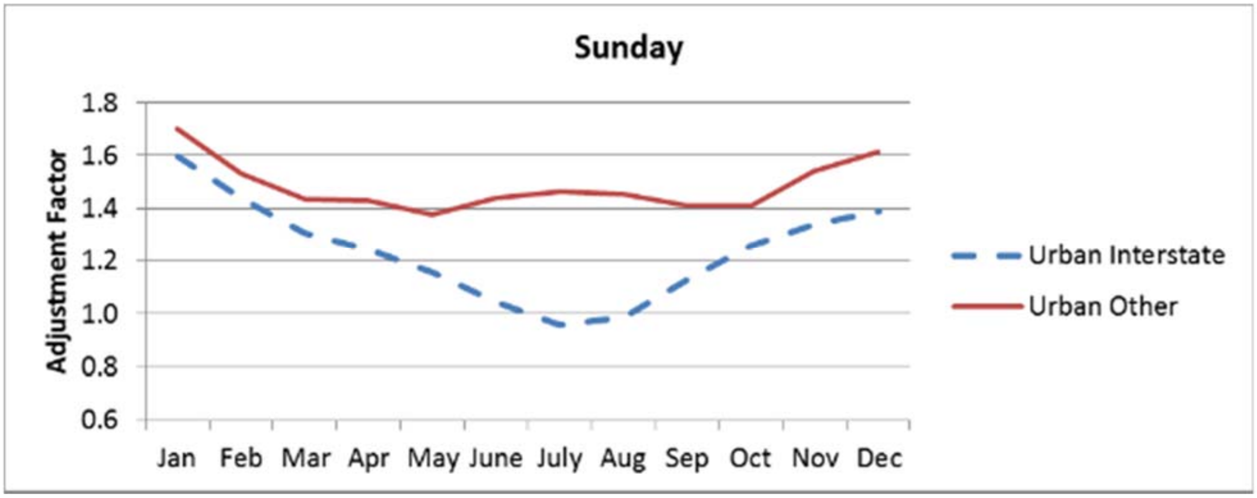


Figure 75: Urban Interstate and All Other Route Adjustment Factors, Sunday

The standard deviations of the adjustment factors for the modified grouping scheme which combined all routes into categories of non-interstates and interstates, urban and rural are presented in Table 46. Standard deviations for the expanded traffic factor groups currently used by MDT are presented in Table 47.

Table 46: Standard Deviations for Factors for Grouping by Modified Functional Classification

Rural Interstate												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.16	0.14	0.11	0.14	0.04	0.04	0.06	0.06	0.05	0.06	0.07	0.17
Friday	0.14	0.10	0.09	0.09	0.05	0.06	0.07	0.06	0.06	0.04	0.07	0.13
Saturday	0.10	0.09	0.05	0.10	0.08	0.12	0.13	0.11	0.09	0.06	0.09	0.14
Sunday	0.13	0.10	0.10	0.11	0.09	0.14	0.13	0.12	0.12	0.09	0.11	0.17
Rural Other												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.39	0.37	0.29	0.21	0.10	0.08	0.12	0.10	0.07	0.13	0.29	0.39
Friday	0.33	0.29	0.21	0.21	0.12	0.08	0.12	0.10	0.07	0.12	0.27	0.31
Saturday	0.37	0.32	0.23	0.23	0.23	0.14	0.20	0.17	0.15	0.16	0.27	0.32
Sunday	0.39	0.34	0.28	0.26	0.24	0.20	0.23	0.22	0.23	0.24	0.34	0.36
Urban Interstate												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.12	0.08	0.08	0.05	0.01	0.01	0.04	0.01	0.01	0.03	0.06	0.10
Friday	0.09	0.05	0.02	0.03	0.02	0.04	0.06	0.05	0.01	0.01	0.03	0.05
Saturday	0.02	0.09	0.04	0.02	0.07	0.09	0.14	0.12	0.06	0.04	0.06	0.07
Sunday	0.07	0.04	0.07	0.08	0.11	0.16	0.18	0.15	0.11	0.01	0.07	0.09
Urban Other												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.04	0.08	0.08	0.05	0.03	0.06	0.12	0.07	0.06	0.07	0.05	0.03
Friday	0.05	0.06	0.05	0.04	0.03	0.10	0.16	0.09	0.04	0.05	0.04	0.04
Saturday	0.15	0.10	0.10	0.08	0.09	0.26	0.36	0.20	0.07	0.10	0.09	0.15
Sunday	0.21	0.11	0.10	0.10	0.15	0.29	0.35	0.25	0.12	0.13	0.12	0.19

Table 47: Standard Deviations for Factors for Grouping by Current MDT Classification

Rural Interstate												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.16	0.14	0.11	0.14	0.04	0.04	0.06	0.06	0.05	0.06	0.07	0.17
Friday	0.14	0.10	0.09	0.09	0.05	0.06	0.07	0.06	0.06	0.04	0.07	0.13
Saturday	0.10	0.09	0.05	0.10	0.08	0.12	0.13	0.11	0.09	0.06	0.09	0.14
Sunday	0.13	0.10	0.10	0.11	0.09	0.14	0.13	0.12	0.12	0.09	0.11	0.17
Rural Major Arterial												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.35	0.31	0.30	0.23	0.08	0.10	0.12	0.11	0.07	0.13	0.30	0.35
Friday	0.34	0.33	0.31	0.24	0.08	0.11	0.12	0.11	0.07	0.12	0.30	0.38
Saturday	0.36	0.31	0.30	0.22	0.08	0.09	0.13	0.10	0.07	0.13	0.27	0.37
Sunday	0.34	0.29	0.26	0.22	0.08	0.08	0.12	0.10	0.06	0.12	0.31	0.31
Rural Minor Arterial												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.32	0.30	0.24	0.19	0.11	0.07	0.12	0.10	0.09	0.13	0.20	0.28
Friday	0.21	0.20	0.17	0.17	0.08	0.06	0.14	0.11	0.07	0.09	0.19	0.22
Saturday	0.41	0.36	0.25	0.22	0.13	0.12	0.24	0.19	0.16	0.12	0.22	0.30
Sunday	0.43	0.41	0.32	0.28	0.14	0.19	0.27	0.24	0.25	0.16	0.29	0.36
Rural Major Collector												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.61	0.62	0.38	0.17	0.17	0.08	0.10	0.08	0.06	0.16	0.38	0.63
Friday	0.52	0.47	0.23	0.11	0.20	0.10	0.14	0.12	0.07	0.11	0.30	0.48
Saturday	0.34	0.29	0.13	0.17	0.45	0.22	0.22	0.21	0.19	0.25	0.27	0.35
Sunday	0.47	0.37	0.25	0.18	0.46	0.27	0.26	0.25	0.24	0.33	0.29	0.41
Urban Interstate												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.12	0.08	0.08	0.05	0.01	0.01	0.04	0.01	0.01	0.03	0.06	0.10
Friday	0.09	0.05	0.02	0.03	0.02	0.04	0.06	0.05	0.01	0.01	0.03	0.05
Saturday	0.02	0.09	0.04	0.02	0.07	0.09	0.14	0.12	0.06	0.04	0.06	0.07
Sunday	0.07	0.04	0.07	0.08	0.11	0.16	0.18	0.15	0.11	0.01	0.07	0.09
Urban Principal Arterial												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.06	0.05	0.05	0.04	0.06	0.02	0.04	0.03	0.06	0.04	0.06	0.05
Friday	0.03	0.02	0.01	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Saturday	0.11	0.10	0.09	0.08	0.05	0.09	0.07	0.08	0.08	0.07	0.10	0.12
Sunday	0.11	0.10	0.09	0.09	0.12	0.11	0.12	0.12	0.11	0.11	0.09	0.13
Urban Minor Arterial												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.03	0.03	0.03	0.04	0.05	0.03	0.04	0.03	0.05	0.03	0.04	0.04
Friday	0.04	0.01	0.01	0.01	0.00	0.03	0.06	0.03	0.02	0.02	0.01	0.01
Saturday	0.07	0.07	0.06	0.07	0.07	0.05	0.03	0.03	0.06	0.09	0.09	0.05
Sunday	0.14	0.14	0.14	0.11	0.12	0.09	0.09	0.09	0.09	0.18	0.16	0.14
Urban Major Collector												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	0.05	0.11	0.10	0.06	0.07	0.10	0.13	0.06	0.14	0.16	0.10	0.05
Friday	0.09	0.07	0.04	0.01	0.02	0.18	0.19	0.08	0.09	0.08	0.03	0.06
Saturday	0.24	0.07	0.08	0.09	0.14	0.44	0.57	0.18	0.05	0.05	0.03	0.24
Sunday	0.28	0.03	0.06	0.02	0.12	0.43	0.51	0.11	0.07	0.03	0.10	0.19

Referring to Table 46 and Table 47, urban and rural interstates exhibited low within group variability, which would be expected given that these groupings are relatively homogeneous. Caution is stressed in assessing the results for the urban interstate group, however, as this group had a small sample size (three sites). Remaining rural categories, including major arterial, minor arterial and major collector, showed a good deal of variability, particularly outside of the summer months (see Table 47). This is similar in trend to what was observed for the rural "other" category in the modified grouping scheme (see Table 46), but the scale of the differences, which often exceeded 0.30, was greater for the current MDT factor categories. These results also underscore the differences among the different routes themselves, which each serve different functions and traffic flows (through goods movement, tourism, agricultural, etc.) during different times of the year. Referring to Table 46 and Table 47, it is evident that aggregation of non-interstate classes into one category did not increase within group variability. In fact, it may have helped reduce the variation due to the larger sample size (with more ATR and WIM stations) in the aggregated scheme.

The combined urban routes category exhibited less variability than the rural category with standard deviations above 0.2 only observed on weekends during the summer months (June to August) and during Sundays in January. The higher standard deviation values may be the result of changes in local travel patterns, such as increases or decreases in shopping-related trips on some routes specifically in retail areas. However, the standard deviations from the current MDT factors found in Table 47 were higher for weekends in June and July, exceeding 0.40. The urban "other" category in the modified approach yielded slightly lower standard deviation values for these same months.

Collectively, the results indicate that, for most groups, variability is low for all days of the week and throughout the year. However, a good deal of variability is present in the rural "other" route category for all days of the week and across most of the year (aside from the late spring through early fall period).

The primary conclusion that can be made regarding adjustment factors using the modified functional classification scheme is that rural and urban interstates generally have uniform traffic patterns at the data collection sites assigned to them. Additionally, traffic patterns are similar on rural interstates and all remaining rural routes combined. When comparing urban interstates to remaining urban routes combined, differences in traffic trends were noted both during the winter and early spring months, as well as during the summer. In the winter and early spring, urban "other" routes had notably lower average adjustment factors compared to urban interstates. These differences were also seen earlier when considering individual urban non-interstate classes, as shown in Figure 64, Figure 65, Figure 66 and Figure 67. It is important to note that the number of "urban" ATR and WIM stations is relatively small (total of 13 stations), which could be responsible for the variability among the non-interstate classes, i.e. some of the patterns may be largely influenced by individual stations at locations with local unique travel patterns.

In addition to examining the standard deviations for the modified functional classification scheme, F tests were also performed to determine whether the variance of the population of the traditional grouping schemes presently used by MDT was significantly different from that of the combined grouping scheme examined in this section. Three F tests were conducted to examine how the variances for the rural principal arterial, rural minor arterial and rural major collector categories compared to the variance of the combined rural category. This analysis was only conducted for the rural traffic categories due to the sparseness of data collection sites in in all urban categories.

As applied to this work, the F test is used to evaluate the null hypothesis, H_0, stating that the variance of population Group 1 is equal to that of population Group 2 ($\sigma_1^2 = \sigma_2^2$) versus the alternative hypothesis, H_1, stating that the variance of population Group 1 does not equal that of population Group 2 ($\sigma_1^2 \neq \sigma_2^2$) (Sheskin 2000). The F test is computed as shown in Equation 4:

$$F = \frac{s_L^2}{s_S^2} \tag{4}$$

where

s_L^2 = The larger of the two estimated population variances.

s_S^2 = The smaller of the two estimated population variances.

The first group evaluated using the F test was the rural principal arterial category. For this category, the critical value (99 percent confidence level) for the F distribution given sample sizes of N = 34 for the traditional and N = 57 for the combined categories was 2.02 (or 2.15 when the variance of the combined category was larger). As the results in Table 48 indicate, only one of the test results exceeded these values. That case was for the Friday factor in March. Collectively however, the results indicate that the null hypothesis cannot be rejected for most cases, and it can be concluded that the revised approach to computing adjustment factors for all rural routes (excluding interstates) produces a similar result to the approach where adjustment factors are developed for individual functional categories.

Table 48: F Test Statistics from Comparison of Rural Principal Arterial Category to Combined Rural Category

Rural Principal Arterial												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	1.30	1.46	1.00	1.16	2.05	1.21	1.00	1.09	1.14	1.13	1.04	1.08
Friday	1.16	1.24	**2.07**	1.34	1.05	1.06	1.46	1.54	1.07	1.71	1.26	1.42
Saturday	1.10	1.06	1.03	1.01	1.90	1.29	1.35	1.30	1.29	1.36	1.13	1.12
Sunday	1.30	1.23	1.56	1.79	1.12	1.29	1.00	1.11	1.29	1.38	1.53	1.43
Bold and shaded cells denote that the alternative hypothesis is accepted												

The next group evaluated was the rural minor arterial category. For this category, the critical value (99 percent confidence level) for the F distribution given sample sizes of N = 14 for the traditional and N = 57 for the combined categories was 2.49 (or 3.35 when the variance of the combined category was larger). As the results of Table 49 indicate, only two of the test results exceeded these values. These results were weekdays in May and June, the time of the year when travel trends begin to change in the state. Collectively however, the null hypothesis cannot be rejected in general, and it can again be concluded that the revised approach computing adjustment factors for all rural routes produces a similar result to the approach where adjustment factors are developed for individual functional categories.

Table 49: F Test Statistics from Comparison of Rural Minor Arterial Category to Combined Rural Category

Rural Minor Collector												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	1.33	1.13	1.07	1.61	**4.79**	**4.95**	2.51	3.05	2.69	1.46	1.86	1.57
Friday	2.26	2.08	1.47	1.40	1.70	1.31	1.30	1.15	1.03	1.50	1.91	2.29
Saturday	1.29	1.30	1.17	1.05	2.95	1.42	1.46	1.15	1.12	1.52	1.44	1.33
Sunday	1.29	1.50	1.30	1.28	2.98	1.18	1.30	1.12	1.20	1.71	1.20	1.23
Bold and shaded cells denote that the alternative hypothesis is accepted												

The final group evaluated was the rural major collector category. For this category, the critical value (99 percent confidence level) for the F distribution given sample sizes of N = 9 for the traditional and N = 57 for the combined categories was 2.85 (or 5.04 when the variance of the combined category was larger). Similar to the previous categories, only a limited number of the test results (six) presented in Table 50 exceeded these values. Notably, all days in May exceeded the critical value, as did weekdays and Fridays in February. Collectively however, all remaining days of the week and months of the year did not exceed the critical value. As a result, the null hypothesis cannot be rejected in general, and it can be concluded that the revised approach computing adjustment factors for all rural routes produces a similar result to the individual category approach.

Table 50: F Test Statistics from Comparison of Rural Major Collector Category to Combined Rural Category

Rural Major Collector												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Weekdays	2.66	**3.06**	1.78	1.60	**2.92**	1.26	1.20	1.56	3.56	1.52	1.86	2.38
Friday	2.81	**2.92**	1.35	3.12	**3.11**	1.46	1.37	1.35	1.19	1.07	1.34	2.17
Saturday	1.08	1.09	2.70	1.65	**4.27**	2.49	1.31	1.60	1.78	2.59	1.12	1.01
Sunday	1.67	1.27	1.17	1.79	**3.99**	1.97	1.38	1.37	1.26	2.04	1.21	1.13

Bold and shaded cells denote that the alternative hypothesis is accepted

In summary, the variance comparisons of adjustment factors for the three individual rural functional classifications and the combined category involved 144 hypothesis tests using the F statistic. In the majority of those tests (135 out of 144), no statistically significant difference was found between the variance of the individual class and that of the combined category at a 99% confidence level.

6.4. Summary

The previous analyses examined three different hypotheses concerning the grouping of ATR and WIM stations for the estimation of traffic adjustment factors on Montana's state highways. While the current traffic factor groupings are based primarily on the nature of a route's use, as categorized by highway functional classification, the prospective alternative approaches are based on a) vehicle type, i.e., commercial versus non-commercial and functional classification b) area of the state and its socio-economic characteristics, and functional classification, and c) a simplified functional classification scheme, i.e., interstate versus non-interstate with subcategories of rural and urban. Graphical analysis and quantitative statistics were used to show the temporal variation of adjustment factors and the variation of factors within a group for each scheme. Further, F-tests were used to test the difference in variance among groups for the simplified functional classification scheme. A summary of the findings are presented below:

1. Commercial vehicles showed different patterns in average daily traffic over the year compared with all vehicles, particularly during weekend days. Using separate adjustment factors for commercial traffic is believed to increase the accuracy of commercial vehicle estimation for use in those activities that are most concerned with freight transportation (e.g. pavement design, weight enforcement, etc.).
2. The second grouping scheme, i.e., by area /economic activity, while generating reasonably accurate adjustment factors, may be somewhat impractical to implement. Notably, the assignment of stations to a group is generally subjective in nature. In assigning existing or proposed stations to a group, the nature of trips at a given location may not be very clear to the user, and of course different types of trips may occur at any particular site. Consequently, as implemented herein, the "rural/other" category, which included all

stations that could not be classified in any of the other groups, was the group with the largest number of stations (approximately 30% of all stations included in the analysis).

3. The third grouping scheme, i.e. the simplified functional classification scheme, has merit in that it simplifies the estimation and use of adjustment factors while not compromising accuracy. This scheme may prove useful should it result in notable savings in time and resources.

Based on the findings above, it is reasonable to recommend a traffic factor grouping scheme which consists of two main groupings in urban and rural areas: interstate and non-interstate, for all vehicles as well as for commercial vehicles, while retaining the recreational grouping that is in use in the current MDT grouping scheme. Specifically, the proposed grouping scheme would consist of the following groups:

1. Interstate Rural - All vehicles,
2. Non-interstate Rural - All vehicles,
3. Interstate Urban - All vehicles,
4. Non-interstate Urban - All vehicles,
5. Interstate Rural - Commercial vehicles,
6. Non-interstate Rural - Commercial vehicles,
7. Interstate Urban - Commercial vehicles,
8. Non-interstate Urban - Commercial vehicles, and
9. Recreational - All vehicles.

The proposed scheme only nominally increases the number of traffic factor groups (from eight to nine), while providing greater sensitivity to commercial vehicle operation on the highway system and its unique patterns over the year by season and day of week.

7) METHODOLOGY FOR FUTURE PLANNING/PRIORITIZATION OF WIM/ATR SITES

Prioritizing the deployment of WIM and ATR systems is an important aspect of any traffic data collection program. Agencies are typically faced with limited resources and the need to select only a subset of the total number of proposed sites. Ideally, adequate resources would be available to deploy and maintain a large number of permanent data collection sites over an entire region to capture the wide variety of seasonal, economic and other traffic trends that are present. In reality, it is possible to only deploy and maintain a limited number of continuous, permanent traffic monitoring sites throughout a state. Thus, when numerous candidate locations have been identified for consideration, the merits of these sites must be comparatively evaluated. Parameters considered in this evaluation include whether acknowledged gaps in data collection needs will be filled and what capital costs are involved.

The approach presently employed by MDT in prioritizing/selecting WIM/ATR deployments uses a formal list of evaluation criteria which includes such items as traffic factor group data needs, physical pavement and roadway conditions at proposed sites, commercial vehicle weight enforcement data needs, etc. Based on this information, the proposed sites are ranked by MDT staff using their collective professional judgment. This prioritization approach has subjective elements in its execution, and thus it can be difficult to ensure that a) the various evaluation criteria have been consistently applied and b) the outcomes have been realized in a replicable framework.

In light of these potential limitations in their current process, MDT elected to explore more objective methodologies to prioritize selection of permanent traffic data collection sites. This chapter discusses the factors to consider in prioritization and the proposed prioritization/ranking scheme that has been developed in this effort.

7.1. WIM and ATR Site Selection

This section provides an overview of the most important needs and criteria that are commonly (or should be) considered in the WIM/ATR prioritization process. Following this overview, the site prioritization process currently used by MDT is described. Note that in reviewing available literature from across the country on traffic data collection programs, no existing methodologies were found for objectively/quantitatively considering the various factors that influence site selection as part of the decision-making process.

7.1.1. WIM and ATR Site Selection Criteria

Key in prioritizing and ranking proposed WIM and ATR sites is understanding what activities the collected data will be used to support. Various uses of traffic data cited by the TMG include pavement, bridge, and geometric design; pavement maintenance; design of traffic control systems; vehicle weight enforcement; vehicle speed enforcement; and local and network level planning activities. Essential to providing data for many of these tasks is the ability to estimate at any given location around the state annual traffic demands based on short term traffic counts conducted at that location. Short-term traffic counts are modified to reflect year around traffic demands using seasonal traffic adjustment factors developed from continuous traffic counts collected from permanent WIM/ATR sites. Thus, WIM/ATR sites need to be located to support accurate development of these factors. Further, and very pragmatically, additional siting considerations can include a) the degree to which specific roadway features at a proposed site are conducive to system installation and data collection, and b) if system installation can be synergistically done during a coincident construction activity planned at the intended site. These criteria are discussed in more detail below.

7.1.1.1. General Data Quality/System Coverage Considerations

As mentioned above, one of the most important uses of continuously collected WIM/ATR data is in the development of traffic adjustment factors. Following the traffic adjustment factor approach, the general pattern of traffic throughout the year is characterized using traffic data continuously collected from a finite number of permanent monitoring sites. The results of a short term traffic count (often performed in Montana for a minimum of 48 hours) can then be temporally matched against the annual pattern determined for routes carrying similar traffic - i.e., for a traffic factor group - to obtain an estimated AADT at the short term monitoring location. Further, estimates of the average daily traffic for other months and days of the year can be obtained for the short term site using daily and monthly adjustment factors available for the traffic factor group to which it is assigned.

Using the data continuously recorded by permanent WIM/ATR sites located on routes in each traffic factor group, adjustment factors are developed to be used with short term data counts conducted at any point on any route included within the group. The accuracy at which adjustment factors are determined for a given traffic factor group is a function of the inherent variability in the traffic patterns on the routes included in the group, and the number of sites at which these traffic patterns are monitored. Statistical procedures are presented in the TMG to determine the number of data collection sites necessary within a given factor group to obtain the desired level of precision for the attendant adjustment factors. The TMG recommends factors be determined with 10 percent precision with 95 percent confidence for each individual group, excluding recreational groups (these groups tend to be subjective in their composition, and no recommended precision is specified). While these calculations can be reasonably performed, the TMG indicates that when these reliability levels are applied, usually five to eight continuous monitoring sites are required per factor group. The TMG goes on to comment that for most factor groups, at least six continuous counters should be included within each factor group, with due consideration of a few additional sites in the event of counter malfunction.

Note that the TMG also comments specifically on having an adequate number of WIM systems appropriately distributed across the state to characterize the weight related demands being placed on the highway infrastructure. Similar to traffic factor groups, weight groups are established to represent distinctive weight related characteristics of the vehicles using various elements of the highway system. A major use of weight related information is in pavement design, where a measure of the structural demand a vehicle places on the highway often is expressed in terms of ESALs For project level work, MDT generates average ESAL factors by vehicle classification and weight, by group – using the same groups as is done for traffic data. For network level work, this information generally is aggregated for the route classifications of interstate, and principal and minor arterials (three weight groups). The TMG indicates that there should be at least two WIM sites per weight group, with a typical target of six WIM sites per weight group.

The number of WIM and ATR sites collecting data for each traffic factor group is reported in Table 51. Referring to this table, the traffic factor groups with the most data collection sites are Interstate – Rural, Principal Arterial - Rural, Minor Arterial – Rural, and Recreational, with at least twelve collection sites per group. The groups with fewer data collection sites (ten sites or less) are Interstate - Urban, Principal Arterial - Urban, Major Collector - Rural, and Minor/Collector – Urban. Relative to supporting vehicle weight related analyses, the groups with the greatest number of WIM sites are Interstate – Rural and Principal Arterial – Rural, respectively. All other groups have six or fewer WIM systems deployed on them.

Table 51: Distribution of WIM and ATR Systems by Traffic Factor Groups.

Traffic Factor Groups	WIM	ATR	Combined
Interstate – Rural	13	5	18
Interstate – Urban	3	3	6
Principal Arterial - Rural	17	11	28
Principal Arterial - Urban	0*	9	9
Minor Arterial - Rural	6	10	16
Major Collector - Rural	1	9	10
Minor/Collector - Urban	0*	7	7
Recreational	2	10	12
TOTAL	42	64	106

*largely due to difficulties in collecting reliable weight data in urban environments using available technologies

As may be obvious, in assessing the adequacy of WIM/ATR coverage by traffic factor group, important factors may be overlooked if only the number of data collection sites per traffic factor group is considered. Absent the performance of detailed statistical analyses as described in the TMG, other relatively simple metrics that could be of interest in such an assessment include geographic extent and volume of traffic carried on each traffic factor group. As might be expected, current deployments of permanent WIM and ATR sites reflect both of these parameters, with traffic factor groups that consist of more miles of roadway and that carry greater volumes of traffic correspondingly having more data collection sites (both WIM and ATR sites).

Considering, for example, geographic extent, one possible metric reflecting this parameter is data collection site density, simply calculated as centerline miles of roadway divided by number of data collection sites by traffic factor group. This metric is reported in Table 52 by traffic factor group (mileage provided by MDT).

Table 52: Density of WIM and ATR Sites (miles of highway/site) by Traffic Factor Group.

Traffic Factor Group	Centerline Mileage	Density (miles/site)		
		WIM	ATR	Combined
Interstate – Rural	1,064	82	213	59
Interstate – Urban	130	43	43	22
Principal Arterial - Rural	2,364	139	215	84
Principal Arterial - Urban	410	-	46	46
Minor Arterial - Rural	2,552	425	255	160
Major Collector - Rural	9,709	9709	1,079	971
Minor/Collector - Urban	1,290	-	184	184
Recreational	771	385	77	64

- indicates no permanent, continuous data collection is done on this traffic factor group

Referring to Table 51 and Table 52, while the greatest number of combined data collection sites (WIM and ATR) is for the Principal Arterial – Rural group (numbering 28), and the fewest number of combined data collection sites is for the Interstate – Urban group (numbering just 6), the Interstate – Urban group (22 miles/site) is more densely represented compared to the Principal Arterial - Rural group (84 miles per site), considered from a miles/data collection site perspective. WIM and ATR density help to quantify coverage, but are not reliable indicators alone as certain traffic factor groups have different traffic characteristics that may warrant higher traffic collection densities than other groups (e.g. urban interstates may require higher density per centerline mile than rural interstates as there is greater variability in traffic characteristics in different urban locations around the state compared to traffic patterns on rural interstates that may have largely similar characteristics across the state). The mileage that must be accounted for by each data collection site increases as functional classification decreases, as might be expected.

Often the lower functional classifications carry less traffic (as discussed further below), and they correspondingly have fewer data collection sites deployed on them. Coverage is especially sparse on lesser functional groups like Major Collector - Rural, with only 7 ATR systems for 9,709 miles of road. It should be noted that MDT only maintains about one third of the total 9,709 miles of Major Collector - Rural roads and usually WIM and ATR placement considerations are limited to state maintained routes. Pavement type is another overall consideration to note, as the Major Collector - Rural group has a considerable portion of unpaved roads (~54%) included in its reported mileage, and WIM and ATR systems are not used on unpaved roads. Once again, traffic on these lesser functional groups is lighter than for most other groups.

While the metric discussed above – average miles of highway per continuous data collection site - provides a measure of the physical dispersion of WIM and ATR sites, it does not offer insight on their distribution by volume of traffic being monitored. Thus, a second metric of interest is the average VMT covered by WIM and ATR sites by traffic factor group, which is reported in Table 53. The data employed to calculate this metric came from MDT and are the estimated annual VMT in 2015.

Table 53: Density of WIM and ATR Sites (VMT/site) by Traffic Factor Group.

Traffic Factor Group	VMT (millions)	Density (millions of VMT/site)		
		WIM	ATR	Combined
Interstate - Rural	2,346	180	469	130
Interstate - Urban	718	239	239	120
Principal Arterial - Rural	1,830	108	166	65
Principal Arterial - Urban	1,658	-	184	184
Minor Arterial - Rural	889	148	89	56
Major Collector - Rural	1,069	1,069	119	107
Minor/Collector - Urban	1,391	-	199	199
Recreational	371	186	37	31

- indicates no permanent, continuous data collection is done on this group of highways

Referring to Table 53, as might be expected, there is less variation in average VMT per data site by group than average highway mileage per data site (reported in Table 52). Relative to combined data collection sites (WIM and ATR), the highest VMT per data site (199 million VMT per site) is for Minor/Collector – Urban. The lowest VMT per data site (31 million VMT per site) is for Recreational.

In considering specifically WIM data collection to support vehicle weight related tasks (e.g., pavement design), average commercial vehicle VMT per WIM site might be a metric of greater interest than total VMT. Notably, passenger cars and light trucks, while constituting the majority of vehicles operating on the highway, only nominally contribute to load related design demands on a pavement structure. Load related design demands are almost solely due to commercial vehicle operations. Table 54 reports the coverage of WIM sites considering only commercial VMT. Again, 2015 MDT provided data was used in calculating the reported values.

Table 54: Density of WIM Sites (commercial VMT/site) by Traffic Factor Group.

Traffic Factor Group	Commercial VMT (millions)	WIM Density (millions of commercial VMT/site)
Interstate – Rural	557	43
Interstate – Urban	92	31
Principal Arterial - Rural	245	14
Principal Arterial - Urban	64	-
Minor Arterial - Rural	94	16
Major Collector - Rural	48	48
Minor/Collector - Urban	25	-
Recreational	36	18

- indicates no permanent, continuous data collection is done on this group of highways due to technological issues in collecting WIM data in urban environments

Commercial VMT coverage by WIM sites are fairly consistent across the groups ranging from 14 million commercial VMT on Principal Arterial - Rural to 48 million commercial VMT on Major Collector - Rural.

Finally, relative to ensuring that traffic data collection efforts are providing adequate group coverage, other factors that should be considered include geographic region and local economic activity. In a geographic context, it is possible that while the total number of data collection sites deployed on a particular traffic factor group statewide appears adequate (i.e., relative to number of sites, and roadway mileage and VMT per site), some regions of the state may have only a few or no WIM/ATR sites. If this is the case, some regions of the state are underrepresented in the overall network of WIM/ATR sites. Notably, if economic conditions change significantly in a particular region (e.g. rapid increase in oil exploration and production), additional data collection sites may be merited in that region.

7.1.1.2. Data Collection to Support Specific Activities

Several MDT activities very directly use traffic data in their execution, including pavement design, speed and weight limit enforcement, border security, etc. As introduced immediately above, one important use of WIM/ATR data is in pavement design. This is particularly true of WIM data, due to the significant impact of heavier vehicles on pavement deterioration. As would be expected, significant resources are required to repair and replace pavements, and WIM/ATR sites provide an effective system for monitoring commercial vehicle traffic and weights. This information is then employed when designing pavements for anticipated traffic volumes and vehicle weights on new and reconstruction projects.

Speed data from WIM/ATR sites can also be used in reviewing and setting speed limits on different roads, as well as serving as an input in the design process for horizontal curves and other geometric features.

In addition to these uses, WIM/ATR data are used by specific agencies in various parts of their operations. Such data is used by Homeland Security to monitor some aspects of trucking activity across the U.S.-Canadian border. Motor Carrier Services uses WIM/ATR data to monitor truck activity throughout the state in order to better identify locations where weight enforcement should be done. Finally, other entities, such as the Montana Highway Patrol also use count and speed data from WIM/ATR sites to identify locations and corridors for increased or targeted enforcement.

Collectively, the uses of data in these activities should receive consideration when evaluating and ranking different potential sites.

7.1.1.3. Opportunistic and Situational Factors

Aside from the uses and users of data collected by WIM/ATR sites, other factors can play a role in identifying and selecting new sites to be deployed. Such factors are related to unique opportunities or specific conditions that favor (or disfavor) WIM/ATR installation at a particular location. Regardless of how these factors are categorized, they are aspects unique to a particular site that should be taken into account during the prioritization process. The following paragraphs discuss such factors in more detail.

One opportunistic factor that can exist is scheduled construction in the near future on a route or in an area for which improved data collection is desired. Such sites present an opportunity to deploy WIM/ATR systems coincident with other planned work (e.g., a widening or reconstruction project), which can minimize disruption of traffic and reduce some costs (e.g., construction mobilization, traffic control, and any paving costs). Consequently, an acceptable but less than ideal site may increase in priority for WIM/ATR deployment, depending on scheduled construction projects in the near future in the target area.

Situational factors that could impact WIM/ATR deployment generally are associated with existing site conditions pertinent to WIM/ATR performance. Somewhat more critical for WIM systems, pavement at deployment sites should be in good condition (smooth and free of distress) and strong enough to support the sensors, and the road alignment should be straight and flat. Traffic at proposed sites should be free flowing at a reasonable speed with minimal passing activity.

Additionally, WIM/ATR sites require power and communications infrastructure to run equipment and transmit data to centralized databases. In light of this, power and communications both represent situational factors that must be considered in evaluating prospective sites. In less populated areas of the state, providing power and communications at a remote location could represent a significant cost.

7.1.2. MDT WIM/ATR Site Selection Process

MDT's current approach to prioritizing WIM/ATR deployments considers all of the factors introduced above, although it is relatively subjective in nature. Potential sites are discussed and numerically ranked based on professional judgment at a meeting each year of TDCA Section staff and traffic data users. Using a checklist approach, each proposed site is evaluated based on whether they support:

- traffic factoring,
- collection of vehicle weight data,
- data requirements for pavement design,
- vehicle speed related data uses,
- data needs of Motor Carrier Services, and
- data needs of Home Land Security.

When any of these items will be supported by a proposed site, it is checked off in MDT's "WIM and ATR Installation/Prioritization Plan" spreadsheet, which is also used to track general comments about each site (MDT 2015). New sites must also support the core needs of the Traffic Program in order to be added to the installation priority list. Comments are made about physical conditions at particular sites that are conducive or counter to system installation (e.g., pavement too thin), as well as about particular reasons for site installation (e.g., need to monitor oil field impacts). Based on this information and its discussion, a numerical ranking is assigned by consensus to each site to reflect its priority independently as a WIM or ATR site; with a further ranking of the two types of systems combined. These rankings and their justifications are recorded in the spreadsheet.

While this approach produces a prioritized list of WIM/ATR deployments, it is subjective in nature, and does not necessarily follow a replicable framework that consistently considers each factor using the same degree of relative importance in a manner that can be repeated from site to site and facilitate objective comparisons and rankings among them. There is a need for a more quantitative and objective prioritization process. From a quantitative perspective, such a process could use a set of weights to establish and consistently apply the relative importance of each criterion in the decision-making process. From an objective perspective, the approach would employ, as possible, a standardized method to establish the value of a particular feature or capability of a site. The use of a standardized framework will result in a prioritization process that reduces the subjectivity of the current approach and allows for a better comparison between sites.

7.2. Proposed Prioritization/Ranking Scheme

In light of the different factors discussed in the previous section of this report, a prioritization/ranking scheme that facilitates a systematic evaluation of potential WIM/ATR sites was developed. The simplest form of multi-criteria decision analysis (MCDA) is a weighted sum model (WSM), in which each identified criterion is assigned a weight (reflective of its importance), and alternatives are evaluated by summing the product of how well an alternative meets the criteria and its weight. As identified above, the major criteria recommended for use in this case and the associated sub-parameters are:

1. Improves the quality/comprehensiveness of the traffic data collected by increasing:
    a. the number of data collection sites within a traffic factor group,
    b. the geographic distribution of sites within a traffic factor group,
    c. the VMT coverage (both for all vehicles and more specifically for commercial vehicles) within a traffic factor group,
    d. the coverage of recognized route/region of increased vehicle activity, and
    e. the coverage of the most important traffic factor group routes.
2. Supports the direct use of traffic data in the activities of:
    a. commercial vehicle weight limit and safety enforcement,
    b. pavement design,
    c. safety analyses using speed data, and
    d. Homeland Security.
3. Offers opportunistic/situational advantages factors specific to the proposed site such as:
    a. the site is already scheduled for other construction activity,
    b. has geometric and pavement conditions conducive to collecting good data, and
    c. has power and communications available.

Considerations in formulating a WSM include that the criteria used are comprehensive and independent, which were taken into account in selecting and using the criteria listed above. A WSM illustrating the use of these criteria with user assigned weighting factors and assessments of the degree to which each criterion is met by a potential site is presented in Table 55. All values used in the table are arbitrary, with the intent of illustrating execution of the prioritization methodology. While the weights used may accurately reflect agency priorities and objectives, they should be reviewed and adjusted as necessary by TDCA staff working together with other traffic data users. As structured in Table 55, the same WSM can be applied to both potential WIM and

Table 55: Proposed WIM/ATR Site Prioritization Scheme

Site Information					Summary of Scores				Prioritization Criteria and Weights																
									Quality/comprehensiveness of data						Support of specific user activities					Opportunistic/situational factors				Other extenuating circumstance	
Name	Dept Route	Dept RP	Traf. Fact. Group	WIM or ATR	WIM and ATR sites (w/ wgt ben)	WIM and ATR sites (w/o wgt ben)	WIM sites only (w/ wgt ben)	ATR sites only (w/o wgt ben)	general coverage within groups	geographic coverage within groups	volumetric coverage within groups	route with increased activity	group imp.	sub total	weight enforce	pave design	speed related safety and other activities	HS[a]	sub total	scheduled for other construct activities	alignment, pavement conditions, etc.	power and comm	sub total	score	explanation
									10	10	10	10	5	45	20	10	5	5	40	5	5	5	15	-	-
Sweetgrass	I-15	392	RI	WIM	86	85	86		0	54	53	50	100	21	50	100	100	100	30	100	100	100	15	20	replacement of exisitng site
Manhattan	I-90	287	RI	WIM	66	67	66		0	54	53	0	100	16	0	100	100	50	18	0	-50	100	3	30	analyze long term travel impacts
Judith Gap	N-63	20	RPA	WIM	55	36	55		0	82	10	50	75	18	100	100	50	50	35	0	-50	100	3		
Eureka	N-5	184	RPA	WIM	48	26	48		0	82	10	50	75	18	100	100	50	50	35	0	-100	0	-5		
E Culbertson	N-1	648	RPA	WIM	65	51	65		0	82	10	100	75	23	100	100	50	100	38	100	0	0	5		
S of Bridger	N-4	10	RPA	WIM	55	36	55		0	82	10	100	75	23	100	100	50	50	35	0	-50	0	-3		
Scobey	P-32	65	RMA	WIM	19	27	19		0	100	4	50	25	17	0	0	0	100	5	0	-50	0	-3		
Miles City	P-18	14	RMA	WIM	52	45	52		0	100	4	100	25	22	50	100	0	0	20	0	100	100	10		
Turner	S-241	43	RMC	WIM	33	39	33		38	100	38	50	0	23	0	50	0	100	10	0	0	0	0		
Stanford	N-57	35	RPA	ATR	35	44		44	0	82	10	100	75	23	0	50	50	50	10	0	50	0	3		
Forsyth	P-14	265	RMA	ATR	32	38		38	0	100	4	50	25	17	0	50	50	50	10	0	100	0	5		
N. of Terry	S-253	25	RMC	ATR	30	36		36	38	100	38	50	0	23	0	50	0	50	7.5	0	0	0	0		
Checkerboard	P-14	73	RMA	ATR	42	52		52	0	100	4	100	25	22	0	50	50	50	10	100	100	0	10		
Maxville	P-19	55	RMA	ATR	33	40		40	0	100	4	0	25	12	0	50	50	25	8.8	100	100	50	13		

-shaded cells are user entries -unshaded cells are WSM results -darkest shaded cells are weighting factors [a] Homeland Security

ATR sites. WIM versus ATR priority is embedded in the evaluation process through the vehicle weight related criteria of pavement design and weight enforcement. Separate but generally similar models could also be set up for independent prioritization of WIM and ATR sites, as is commented on further below.

In evaluating each individual site, participants in this process assign scores representing the degree to which a particular site meets various criteria and situational factors. The following paragraphs discuss the overall approach to assigning relative weights to the various criteria and subsequently assessing the degree to which proposed sites meet these criteria.

Note that final decisions on WIM/ATR deployment are not expected to be made simply based on the output from a WSM. Rather, results of the WSM are expected to a) promote more thorough and consistent discussion of various key factors that affect such decisions, and b) provide a relatively objective and quantitative input to be considered in what otherwise could be a subjective decision making process.

7.2.1. Criterion Weights

The first step in the proposed prioritization process is the assignment of relative weights to the identified criteria. In the specific structure suggested herein, the relative weights should sum to 100, as shown in Table 55. The values of these weights are very important, as they represent a binding assessment of the relative importance of the various factors and motivations that affect site prioritization. These relative weights have to be agreed upon among the individuals/agencies included in the evaluation process. Participants in this process include the TDCA Section staff and stakeholder groups that employ WIM/ATR data for pavement design, weight enforcement, planning, etc.

The weights suggested by each group are likely to differ based on the competing priorities of the entities they represent. If achieving consensus on values for the relative weights is difficult, average relative weights could be calculated for each criterion across the values suggested by the various stakeholder groups. These average values represent the collective opinion of these groups, assuming that input from each group carries the same weight. The average relative weights could then be further discussed as necessary. Values of the relative weights should be revisited in each ranking round or as often as deemed necessary to reflect changing needs and priorities of MDT and its constituents.

Reviewing the weights as they are assigned in Table 55, for example, shows that improving the quality/comprehensiveness of the data being collected is more important (collective weight of 45) relative to deploying a WIM or ATR system to take advantage of situational factors at a specific location (weight of 15). Viewed from a slightly different perspective, if two potential sites equally support improvements in the quality/comprehensiveness of the data being collected, the site that also has situational advantages will realize an increased score consistent with the advantage it offers (for the indicated example weights, the score could increase by a maximum of 15 points out of a possible total score of 100 points).

7.2.2. Assessment of Degree Criteria are Met

Another critical step in the ranking scheme is to assess for each proposed site the degree to which the site satisfies each criterion. This assessment is made on a scale of 0 to 100, with zero corresponding to a criterion unsupported by a given site and 100 corresponding to a criterion fully supported by a given site. Participants in this process are expected to only offer input on those criteria on which they have some knowledge and expertise. Motor Carrier Services, for example, may primarily and potentially only offer input on the degree to which proposed sites are important in their weight enforcement efforts. The TDCA Section may primarily determine the degree to which various sites would be expected to improve overall data quality and level of system coverage. Certainly, it is anticipated that the various participants in the process could generate different assessments of the degree to which a particular criterion is met by a given site, reflecting their individual professional experience and perspective. In such situations, the WSM could be executed with these different assessments and the results compared, and/or the assessments could be discussed and consensus reached on a value to be input for that criterion prior to executing the WSM. One such value might be the average score calculated from the individual stakeholder assessments.

For many of the criteria, and at the discretion of the participants in the process, numerical “scales” and/or guidelines could be developed to promote consistency in applying the criteria across potential sites, as described below for each category of criteria.

1. Improves the quality/comprehensiveness of the traffic data collected

Increase in number of data collection sites within a traffic factor group

The most comprehensive technique to assess the need and impact of increasing the number of data collection sites for a traffic factor group is to use the statistical analysis procedure presented in the TMG for this purpose, coupled with a target reliability level. That being said, and as previously mentioned, at recommended data reliability levels (10 percent precision with 95 percent confidence), a minimum of six data collection sites (WIM plus ATR combined) typically are needed in a traffic factor group, with due allowance for sites that are temporarily offline. Thus, pursing a simpler but less precise approach, a scale could be used, for example, that assigned values of 0 to 100 for this criterion as follows:

No data collection sites for group 100
Sixteen or more data collection sites (counting WIM plus ATR for group) 0
For other cases, linearly interpolate between these two values

This scale was simply established so that a "neutral" score of 50 would be assigned to a proposed site for a traffic factor grouping with eight monitoring sites, which corresponds to the TMG "rule-of-thumb" that approximately six sites are required to realize an acceptable level of reliability, with contingencies (in this case, two additional sites) for sites being offline for maintenance and repair. To put this scale in perspective, the current disposition of data collection sites by traffic factor group was presented in Table 51, with values ranging from 6 to 28 sites (combined WIM plus ATR sites) across the various traffic factor groups, and an average of approximately 13 sites per group.

Improvement in centerline miles per data collection site by group

In general, a strategic objective of traffic data collection programs typically is to increase data collection on elements of the system that have geographically sparse coverage. In certain situations, especially more rural settings, relatively sparse geographic coverage may be sufficient if the sparsely covered roads all operate in a similar fashion. The previously introduced parameter of centerline miles of highway per data collection site calculated by traffic factor group (reported earlier in Table 52) reflects the degree of current coverage in this regard (albeit assuming the sites are at least to some degree dispersed rather than clustered on the routes comprising the group). A scale for this metric could be, for example:

Average centerline mileage per site for group of greater than 100 mi
(or, no data collection sites are presently on the group) 100
Average centerline mileage per site for group of less than 10 mi 0
For other cases, linearly interpolate between these values

In general, large values of average centerline miles per data collection site can imply that sites are too widely spaced to capture variations in traffic characteristics on different highway segments. To a large extent, the specific scale suggested above was derived based on a subjective assessment of the general nature of traffic operations on the state highway network. Traffic can be relatively constant on highway segments between one or more major intersections with major changes in traffic spaced anywhere from a few miles to 100 miles apart. This scale results in a score of approximately 50 for a proposed site on a group with an average mileage per site of 50 miles. To provide further perspective on this scale, average current centerline mileage per site ranges from 22 to 971 miles across the various traffic factor groups (see Table 52), with an average value of 199 miles.

Improvement in VMT per data collection site by group

Another strategic objective of the traffic data collection program generally is to increase data collection on elements of the system that currently have relatively sparse data representation based on volume of traffic carried. The previously introduced parameter of VMT per data collection site, calculated by traffic factor group, reflects the degree of this coverage (reported above in Table 53). Based on a qualitative review of current values for this metric, the following type of scale with scores ranging from 0 to 100 could be used:

Average VMT per site (WIM plus ATR sites) for group greater than 200 million (or, no sites presently on the group)	100
Average VMT per site is less than 50 million	0
For other cases, linearly interpolate between these values	

This scale was simply derived based on current practice, by approximately bracketing the existing range of VMT per site across the various traffic factor groups (see Table 53).

Provide better coverage of a route/region of increased vehicle activity

Professional judgment will have to be used in assessing the degree to which a proposed site meets the criterion of supporting data collection along a route or in a region of expected (or realized) increased vehicle activity. One possible approach for assessing the degree to which this priority will be met by a proposed site would be to assign a score relative to an extreme scenario generally familiar to the transportation community. Energy development in the Bakken, for example, is expected to have a significant impact on highway transportation in that region. It is difficult to foresee other events that would have more impact on traffic than the situation in the Bakken. Thus, proposed sites in the area impacted by the Bakken would be assigned a value of 100 for this criterion, with this criterion being scaled accordingly (using professional judgment) in other areas experiencing some form of distinct socio/economic event that has traffic impacts. This factor conceivably could be negative, if for whatever reason vehicle activity in a region is expected to decrease into the foreseeable future.

Provide better coverage of routes in traffic factor groups that are of higher importance

In general, coverage of Interstates and principal arterials is more important than coverage for lesser traffic factor groups. All other metrics in this first category being equal (sites in group, geographic coverage in group, volumetric coverage in group, and increased vehicle activity), higher functional groups like Interstates and principal arterials should be ranked higher for prioritization. A scale for this metric could be, for example:

Traffic Factor Group:

Interstates	100
Principal Arterials	75
Minor Arterials	25
Collectors	0
Recreational	professional judgement (consider highway functional class)

Different recreational routes may have considerably different highway functions, therefor professional judgement should be used to score these routes. Since traffic factor groups and highway functional classifications are largely similar, it may be appropriate to consider the recreational route's functional class in relation to the relative scoring values. This scale was derived based on a simple subjective assessment of the general importance of highway functions of different traffic factor groups.

2. Supports direct use of data in various selected MDT activities

Commercial vehicle weight limit and safety enforcement

The degree to which a proposed site supports vehicle weight enforcement will have to be determined based on professional judgment. Generally, the type of site in such cases will be a WIM site. Factors to be considered for any given location include the expected degree of overweight vehicle operations, use of the route as a major corridor to transport equipment/commodities, the nature of equipment/commodities involved, etc. As for all the criteria, an important aspect in determining appropriate scores is relative consistency in their determination. For example, a location on a "heavily" travelled route with an expected high incidence of overweight vehicle operation, might be assigned a score of 100. Correspondingly, a site on a relatively "lightly" travelled route with an expected low incidence of overweight vehicle operation would be given a somewhat lower score, of say 30. Other situations would then be scored based on these benchmark values.

Pavement design

Pavement design is dependent on both vehicle weight and volume data. A fairly gross scale for this criteria could be a score of 50 for ATR sites, as only traffic volume/configuration data is collected, and a score of 100 for WIM sites, as both traffic volume/configuration and weight data is collected.

3. Offers opportunistic/situational advantages

Opportunistic advantages

Significant cost benefits are realized when WIM and ATR systems can be opportunistically installed coincident with a roadway construction/reconstruction project. This criterion is generally binary in nature, i.e., if coincident construction is planned at the proposed site, the input value is 100; if not, the input value is zero.

Situational advantages

As introduced above, favorable circumstances at data traffic collection sites include good pavement conditions (strong and free from distress); straight and flat roadway geometry; and free flowing traffic moving at a reasonable speed with minimal passing activity. The basis for one ranking scheme would be to assign a site a value of 100, if all of these conditions are well met, linearly transitioning to a value of zero, if none of these conditions are met. Further, if physical conditions at a site do not support deployment (i.e., the pavement is too thin), a negative score could be assigned to this criteria. Additionally, WIM/ATR sites require power and communications infrastructure to run equipment and transmit data to centralized databases. Similarly, one ranking scheme would be to assign a site a value of 100 if both power and communications are readily available, with a score of 50 assigned if only one these services is readily available.

4. Other extenuating circumstances

The intent of the WSM approach proposed herein is to include all the major factors involved in, and appropriately represent their effect on, the prioritization of future WIM and ATR deployments. Occasionally, however, some relatively unique feature of a proposed site that is obviously critical in the decision making process could fall outside the criteria listed above. While this factor could be introduced into the decision making process during subsequent discussion and formulation of final recommendations for the future, it can also be introduced by providing within the WSM the opportunity to adjust the total score for a site based on this factor. Thus, the WSM described in Table 55 includes an entry labeled "Other extenuating circumstance." The numerical value entered here simply is added to the weighted sum generated for the standard criteria. This entry could be positive or negative. An explanation of this input should/must be offered and readily accessible for review by participants in the prioritization process.

7.2.3. Prioritization of WIM Versus ATR Sites

The ranking scheme developed herein provides an objective comparison among sites regardless of the type of data collection, i.e., WIM or ATR. That being said, two WSM scores are calculated for each proposed site, one with and one without consideration of the weight related benefits sites may offer (i.e., data for weight enforcement and vehicle weight information for pavement design). The score calculated without weight related benefits is further re-normalized to produce a highest possible score of 100 points. This score effectively evaluates all proposed sites as ATR sites.

As a) WIM data can be used for very different purposes from ATR data, b) some funding available for data collection may be exclusively directed to WIM versus ATR systems, and c) WIM systems are significantly more expensive than ATR systems, there may be a need to separately prioritize proposed deployments by system. As previously mentioned, one of the outputs from the WSM already introduced effectively prioritizes deploying all proposed sites as ATR sites, namely WIM and ATR sites considered together, without weight criteria included in the assessment. While another output of this WSM is "WIM sites considered independently", this output evaluates the contribution of such sites to improving data quality and comprehensiveness only in the context of the volume/classification data a WIM site collects, rather than in the context of the weight data it collects. Recall that in addition to traffic factor groups, traffic weight groups are important to support agency tasks that are significantly dependent on load related vehicle characteristics, such as pavement design. Therefore, a second WSM was developed for prioritizing just WIM sites with the criteria addressing data quality/comprehensiveness being focused on WIM metrics rather than combined WIM and ATR metrics. An example of a WIM-focused WSM is presented in Table 56. Relative to appropriate criteria and scales, and following the earlier discussion of the combined WIM and ATR WSM, adjusted criterion and scales for the WIM-focused WSM could be:

Increase in number of WIM sites within a weight group

The TMG indicates that there should be at least two WIM sites per weight group, with a typical target of six WIM sites per weight group. A possible scale for this criterion thus could be:

No WIM sites in weight group	100
Six or more WIM sites in weight group	0
For other cases, linearly interpolate between these two values	

Following this scale, a score of 50 would be used for a proposed site on a group with three existing WIM deployments.

Improvement in centerline miles per WIM site by group

As previously mentioned in the discussion of combined WIM and ATR sites, traffic can be relatively constant on highway segments between one or more major intersections with major changes in traffic spaced anywhere from a few miles to 100 miles apart. Based on this subjective observation, a possible scale for this criterion would be:

Average centerline mileage per site for group of greater than 100 mi (or, no WIM sites are presently on the group)	100
Average centerline mileage per site for group of less than 10 mi	0
For other cases, linearly interpolate between these values	

This is the same scale suggested for evaluating WIM and ATR sites together; however, for this WSM it is evaluated using average centerline miles per WIM site by group (i.e., as reported in the third column in Table 52), rather than average centerline miles per data collection system for WIM and ATR sites combined (i.e., as reported in the fifth column in Table 52).

Improvement in commercial VMT per data collection site by group

As discussed above, the previously introduced parameter of commercial VMT per data collection site, calculated by group, reflects the degree of WIM coverage by commercial volume on each group (reported earlier in Table 54). Based on a qualitative review of current values for this metric, the following type of scale with scores ranging from 0 to 100 could be used:

Average commercial VMT per WIM site for group is greater than 50 million (or, no data collection sites presently on the group)	100
Average commercial VMT per WIM site for group is less than 15 million	0
For other cases, linearly interpolate between these values	

This scale was simply derived based on current practice, by approximately bracketing the existing range of commercial VMT per site across the various traffic factor groups (see Table 54).

Table 56: Proposed WIM Site Prioritization Scheme

Site Information					WIM Score	Prioritization Criteria and Weights																	
						Quality/comprehensiveness of WIM data						Support of specific user activities					Opportunistic/situational factors				Other extenuating circumstance	
						general WIM coverage within groups	geographic WIM coverage within groups	volumetric WIM coverage within groups	route with increased weight activity	group imp.	sub total	traffic group factors	weight enforce	speed related safety and other activities	HS[a]	sub total	scheduled for other construct activities	alignment, pavement conditions, etc.	power and comm	sub total	score	explanation
Name	Dept Route	Dept RP	Traf. Fact. Group	WIM or ATR	WIM Score	10	10	10	10	5	45	15	15	5	5	40	5	5	5	15	-	-
Sweetgrass	I-15	392	RI	WIM	90	0	80	80	50	100	26	46	50	100	100	24	100	100	100	15	25	replacement of exisitng site
Manhattan	I-90	287	RI	WIM	66	0	80	80	0	100	21	35	0	100	50	13	0	-50	100	2.5	30	analyze long term travel impacts
Judith Gap	N-63	20	RPA	WIM	32	0	100	0	50	75	19	40	0	50	50	11	0	-50	100	2.5		
Eureka	N-5	184	RPA	WIM	40	0	100	0	50	75	19	40	100	50	50	26	0	-100	0	-5		
E Culbertson	N-1	648	RPA	WIM	59	0	100	0	100	75	24	51	100	50	100	30	100	0	0	5		
S of Bridger	N-4	10	RPA	WIM	34	0	100	0	100	75	24	51	0	50	50	13	0	-50	0	-2.5		
Scobey	P-32	65	RMA	WIM	40	0	100	3	50	25	17	37	100	0	100	26	0	-50	0	-2.5		
Miles City	P-18	14	RMA	WIM	39	0	100	3	100	25	22	48	0	0	0	7	0	100	100	10		
Turner	S-241	43	RMC	WIM	45	83	100	94	50	0	33	50	0	0	100	13	0	0	0	0		

-shaded cells are user entries -unshaded cells are WSM results -darkest shaded cells are weighting factors [a] Homeland Security

Provide better coverage of a route/region of increased heavy vehicle activity

Heavy vehicle traffic increases and decreases in response to many factors, generally connected to changes in economic activity in a particular industry and area of the state. Professional judgment will have to be used in assessing the degree to which a proposed site meets the criterion of supporting WIM data collection due to expected (or realized) increased heavy vehicle activity. Once again, areas affected by energy development in the Bakken could possibly provide a benchmark for scoring this criterion. Routes/areas feeling direct impacts of intensive well drilling activity could be scored as 100 on a zero- to-100 scale, while areas provide ancillary support for these activities are scored at 50. Increased heavy vehicle operations at other locations and for other reasons around the state would be assessed in the context of the Bakken activity.

Provide better coverage of routes in groups that are of higher importance

As discussed above, coverage of Interstates and principal arterials is more important than coverage for lesser traffic groups. This general concept is true of both traffic data collection and weight data collection. Therefore the same scale example is provided for this metric:

Factor Group:

Interstates	100
Principal Arterials	75
Minor Arterials	25
Collectors	0
Recreational - professional judgement (consider highway functional class)	

Two additional changes were made to the WIM-focused WSM. Improvements in the quality and comprehensiveness of the weight data collected directly supports pavement design. Thus, this criterion was removed as a separate input from the category “Support of specific user activities”. Additionally, WIM sites collect traffic volume/classification data which is used for among other things, traffic group factoring. Thus, in prioritizing potential WIM sites, the degree to which they contribute to improving the quality and comprehensiveness of volume/classification data should be considered. The corresponding factor included in the WIM-focused WSM is the subtotal from the WIM and ATR WSM for the category “Quality/comprehensiveness of data,” with an adjusted weighting factor (from 45 to 15 percent) to reduce its influence on the model results, consistent with the focus of this WSM being on weight data rather than volume/classification data.

7.2.4. Use of the WSM Output

The WSM processes developed herein are intended to help identify top priority WIM and ATR sites for further consideration and selection based on program objectives as embodied in the criteria and weighting system used in the WSM. While the outcomes appear numerically crisp, the process is sufficiently subjective that users should be careful not to place too much emphasis on the exact numerical scores that are generated. The list of prioritized sites that is produced can serve as a starting point for further discussions between stakeholders that will lead to final selections. It is important to note that while some situational/opportunistic factors may have implications on deployment cost, the capital investment required to build a proposed site (i.e. its total cost) is not currently directly used in the prioritization scheme. Conceivably, this could be accounted for after the initial rankings have been developed by considering the cost of the top sites generated by the ranking process before making final site selections.

Note that the proposed criteria, weights and "scales" suggested above for the WSM also provide one starting point to generally identify data collection sites that merit consideration by MDT. Any element of the highway system, for example, with a high score for criteria related to data quality/comprehensiveness is a candidate for deployment of a new data collection site. Other criteria similarly may suggest general elements of the transportation network on which improved data collection is merited.

7.2.5. Sample Results from Ranking Scheme

In addition to generally describing the WSM structure that could be used in prioritizing WIM and ATR site deployment, Table 55 and Table 56 also include sample assessments of various potential WIM and ATR sites on the state highway network. These sample assessments were drawn from the MDT WIM and ATR Installation/Prioritization Plan spreadsheet that includes a) all the sites considered for the 2014 construction season, b) various entries on their characteristics, and c) their rankings (MDT 2015). The spreadsheet includes approximately 80 sites, consisting of 30 WIM sites and 50 ATR sites. For demonstration purposes, 14 sites were used, 9 WIM sites and 5 ATR sites. These sites were qualitatively selected to cover the more common traffic factor groups and to include some diversity in site characteristics. More WIM sites were selected than ATR sites for demonstration purposes, as this underlying project is focused more on WIM systems than ATR systems. The degree each site met the various prioritization criteria was evaluated using the information available in the spreadsheet and professional judgement.

As previously mentioned, the WIM and ATR Installation/Prioritization Plan spreadsheet contains information on each of the criteria proposed in the WSM. However, and as previously mentioned, the relative importance of each criterion (i.e., its weighting factor) is not apparent in the current MDT prioritization scheme as embodied in this spreadsheet. Thus, the weights used in the WSM were generated by the researchers and need to be reviewed and modified as appropriate by MDT. Additionally, the degree to which each criterion is met by each proposed site is generally treated in binary fashion in the spreadsheet. That is, each criterion is either checked-off or not, with no indication of the relative degree to which the criterion is met by a particular site. Thus, to more fully demonstrate the proposed WSM, some refinement had to be introduced in the degree by which various sites met various criteria.

For the data quality/comprehensiveness criteria in the WSM, refinement of the degree to which a particular site met these criteria was readily accomplished using the example scales introduced earlier. For other criteria, refinement was introduced simply using broad rationale based on their nature. For example, several sites are reported in the spreadsheet as contributing to data needs of Homeland Security. For purposes of this demonstration, and with only the broadest justification, sites located at or near the border were scored 100 for this criterion, while sites distant from the border were scored 50. Many WIM and ATR sites reportedly supported pavement design needs. Once again, the degree to which these needs were supported by each site was not presented in any detail. The decision was made to score WIM sites at 100, as they provide both weight and volume data which are used in pavement design, while ATR sites were scored at 50, as they provide only volume/classification data. Similar, simple rationale were used across the remaining criteria

The results of these sample prioritization calculations for the WIM and ATR WSM and the WIM-focused WSM are included in Table 55 and Table 56, respectively. An immediate observation in reviewing these results is that both prioritization schemes generate a considerable range in final site scores, with these scores moderately well distributed within these ranges. Considering prioritization of WIM and ATR sites together (Table 55), scores across the 14 sites considered ranged from 19 to 86 out of 100. Scores ranged from 36 to 52 (Table 55) and 32 to 90 (Table 56) out of 100 for the five ATR and nine WIM sites, respectively, when considered independently. As previously mentioned, while the numerical results of these models appear exact, due to the subjectivity in arriving at some of the numerical inputs, the results are only approximate. In light of this uncertainty, if all the results were in a narrow range, or clustered tightly around certain values, the usefulness of their precise numerical order would be diminished, as modest changes in the subjective inputs could change this order. More widely spaced scores increases the likelihood that substantive differences in site priorities do exist, rather than these differences simply being introduced by inherent variability in assessing the input parameters.

To offer further perspective on the proposed prioritization schemes, the site scores generated by the WSM and presented in Table 55 and Table 56 were used to rank the relative priority of these sites (see Table 57). It is difficult to comment on these results, as the "correct" priorities are unknown, but, in some cases these results can be compared to the priorities actually assigned by MDT to these potential sites, as these priorities are included in the WIM and ATR Installation/Prioritization Plan spreadsheet. Such a comparison, for example, is provided by columns (d) and (f), and columns (e) and (g) in Table 57, respectively, for ATR and WIM sites ranked independently (comparison of the rankings for the WIM and ATR sites considered together was not possible based on the information available in the MDT spreadsheet). Recall that the MDT spreadsheet considered approximately 80 total sites, consisting of 30 WIM sites and 50 ATR sites, while this demonstration considers only 14 of these sites, consisting of 9 WIM sites and 6 ATR sites. Thus, for the purposes of this comparison, the MDT priorities were renumbered for these subsets of WIM and ATR sites, based on each site's relative rank within the larger population of sites considered.

Referring to Table 57, i.e., comparing the entries in columns (d) and (f) and columns (e) and (g), it is apparent that the sample rankings determined using the proposed WSM prioritization approach and those determined by MDT are not closely correlated. The correlation coefficients in both cases are low. This outcome is not unexpected, as several assumptions were made by the researchers in refining input information to execute the WSM (i.e., the relative importance of the various criteria was assumed, as well as the specific degree to which each site met these criteria). When the WSM approach is put into practice, the criteria weights and subsequent scores for each site will be better determined by MDT personnel integrally involved in traffic data collection and its use. The inherent subjectivity in the process used by MDT to arrive at their rankings could also have contributed to some variability in their outcomes, and corresponding absence of strong correlation between the MDT and WSM generated priorities.

Table 57: Prioritization of Sample Results

Site Information					Relative Priorities - WSM Models -					Relative Priorities - MDT -	
					WIM and ATR considered together				WIM site focused criteria		
Name	Dept Route	Dept RP	Traf. Fact. Group	WIM or ATR	(a) WIM and ATR sites (wghtd)	(b) WIM and ATR sites (not wghtd)	(c) WIM sites only	(d) ATR sites only	(e) only using WIM criteria	(f) MDT ATR sites only	(g) MDT WIM sites only
Sweetgrass	I-15	392	RI	WIM	1	1	1		1		1
Manhattan	I-90	287	RI	WIM	2	2	2		2		3
Judith Gap	N-63	20	RPA	WIM	4	10	4		9		4
Eureka	N-5	184	RPA	WIM	7	14	7		5		6
E Culbertson	N-1	648	RPA	WIM	3	4	3		3		7
S of Bridger	N-4	10	RPA	WIM	4	10	4		8		5
Scobey	P-32	65	RMA	WIM	14	13	9		6		8
Miles City	P-18	14	RMA	WIM	6	5	6		7		2
Turner	S-241	43	RMC	WIM	11	8	8		4		9
Stanford	N-57	35	RPA	ATR	9	6		2		4	
Forsyth	P-14	265	RMA	ATR	12	9		4		3	
N. of Terry	S-253	25	RMC	ATR	13	12		5		5	
Checkerboard	P-14	73	RMA	ATR	8	3		1		1	
Maxville	P-19	55	RMA	ATR	10	7		3		2	

7.3. Conclusions

The prioritization of WIM and ATR sites is an important aspect of any traffic data collection program. Due to resource constraints, agencies typically are unable to deploy and maintain all the sites necessary to ideally support data user needs. Thus, a process is necessary that systematically and uniformly assesses the relative importance of each site based on agency priorities. Presently, MDT has such a process that uses a list of evaluation criteria that includes such items as traffic factor group data needs, physical pavement and roadway conditions at proposed sites, commercial vehicle weight enforcement data needs, etc. Based on stakeholder discussion of this information, the proposed sites are ranked by MDT staff using their collective professional judgment. This process does not necessarily follow a replicable framework in which each criterion is consistently applied in making prioritization decisions. To address this, an alternative process was developed herein which proposes to facilitate a systematic evaluation of potential data collection sites using a WSM approach.

The proposed WSM approach includes the same criteria used in the current MDT prioritization process. Following the WSM approach, each criterion is assigned a weight which reflects its relative importance to the agency. Subsequently during the site assessment process, numerical scores are assigned indicating the degree to which the site meets each criterion, and its total score is determined as the sum of the score for each criterion multiplied by that criterion's weighting factor. The criteria considered in the WSM were grouped into the categories of data quality/comprehensiveness, specific data user needs, and opportunistic/situational factors. Two WSM models were developed, one that considers ATR and WIM sites together in the prioritization process, and one that considers them separately.

To demonstrate WSM operation, sample weights were assigned to the various criteria and sample scales were used to evaluate the degree to which sites meet these criteria. When this approach is implemented, both these weights and scales should be reviewed and modified by MDT personnel, as necessary, based on their intimate and expert knowledge of MDT's needs. The WSM were demonstrated using information available from past MDT prioritization work, consisting of the sites being considered, their characteristics, and ultimately the priority they were assigned. To execute the WSM, several assumptions had to be made in the criteria scoring process, notably to refine the degree to which a particular site met certain criteria. In this demonstration application of the WSM, rankings produced by the WSM only moderately correlated with the actual rankings generated by MDT (low correlation coefficients), in part due to these assumptions. In practice, the user of these WSM will be MDT personnel intimately familiar with the sites and data needs of the program, and thus their assumptions will be well founded and will support the generation of accurate and useful results.

The expectation is that the results of the WSM will not be the sole input used in the decision-making process for WIM/ATR site prioritization. While factors important to this process are considered in the WSM, the problem is complicated, and the WSM may not fully represent and adequately model all the unique elements of a particular siting decision. Nonetheless, and with some adjustments by the users, the WSM will provide a quantitative input to this process based on a systematic and uniform consideration of many of the important factors involved.

8) ASSESSMENT OF ADEQUACY OF DATA COLLECTION EFFORT

This chapter consists of a summary assessment of the adequacy of MDT's existing traffic data collection program based on the information presented in the previous chapters. This assessment considered the full spectrum of TDCA Section activities, from data collection to data dissemination. Provisions from the Moving Ahead for Progress in the 21st Century (MAP-21) and the Fixing America's Surface Transportation (FAST) Acts directly related to traffic data collection programs were also considered. Recommendations were made on potential changes to the current program based on this assessment, with the goal of providing the best possible information in the most cost effective manner to meet current and future user needs.

Assessments and associated recommendations are made below specifically with respect to the current traffic data collection sites and associated system coverage; the data collection equipment being used; the management/operation of the data collection program, itself; and the types of traffic data being collected, and the manner in which this data is being processed and disseminated.

8.1. Traffic Data Collection Sites/System Coverage

As previously introduced, transportation agencies commonly use a combination of short term counts and permanent sites to collect traffic data. An adequate number of data collection sites and appropriate locations of those sites are vital to collect traffic data that can reasonably capture the characteristics of vehicle usage of a highway network. Overall guidance on traffic data collection is provided in the HPMS Field Manual (FHWA 2014) and the TMG.

The HPMS Field Manual provides the following general guidance:

> *"The State's traffic monitoring program shall cover all NHS, Interstate, Principal Arterial, and HPMS sample sections on a three-year cycle or better; at least one-third should be counted each year. […] The State shall also have a traffic count program on a six-year cycle or better for all sections that are neither samples nor NHS but are on the minor arterials and collectors (except for rural minor collectors)."*

As explained further below, the TMG suggests on average five to eight continuous data collection sites are required per traffic factor group to realize their recommended level of data reliability, and two WIM sites per truck weight group.

The general adequacy of MDT's traffic data collection sites (number and location) was evaluated in the context of the above guidelines using the description of the physical data collection system presented in Chapter 3, coupled with information on traffic flow patterns identified in Chapter 4, and MDT traffic/weight factor groups discussed in Chapters 6 and 7. Both short term and permanent sites were assessed, with a focus on the permanent ATR/WIM sites.

8.1.1. Short-Term Counts

MDT currently designates approximately 5,800 short term count locations across the state and collects traffic data from approximately 3,000 locations annually. These locations cover highways of all classes in the state, with preset count cycles for each highway class ranging from one to three years (as reported in more detail in Chapter 3). As previously discussed (see Table 13), the number of short-term counts conducted by MDT is similar to the number of short term counts conducted by multiple other states with somewhat similar amounts of traffic and road miles. Referring to the general guidance above from the HPMS Field Manual on where/when traffic data must be collected, and assuming the short term sites (in combination with the permanent counter sites) cover all the necessary sample sections, the current counting procedures satisfy HPMS Field Manual guidelines. The number of short term count locations increases as new additions are made to the highway network. Furthermore, by sharing data with counties, cities, and MPOs, MDT acquires short term count data from additional locations on the state's highway system.

8.1.2. ATR/WIM Sites

ATRs and WIMs are the foundation of state DOT traffic data collection programs, providing essential information for a myriad of transportation related activities. As of June, 2016, MDT operates a total of 64 ATR and 42 WIM sites across the state's highway network (Figure 76).

In addition to regular volume and classification ATR sites, MDT also developed a unique site configuration to classify motorcycles and maintains 17 such ATR motorcycle sites.

Looking further at Figure 76, one piece of feedback obtained from the Survey of Data Users (see Chapter 5) was that some tribes use MDT's count information as input into their planning processes. Qualitatively, based on Figure 76, the Flathead Reservation (westernmost reservation in this Figure) has several permanent sites from which traffic data is collected. Conversely, ATR and WIM coverage on the Fort Belknap and Rocky Boy's Reservations (north central) as well as portions of the Fort Peck reservation (north east) is relatively sparse.

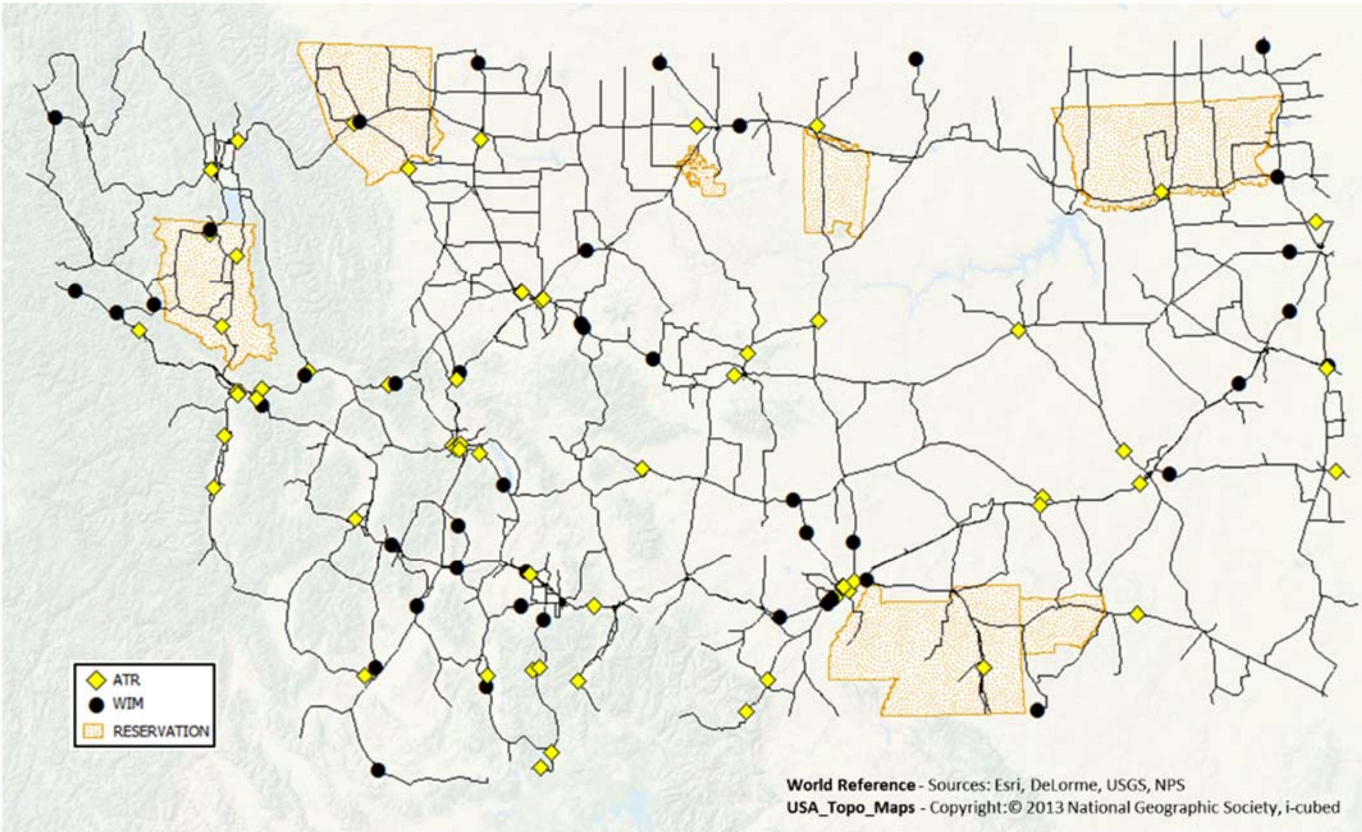


Figure 76: ATR and WIM Sites

As previously discussed, the number of ATR sites in Montana is similar to that in other states (see Table 12), while Montana has considerably more WIM sites than many of these states. Montana has diverse economic activity with significant and distinct commercial vehicle operations, which is better monitored with an increased number of WIM sites. Further, Montana uses quartz piezo-electric WIM systems, which are significantly less expensive than WIM technologies used by other agencies (i.e., load cell and bending plate sensors). The current number and locations of ATR/WIM sites also reflect the needs and requirements from cooperative programs in Montana, like MCS, MHP, and Home Land Security, since those needs and requirements are considered in ATR/WIM site selection process.

An important function of permanent traffic monitoring sites is to capture seasonally and spatially varying traffic flows encountered in the state as a result of various economic activities. Large local/regional fluctuations in traffic volumes and in the composition of the traffic stream are encountered on many of Montana's highways both temporally and spatially, as the state's economy is agriculture, natural resource extraction and tourism intensive. In Chapter 4, eight areal traffic flow patterns related to these various activities were identified, along with twelve temporal patterns resulting from crop planting and harvesting related activities. A detailed analysis of the specific route segments impacted by these patterns and the absence/presence of ATR/WIM sites situated to capture associated seasonal and spatial traffic patterns in Montana was beyond the scope of the task included as Chapter 4. Such an analysis could be undertaken by MDT, possibly in conjunction with a more in-depth and comprehensive effort to identify remaining significant commodity related traffic flows in the state, building on the initial work put forth in Chapter 4. It should be noted that traffic data collection equipment is not capable of identifying the commodity being transported. Therefore any commodity related traffic flow data will need to be acquired outside of current data collection activities.

Integrally related to the issue described above, one of the important uses of continuous traffic data collected by permanent WIM/ATR installations, as previously discussed, is to provide the data necessary to adjust traffic data collected from short term counts to obtain reasonable estimates of AADT or forecast the average daily traffic for any other time during the year. The factors necessary to make these adjustments are developed from the traffic data continuously collected for each traffic/weight factor group, with these groups collectively representing all traffic patterns encountered across the state. Pertinent to this specific discussion, the number of ATR and WIM sites that are located on routes within each of MDT's current traffic/weight factor groups is shown in Table 51.

Relative to traffic factor groups, as mentioned in the introduction to this section, the TMG indicates that usable data generally is collected if five to eight continuous monitoring sites are available per traffic factor group. The TMG goes on to comment that for most factor groups, at least six continuous counters should be included within each factor group, with due consideration of a few additional sites in the event of counter malfunction. Referring to Table 51, and considering the combined number of WIM/ATR collection sites per group (data from both WIM and ATR data systems support traffic factor group characterization), the number of collection sites per traffic factor group is within the broad TMG guidelines for most elements of the highway system. Notably, data collection sites are sparse on the urban system. Variation in the number of sites by traffic factor group reflects further parameters that affect the minimum number of sites necessary to more fully characterize highway use by group, such as highway mileage and volume of traffic for each specific group. Review of the distribution of existing sites is an ongoing process (as discussed in Chapter 7), with the intent of adding additional sites as necessary.

Relative to weight factor groups, and as commented in the introduction to this section, the TMG suggests that generally a minimum of two WIM sites are required per weight factor group to reliably characterize weight related attributes of use of the state highway network. Similar to the conclusion for traffic factor groups, the number of WIM sites is generally within this broad guideline of the TMG (see Table 51), with the variation in the number of sites driven by the need to better characterize demands on particular routes in response to known patterns in heavy vehicle use around the state, as commented on above and in more detail in Chapter 4. The absence of WIM sites on Urban Arterials and Collectors results from a long standing and industry-wide problem with collecting reliable data in urban traffic environments.

Of course the above assessments are predicated on the assumption that the traffic and weight factor groups being used are adequate to represent traffic operations across the state. In light of possible changes in traffic patterns across the state through time, these traffic and weight factor groupings need to be periodically reviewed. Such a review was conducted in this project for traffic factor groups, as presented in Chapter 6. This review resulted in the recommendation of a possible new traffic factor grouping scheme, based on interstate versus non-interstate, urban versus rural, and commercial versus all vehicles in the traffic stream.

Prioritization of future site locations is critical to optimize their cost effectiveness in meeting the diverse needs of traffic data users. MDT currently has relatively well established criteria that are used in this regard, which could be used in the weighted sum prioritization model proposed herein in Chapter 7 to generate a quantitative input into the decision making process that systematically acts on these criteria.

8.1.3. Other Considerations

Legislative – Federal transportation legislation can contain provisions related to traffic data collection requirements by the states. Among other things, such legislation can contain performance related metrics that are calculated using traffic data. MAP-21, for example, required all states "to evaluate and report more effectively and consistently on transportation system performance, including travel time reliability, delay hours, peak-hour congestion, freight movement, and on-road mobile source emissions." Both MAP-21 and the FAST Act that has superseded it speak with a renewed and vigorous interest about freight. U.S. DOT has designated a National Highway Freight Network (NHFN) of approximately 51,029 miles of Interstate highways. Currently, Montana Interstates I-15, I-90, and I-94 are part of the NHFN. In addition to these Interstate highways, states are responsible for identifying Critical Rural Freight Corridors (CRFCs) and Critical Urban Freight Corridors (CUFCs) that may be considered for addition to the NHFN (USDOT, 2016a). The FAST Act also requires States receiving National Highway Freight Program funds to develop a State Freight Plan either individually or in conjunction with the State's strategic long-range transportation plan and encourages States to establish freight advisory committees (USDOT, 2016b). New and existing WIM sites on certain corridors may provide valuable information for these freight related activities/mandates.

Other Modes of Transportation - As identified in the survey of data users, there is some interest in collecting data on other modes of transportation, notably bicycle and pedestrian counts. Setting up data collection locations and through sharing data with MPOs, cities, and counties, MDT could gather and acquire data to support pedestrian and bicyclist safety related activities.

8.1.4. Recommendations

The current WIM/ATR sites deployed around the state are, on average, adequate in number and distribution to meet general HPMS and TMG guidelines. The number of sites is similar in magnitude to those in other states. Prioritization of future WIM/ATR deployments is important to ensure any new data collection sites optimally support the needs of the data collection program, and the weighted sum model investigated in this project could provide a useful input into this process. Additionally, work should continue on identifying trends in social/economic activity and attendant increases in vehicle operations that merit increased data collection coverage. Needed coverage will reflect the traffic/weight factor groups necessary to represent various traffic patterns encountered around the state. The traffic/weight factor groups that are used need to be periodically reviewed and possibly modified, in response to changes in traffic operations around the state. A review of the current traffic factor groups was conducted as part of this investigation; and such a review of weight factor groups should also be conducted. In reviewing future data collection plans, consideration should be given to emerging data needs related to freight movements, and use of alternate transportation modes, i.e., bicycle and pedestrian travel.

8.2. Data Collection Equipment

Automation is the trend for traffic monitoring and data collection. While employing advanced technologies with a high level of automation for most of its traffic data collection, MDT still retains the use of manual methods for short term counts and as a complement to automated counts. The appropriate data collection equipment/devices should achieve the balance among reliability, data quality, and cost. The adequacy and efficiency of data collection technologies used by MDT for both short term counts and permanent sites are assessed below, with an emphasis on permanent ATR/WIM sites.

8.2.1. Short-Term Sites

MDT employs three types of technologies/methods to collect short term data, with specific implementation and data collection capability for each method. Road tube counters (i.e. pneumatic tubes) are used to collect volume, vehicle classification (FHWA 1-13), and speed data. They are the most used short term data collection form because they are relatively inexpensive and do not require modifications to the road bed. However, they are highly susceptible to damage by traffic and road maintenance operations. MDT also uses non-intrusive traffic data collection camera units, which are capable of gathering volume and length based classification data through processing the video data. The non-intrusive camera units are safe to install and operate; however, manual review is required to obtain the FHWA 1-13 classification. In addition, manual counts are still used by MDT for quality control checks on permanent sites and special studies. In addition to vehicle data, manual counts can also collect data on bicycles, pedestrians, and recreational vehicles. Chapter 4 of the 2013 edition of the TMG includes information about technologies available and practices for short-term and longer-term counts of non-motorized traffic including bicycles and pedestrians. With the three approaches used comprehensively and to complement each other, the technologies/equipment employed by MDT generally meet the current needs for short term traffic data collection.

8.2.2. Permanent Sites

Unlike the peer states surveyed in this project (North Dakota, Maine and South Dakota) who use multiple technologies and devices for permanent site data collection, the equipment/hardware employed by MDT for ATR and WIM sites are quite uniform. Piezoelectric sensors from MSI and inductive loops laid out by TDCA personnel are the two major technologies used by MDT for ATR sites. Four types of ATR sites are maintained in Montana: 1) volume only, 2) class by length, 3) class by axle, and 4) motorcycle. Depending on the type of site, the use and layout of piezoelectric sensors and inductive loops varies. As for WIM sites, almost all the sites use Kistler quartz piezoelectric sensors. Kistler sensors have been found to be very accurate, easy to maintain, and relatively insensitive to Montana's weather conditions. Since Kistler sensors have proven to be reliable, MDT plans to upgrade several sites that currently do not use them. Also, all future WIM sites are expected to use Kistler sensors. Relative to the communication technologies, like other peer states, landline phone is the primary communication technology employed by MDT for ATR and WIM sites, along with wireless internet, DSL, and manual retrieval.

This evaluation highlighted the good performance of Kistler sensors for WIM sites and the unique ATR motorcycle site layout composed of piezoelectric sensors. Assessment of the information gathered for permanent sites in previous tasks indicates that the currently employed WIM/ATR equipment generally meets the data collection needs of MDT, except for those in urban areas within the state. Common to the industry, urban areas are problematic in that current sensor technologies are unreliable in urban environments (stop-and-go traffic, frequent lane changes, geometric issues, etc.). Manual and video based monitoring mitigate these issues, but often at the expense of increased time/cost in collecting (manual) or processing (video) the associated data.

8.2.3. Recommendations

As it has traditionally done, the TDCA Section uses contemporary data collection technologies that they have found effective for Montana, while continually staying abreast of the state-of-the-practice in this regard. The urban areas within Montana are those areas which challenge present data collection methods. The technologies currently employed by MDT and most other available technologies all have issues when deployed in urban environments and on interchange ramps, due to congestion, high traffic volumes, and geometric constraints. In light of this situation, investigation should continue of technologies/devices suitable for data collection in stop-and-go congested conditions in urban areas and on interchange ramps. In addition, as an effort to further improve program efficiency and reduce costs, MDT should continue to look into ever evolving communication technologies for ATR/WIMs under development as discussed in Chapter 2 (e.g. high-speed wireless and network technologies).

8.3. Management and Operations of Traffic Data Collection Programs

Efficient management and operation are critical features of an effective traffic data collection program. The efficiency and adequacy of the current organizational structure of the traffic data collection unit in MDT and its operations of short term and permanent sites are assessed in this section, with a focus on permanent WIM/ATR site operations.

8.3.1. Organizational Structure

MDT has all the traffic data collection functions integrated into one unit: the TDCA Section. Staffed with fourteen permanent employees, a supervisor, and three temporary positions, the TDCA Section is in charge of a full spectrum of short term counts and permanent traffic data collection activities, including field installation, operation, calibration, and maintenance; in-office data download, processing, reporting, display, and distribution; and program planning/budgeting. In the limited survey of peer practices conducted (see Chapter 2), it was found that ND and ME divide ATR/WIM site operations and traffic data analysis between two units. Compared to those states, MDT's traffic data collection unit organization may be more technically integrated and resource efficient. Putting all of the resources and responsibilities of the traffic data program in one administrative unit should result in more seamless and coordinated flow of information, from collection of the basic data to its distribution to the end user. Thus, the current organization structure of the TDCA Section is appropriate and efficient for the traffic data collection program in MDT.

8.3.2. Short-Term Counts - Operations

The short term counts program within MDT consists of four traffic technicians located in the four established traffic regions, a program manager at the central office, and three seasonal staff who are strategically hired in traffic regions based on the greatest need. The short term counts program performs the full spectrum of short term traffic data collection functions (except for video camera image processing), with approximately 3,000 short term counts conducted per year, with each count requiring sensor installation, calibration, field check, removal, and data retrieval and associated general maintenance, QA/QC and other activities. Through its traffic counts exchange program, MDT shares short term counts with and gets short term counts from local agencies, at sites not covered by MDT. The data exchange program is an efficient way to address the understaffing issue of MDT to obtain more short term counts across MT and to maximize the outcome of the investments of MDT and local agencies in traffic data collection. It is beneficial to MDT, local agencies, and the general data users. It is anticipated that the exchange program will see more usage in traffic data collection activities of MDT to address the current and future data needs.

8.3.3. ATR/WIM Sites Operations

There are four field staff and four central office staff in the TDCA Section performing all of the permanent ATR/WIM data collection and processing functions. The field staff is responsible for ATR/WIM installation, annual routine winter maintenance, site calibration, special maintenance and repair work. Only new WIM site installation is contracted out. Of the three peer states surveyed in this project, two of the three contracted out maintenance and repair (ND and SD). However, MDT has significantly more WIM sites as compared with the surveyed states (42 vs. an average of 15), so it is not surprising that they find value in performing these annual duties in-house. Standard procedures are followed for ATR/WIM site maintenance and calibration. Field staff document all repair, maintenance, and calibration work done, as well as pavement conditions at each site, but the data are currently not in a readily queried format. In addition, MDT maintains a description record for all ATR/WIM sites, which contains the information describing the characteristics of each site including station ID, year established, data collection method, data retrieval method, classification method, etc. The station description record is the major source of information on MDT’s inventory of ATR/WIM sites. However, like the repair record, the inventory data are not well established in a database management system.

Currently, the age (years in service) of ATR/WIM site obtained from the inventory data is the sole index used to describe the site condition. However, age alone has been found to be a poor indicator of the site’s performance. A comprehensive site evaluation approach is needed, the development of which is very feasible considering that the site inventory, maintenance, and pavement condition data are well documented. With respect to the ATR/WIM site performance, the impacts of pavement conditions cannot be ignored. System performance significantly degrades when pavement condition deteriorates. The TDCA Section needs to be aware of proposed pavement related construction activities at existing WIM/ATR sites. Furthermore, if the TDCA Section is more generally aware of such projects around the state, they may be able to seize on an already proposed project to replace/upgrade a nearby site, or to add a new site to the system, in a cost effective manner. Following current practice, the Pavement Analysis Division will notify the TDCA Section if they recognize road projects that may affect an ATR/WIM site, and the TDCA Section also monitors the scheduled project lists to see if any permanent sites may be affected. An official/formal procedure for these two units to communicate may be warranted.

Another issue identified for the ATR/WIM field operation is the need for additional summertime personnel. Due to the short construction season and the long, harsh winters in Montana, a major amount of field work has to be compressed into a short construction season. Often, scheduled maintenance and necessary repair work have to be deferred because of insufficient staff available during the short construction season.

The central office staff for the ATR/WIM program is also understaffed. Four FTEs are assigned for ATR/WIM data download, processing, and dissemination. More specifically, an FTE is assigned for each of:

- ATR data download, process, and QA,
- WIM data download, process, and QA,
- data analysis and reporting, and
- GIS mapping and data requests.

All these are high load FTE positions.

8.3.4. Recommendations

A traffic data exchange program is an effective way to save the agencies' resources and expand the coverage of traffic data collection with few extra costs. Other state programs, like that of Mn/DOT, have leveraged data collected by local agencies to expand the quantity of data collected (CTC and Associates LLC 2012). Future efforts should be made to improve the data exchange program and expand it to incorporate permanent sites if possible. In addition, more automatic processes (e.g. software to facilitate data sharing instead of using email or weblink, a program to pull short-term counts automatically instead of manually) need to continue to be implemented to reduce the work load and improve program efficiency. As the number of ATR/WIM sites increase, the issue of deferring maintenance and repair work will become more severe. MDT should continue to seek resources or process modifications to maintain the program efficiently, particularly for field operations, including the possibility of contracting out WIM calibration or more seasonal repair work to avoid delaying repairs until the following season.

The inventory and maintenance records of ATR/WIM sites are well documented, but are not currently in a manageable database system. Future efforts should be made to establish such a database system that contains all of the inventory information and the maintenance and repair history for all permanent sites. This system should be updated on a regular basis, and it should be easy to access, use, and maintain by TDCA Section field and office personnel. Using the information from this database system, a comprehensive assessment approach could be developed to evaluate the performance and condition of the inventoried ATR/WIM sites in Montana. The evaluation approach should take into consideration the number of years in service, maintenance history, calibration records, quality of the data collected, and site pavement condition, to yield a composite index to fully describe the condition and level of performance of each site. The condition and level of performance index could be further used to estimate the remaining life expectancy of each site, which could eventually serve as an input for program planning and prioritization.

Given the importance of the effects of pavement conditions on ATR/WIM sites, quantitative measures that objectively characterize ATR/WIM site pavement conditions should be developed. These quantitative measures could be incorporated into the ATR/WIM database system as one factor that describes site condition and performance. With respect to communication between the TDCA Section and Pavement Analysis Division, a formal mechanism should be developed to ensure TDCA Section staff are aware of pavement project activity around the state.

8.4. Traffic Data Types, Processing, and Accessibility

The TDCA Section has in-house personnel for data retrieval, analysis, display/presentation and distribution. This section evaluates the adequacy of the types of data collected, types of analysis performed, and accessibility of the data. Chapter 4 of this project reviewed in detail the data collection, analysis and presentation activities of the TDCA Section. Chapter 5 of this project surveyed data users within and outside MDT regarding how they used traffic data, how important it was to their activities, and how useful they found the specific data provided by the TDCA Section to be (i.e., relative to format and accessibility). The 33 responses received were overwhelmingly positive with respect to overall usefulness of the data provided and its importance to the many tasks they performed.

8.4.1. Data Types and Format

Generally, the traffic data collected by MDT can be grouped into three broad categories: volume, classification, and weight. The more sophisticated permanent ATR/WIM sites are capable of gathering more data items, such as refined classification data, when compared with short term counts.

Short Term Counts

The types of data collected from short term counts are restricted due to the limitations of the data collection devices (road tubes, video camera, and manual counts). Depending upon the setup, road tubes are capable of collecting volume, vehicle classification (FHWA 1-13), and vehicle speed data; video camera and manual counts are capable of collecting volume and vehicle classification data. Although individual vehicle data are captured, short term counts usually yield 1-hr binned data. This 1-hr binned data has sufficient resolution for the primary purpose of calculating estimated AADT.

Permanent Sites

Dependent upon the site configuration, the ATR sites within MT are capable of gathering volume, axle spacing/vehicle length (for determining vehicle classification), and speed data. In addition to the data that can be collected by ATRs, the quartz-piezoelectric WIM systems are capable of collecting the weight of each tier assembly, which is then used to calculate the axle weight and Gross Vehicle Weight (GVW). With respect to the raw data format, all WIM sites provide Individual Vehicle Records (IVR), whereas IVRs are only available from 19 ATR sites. All of the remaining ATR sites yield 1-hr binned data.

Recommendations

The traffic data collected from short term counts and permanent sites generally meet current needs. To fulfill future data needs, MDT may be required to report on several new data items. For instance, vehicle speed data are currently collected, but this information is not widely used. That being said, individual vehicle speed is an important indicator of traffic conditions/level of service. The three peer states that responded to the survey of data collection practices in Task 1 - ME, ND, and SD - all collect speed data, although no state appeared to attach major significance to it.

Travel time is another type of data that is very useful for various transportation activities, such as transportation planning, truck fleet management, etc. Interest in this information from the traveling public and commercial vehicle operators continues to increase, with this interest beginning to be reflected in government traffic data requirements. Travel time is not currently included in the data collected by the TDCA Section, partially due to the time consuming, costly and intrusive methods historically involved in collecting such data. Technologies have emerged and are commercially available for collecting travel time data non-intrusively (e.g. Bluetooth mac address matching, detective loop signature for truck travel time collection). Considering future needs, MDT may need to look into those new technologies and examine the feasibility to include travel time data in the traffic data collection program.

8.4.2. Data Processing

Traffic data processing at MDT includes data quality control/quality assurance (QC/QA). Quality control checks are performed before any analysis is done, and the processed data goes through further quality checks before being published.

Quality Control

Before the unprocessed (raw) data from short term counts and permanent sites are analyzed and made public, a quality control process is used to screen the data for erroneous and missing entries. The screening process is done automatically and/or manually based on a set of quality control criteria developed by MDT. The quality control checks review the reasonableness of the data relative to physical limits of the phenomena being measured and historical values.

Data Analysis

There are several types of data analysis performed by MDT. The volume data from ATR/WIM sites are used to determine ADT by day of week for each month and AADT. Vehicle classification is determined with axle spacing and vehicle length data. The volume and classification data determined from ATR/WIM sites are then used to calculate the traffic factors for each traffic factor grouping by day of week for each month. Further, these traffic factors are then employed to expand the short term counts to an estimated AADT. Another major type of analysis performed by MDT is the calculation of ESALs from weight data for pavement design (project level) and planning (network level) purposes. In addition, MDT calculates VMT from AADT.

The TDCA Section produces a series of data reports from the information collected and processed from ATR/WIM sites. The annual Traffic by Sections Report includes AADT and Daily VMT by various vehicle groups and truck percentages for highway sections delineated by major intersections, interchanges, and political boundaries. The annual VMT report presents the VMT by various road systems for the year, while the Estimated Monthly VMT Report has the VMT for rural and urban roads for each month. MDT also develops annual and monthly ATR/WIM reports. The annual ATR/WIM report includes the ADT for day of week, week for each month and their percentages in average weekday traffic and yearly ADT. Also included are traffic composition, directional distribution, current and historical AADT and percentages of design hourly volume in daily traffic. The monthly report presents monthly ADT and its change from year to year for commercial vehicles and all vehicles, as well as traffic volume by day, direction, and month for each ATR/WIM site in a calendar format. In addition to traffic reports, MDT also develops traffic factor tables for day of week in each month for nine traffic factor groups.

Recommendations

MDT currently covers all the analysis required for FHWA - HPMS data reporting (note that traffic collection impacts from the recently passed FAST Act may not be fully known at the time of preparation of this report). Furthermore, most of the analyses done by MDT are also done by the peer states surveyed in the study.

Axle load spectra is an important input for the MEPDG and some states (e.g. ME) develop the load spectra from weight data for pavement design purposes. Currently, MDT has not adopted the MEPDG, therefore, no data processing is performed to develop the axle load spectra. Given the WIM data being collected, it is possible to develop load spectra in the future. Another major change possible in data analysis in the near future is modification of the traffic factor groups that could possibly result from the traffic factor group study conducted (see Chapter 6).

8.4.3. Data Accessibility

All the traffic data reports are made available to the public. The high demand reports are accessible online as downloadable files and less frequently requested reports or user specific data are available upon request. In addition, MDT employs online tools to present and display the traffic data.

Online Tools

The online interactive map-based GIS tool used by MDT allows users to select a highway section and retrieve selected traffic data. The data includes general location data, site data, AADT, traffic composition, etc. With the GIS tool, the traffic data can be displayed in a graphical format and a map format. An example of the MDT traffic data GIS system is shown in Figure 77.

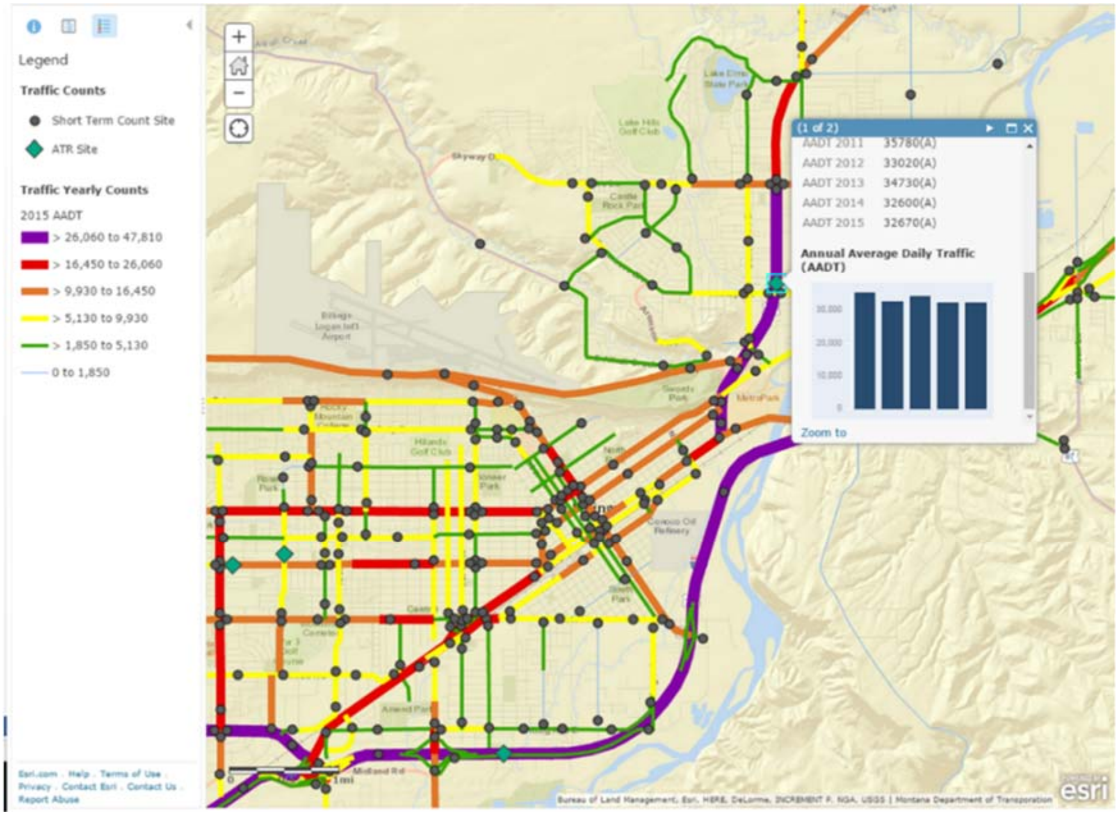


Figure 77: MDT Traffic Data GIS System

As previously discussed, MDT has recently transitioned to an interactive data management system, the TCDS. The TCDS has functions to calculate all of the traffic statistics provided by MDT's previous traffic processing software system and is capable of presenting traffic data in both a visual and numerical format. While few respondents to the survey in Task 4 had used the TCDS, the available feedback was positive. One respondent that had used the system felt it was less user-friendly than the previous system, but also explained that they anticipated becoming accustomed to it over time.

Recommendations

With regard to traffic data accessibility, MDT is ahead of the peer states surveyed. Data mapping is the trend to present and display traffic data. In the future, work should continue on refining the general users' online interactive map-based GIS tool and providing users with training on the enhanced data analysis and reporting capabilities of the TCDS.

8.5. Summary

Overall, MDT's traffic data collection efforts meet their basic data needs, as well as the needs of other data users (i.e., state highway patrol, metropolitan planning districts, and tribes), and they do so in a manner consistent with the level of facilities and resources of other state programs. That being said, and as the TDCA Section has and continues to do, various improvements could and should be considered, notably as technologies improve and data user needs continue to evolve and become more sophisticated.

Relative to traffic data collection sites, the current WIM/ATR sites are, on average, adequate in number and distribution across the highway network to meet general HPMS and TMG guidelines, and are generally similar in number to those found in other states. Nonetheless, work should continue on identifying routes that merit increased data collection to improve representation of traffic operations across the state with respect to both volume and weight related traffic demands. On a related task, assessment should continue of the basic structure of the traffic factor and weight factor groups used by MDT, to ensure these groups reasonably represent operations across the highway network. Prioritization of future WIM/ATR deployments is critical to ensure any new data collection sites optimally contribute to the needs of the data collection program. This prioritization process is addressed in Chapter 7.

Relative to data collection equipment, MDT continues to employ advanced technologies with a high level of automation. One area of needed improvement is in data collection in urban environments, although this problem is not unique to MDT. Cost effective technologies to reliably collect traffic data under stop-and-go conditions are not available. MDT should continue to be alert for the development and validation of any such technologies.

From a management and operations perspective, MDT's vertical integration of data collection activities within a single administrative section should result in ongoing positive technical and fiscal performance of the overall program. That being said, the current staff only consists of fourteen permanent employees, a supervisor, a unit supervisor, and three seasonal workers, which are responsible for all traffic data activities, including field installation, operation, calibration, and maintenance; in-office data download, processing, reporting, display, and distribution; and program planning/budgeting. Relative to equipment, while extensive inventory information and maintenance and repair histories are available for all permanent sites, this information needs to feed a database that subsequently can be used to proactively plan/manage equipment maintenance and replacement activities. Pavement conditions are critical to system performance. Therefore, current pavement condition at sites needs to be better evaluated and routinely documented. This information could then be used in conjunction with other equipment related information to objectively establish the condition and level of performance of each permanent data collection site.

Based on a survey of data users both within and outside MDT, the types of data made available by the TDCA Section, and the manner in which it is made available, is satisfying their needs. Independent of this survey, interest in freight transportation continues to be strong at the federal level, and associated traffic data needs related to freight initiatives should be considered. At the opposite end of the spectrum, interest in bicycle and pedestrian traffic data is also increasing, and collection of this data should also be given some consideration. Interest in travel time data and related performance measures is increasing in general across the motoring public and commercial vehicle operators, and MDT might begin investigating how this data can be collected and disseminated.

9) SUMMARY AND RECOMMENDATIONS

The objective of this project was to assess the adequacy of the traffic data collection efforts of MDT, with a focus on its continuous/permanent data collection activities. Several major tasks were completed in realizing this objective – as summarized in each Chapter of this report:

- the state-of-the-practice was reviewed (Chapter 2),
- a detailed description of MDT's current traffic data collection program was prepared (Chapter 3),
- the current data collection, analysis, and dissemination practices of MDT were reviewed, with preliminary work being done to identify areal traffic patterns and their associated economic causation (Chapter 4),
- traffic data users were surveyed regarding what data they use, how they use it, and how well their data needs are being met (Chapter 5),
- current traffic factor groups and selected alternative grouping schemes were investigated (Chapter 6),
- a methodology was developed for the prioritization and planning of new permanent count sites (Chapter 7), and
- based on the preceding tasks, the overall adequacy of MDT's traffic data collection effort was assessed (Chapter 8).

MDT's data collection efforts are the responsibility of the TDCA Section, and this assessment considered the full spectrum of their activities, from data collection, to data analysis, to data dissemination.

Overall, MDT's WIM/ATR program was found to be efficiently and effectively meeting traffic data needs, both within and outside MDT. This conclusion is supported by, among other observations, that

- data is being collected using accepted technologies researched by TDCA Section personnel as appropriate to conditions in Montana,
- ATR/WIM data collection sites are generally comparable in number with similar states and are located to support the state's traffic/weight factor groups consistent with established practice,
- data processing includes appropriate quality control checks, and
- data users are well satisfied with the data they are being provided.

That being said, traffic data collection is a dynamic activity, due to ever evolving technologies and practices to collect, process and present data, and ever changing data user needs. As they have done, the TDCA Section needs to continue to stay abreast of developments in this field, to maintain the efficacy of their efforts.

Selected observations from each task above include:

State-of-the-Practice Review:

- Many technologies can be used to collect traffic data, but typically the more-established technologies that are used consist of inductance loops and piezoelectric sensors for ATRs, piezoelectric sensors, bending plate, and single load cells for WIMs, and pneumatic tubes for short-term counts.
- Many communication technologies are used to transmit the traffic data including landline, cellular, and high-speed wireless and network systems.
- Many software packages exist for data processing and quality checking.
- Several states, like MDT, are using WIMs in Virtual Weigh Stations and real time weight enforcement.

Description of MDT Data Collection Program:

- The TDCA Section is responsible for short-term and permanent traffic data collection, traffic data processing, and data QA/QC and analysis, as well as data presentation/display.
- There are currently 106 permanent count sites (64 ATR and 42 WIM) spread across the state, and 5,800 short-term count locations, with approximately 3,000 counts performed annually.
- Overall, the TDCA consists of fourteen permanent employees, a unit supervisor and a section supervisor and, three seasonal staff positions.
- Total annual program cost (labor, equipment, supplies, travel, contracted services, personnel training, etc.) is approximately 1.9 million dollars.

Data Collection, and Analysis and Dissemination:

- The ATR systems collect volume, speed and vehicle classification data; the WIM systems collect data on axle/gross vehicle weight (in addition to volume and speed data).
- The data are quality control checked for "reasonableness" both automatically and by experienced TDCA personnel based on physical limits on the parameters being measured and on their historic recorded values.
- The data are used to determine various characteristics of the traffic operating on the state's highways, such as AADT, VMT, ESALs, etc.
- Traffic data dissemination is realized through a variety of publications, interactive maps and software applications, and are generally available on the internet or upon request; MDT also uses TCDS, a commercial software package that allows those within MDT (notably including MCS enforcement) and external data sharing partners, including metropolitan planning organizations and other local agencies, to view timely speed, volume and weight data.
- Large local/regional fluctuations in traffic volumes and in the composition of the traffic stream are encountered on many of Montana's highways both temporally and spatially, as

the state's economy is agriculture, natural resource extraction and tourism intensive; identification and characterization of these flows is important to ensure they are being captured by data collection efforts.

Survey of Traffic Data Users:

- Traffic data users both within and outside MDT are well satisfied with the information being provided to them.
- The data are primarily being used for planning, design and safety analysis purposes, with the most frequently used data being AADT, ESALs, and percentage of trucks.
- The data was described as vitally important, supporting for example, numerous federal reporting requirements, which are directly tied to the funding that a state department of transportation receives.
- Some data may not be provided in as timely a manner as necessary to optimally support reporting requirements. For example, much of the traffic data required for submittal to FHWA as part of the HPMS isn't available until sometime in May, which can make it difficult to prepare for the submittal deadline in June.
- Certain ATV, pedestrian, and transit data are desired by some users, but these data may be outside the scope of typical traffic data collection activities.
- The majority of survey respondents currently made use of the website, and those that use it found it valuable.

Traffic Factor Grouping Analysis:

- The traffic factor groups analysis investigated three alternative approaches to the current groupings that are based primarily on the nature of a route's use, as generally categorized by highway functional classification; these alternatives were:
    - grouping by vehicle type, i.e., commercial versus non-commercial and functional classification,
    - grouping by area of the state and its socio-economic characteristics, and functional classification, and
    - grouping by a simplified functional classification scheme, i.e., interstate versus non-interstate with subcategories of rural and urban.
- In considering the first alternate grouping scheme, commercial vehicles were found to have different patterns in average daily traffic over the year compared with all vehicles, particularly during weekend days, and using separate adjustment factors for commercial traffic may be beneficial.
- The second grouping scheme, i.e., by area /economic activity, while generating reasonably accurate adjustment factors, may be somewhat impractical to implement. Notably, the assignment of stations to a group is generally subjective in nature.
- The third grouping scheme, i.e. the modified functional classification scheme, has merit in that it simplifies the estimation and use of adjustment factors while not compromising accuracy.

- A hybrid traffic factor grouping scheme that uses the simplified classification scheme coupled with subdivision by commercial versus non-commercial vehicles may be the direction that should be pursued.

WIM/ATR Site Prioritization Methodology:

- In a resource constrained environment, it is essential that future WIM/ATR sites be selected to optimally support the objectives of the overall data collection program.
- Optimization of WIM/ATR site selection is complicated, in that traffic data is collected to support several activities, of competing priorities.
- A potential approach to developing a methodology that ensures the factors important in the selection of future sites are systematically considered with consistent application of agency priorities is a WSM model.
- In this case, the outcome of the WSM is a numerical ranking for a potential site, based on a) how well the site meets various agency selected criterion, and b) the priority of that criterion in the selection process, also as established by the agency.
- The results of the WSM is not expected to be the sole input used in the site selection decision-making process, as the problem is complicated, but the WSM will provide a systematic, quantitative input in this regard.
- Two example WSM models were developed, one that considers ATR and WIM sites together in the prioritization process, and one that considers them separately.
- The WSM should also be an effective tool in evaluating the efficacy and potential retirement of existing data collection sites.

General Summary - Adequacy of Data Collection Efforts and Recommended Actions:

- Overall, MDT's traffic data collection efforts meet their basic data needs, as well as the needs of other data users (i.e., metropolitan planning districts, and tribes), and does so in a manner consistent with the level of facilities and resources of other state programs.
- The TDCA Section has and should continue to consider various improvements in data collection (especially for urban environments) and processing technologies, notably as they potentially advance and as data user needs continue to evolve.
- The current WIM/ATR sites are generally adequate in number and distribution across the highway network to meet broad HPMS and TMG guidelines, and are generally similar in number to those found in other states; nonetheless, work should continue on identifying local areas with increased vehicle activity that merit increased data collection coverage to adequately characterize both volume and weight related traffic demands.
- Assessment should continue of the basic structure of the traffic and weight factor groups used by MDT to ensure these groups reasonably represent operations across the highway network; relative to traffic factor groups, the alternative grouping scheme consisting of a simplified classification of interstate versus non-interstate, and commercial versus non-commercial vehicles developed in this project should be considered.

- The site selection/prioritization method developed (WSM model) in this project should be used to improve the objectivity of the site selection planning process and also used in the evaluation of the efficacy and possible retirement of existing sites.

Additional Points - Adequacy of Data Collection Efforts and Recommended Actions:

- MDT should continue its practice of vertical integration of data collection activities within a single administrative section to continue to realize the positive technical and fiscal benefits this brings to the overall program.
- Additional staff and/or seasonal staff may benefit the TDCA Section to ensure critical seasonal field work can be completed each year (e.g., equipment maintenance), and to allow various new operations initiatives to be pursued, such as implementation of an improved equipment database to better support system planning/management decisions.
- Traffic data collection in urban environments continues to be problematic (not just for MDT, but in general), and MDT should remain alert for any developments in technology that make this feasible.
- The current pavement condition at sites needs to be better evaluated and routinely documented as it is a critical element in system performance.
- The current database of maintenance, repair and pavement information at WIM and ATR sites should be improved to better use this information and better manage these assets.
- Opportunities to work with local and other agencies in data exchange programs could be a cost effective way to expand data collection and meet additional data user needs.
- Looking toward the future, interest in freight transportation continues to be strong at the federal level, and associated traffic data needs related to freight initiatives should be considered as they become more clearly defined.
- Interest in travel time data and related performance measures is increasing in general across the motoring public and commercial vehicle operators, and MDT should begin investigating how this data can be gathered, disseminated, and utilized by the appropriate groups within MDT.
- Interest in bicycle and pedestrian data is also increasing, and collection of this data should be given appropriate consideration.

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APPENDIX A: PEER STATE SURVEYS

For each responded questionnaire, the answers in green are the information filled in by the research team and verified/updated by each state, those in black are responses from each state, and those in red are clarified information through follow-up phone interviews or emails.

North Dakota's Survey Response

Part I Preliminary Questions

1. **General size of your current WIM and ATR traffic data collection program**
    a. **Number of WIM sites:**
    13
    Number of *functioning* WIM sites:
    7 – remaining sites will be repaired in 2013/2014

    b. **Number of ATR sites:**
    50
    Number of *functioning* ATR sites:
    ~~49~~

    c. **Number of WIMs or ATRs owned or operated by data sharing partners outside of your DOT: (i.e. MPOs, cities, etc.):**
    2

    d. **What other technologies are you currently using to collect traffic data year-round? (i.e. cameras, infrared sensors, in-road pucks such as Groundhogs, etc.)?**
    Miovision Video ~~Camera~~ Technology

2. **Management and operation of your current traffic program**
    a. **Staffing composition and organizational structure of the traffic data collection unit in your DOT.**

    If possible, please provide a chart showing the organizational structure and size of the traffic collection unit in your DOT.

    - Staffing composition and organizational structure is comprised of;
        - 1- FTE Section Leader, office personnel
        - 2- FTE traffic/WIM data analysis/quality control etc, office personnel
        - 2- FTE traffic data collection crew members, field personnel
        - 1- FTE traffic data collection crew member (field personnel) but only 50% of their time is utilized for traffic data collection duties.

    b. **Number of personnel involved**

Indicate the number of FTEs responsible for each of the following WIM and ATR functions. If the work is contracted out, check the "Contracted out" box:

Functions	# of FTEs if done in house	Check the cell if contracted out
Installation		x
Maintenance	8	
Repair		x
Calibration	8	

Indicate number of FTEs responsible for processing, QCing, and analyzing WIM and ATR data:
2
Please check this box if these services are contracted out: ☐
Maintenance and Calibration are separate Divisions/Departments from the Traffic Data Collection Division/Department

c. **WIM calibration**
Please indicate how your WIMs are calibrated, even it is contracted out:
Method: several calibration runs are made over the site with a (known weight) 5 axle semi-tractor/trailer loaded between 76,000 and 80,000lbs
We make enough calibration runs with the calibration vehicle until we are satisfied that the site can't be calibration any further or that the results can get any better so the threshold will vary and so we really have no threshold.
Cycle: yearly
Typically every fall or late summer. We are in fact starting next week with the calibration.

d. **Annual ATR and WIM program costs. If these services are contracted out, please indicate if the contract is a set fee per year or by the volume of data or number of sites, etc.**

Services and Duties	Annual Cost ($)	
	Done in house	Contracted out
Installation		N/A depends on the number of sites being installed, but this work is bid out
Maintenance	See Traffic data collection from WIM and ATR's below	
Repair		N/A depends on the number of sites being repaired, but this work is bid out
Calibration	$10,000	
Traffic data collection from WIM and ATRs (i.e telephone, power, etc.)	This is an estimate only $35-$40k but includes Maintenance from above	
Traffic data analysis	$110,000	

Distribution (i.e. compiling/printing of monthly, annual publications, etc.)	This is an estimate only < $5000	

permanent installation costs of those sites only and not a cost for portable (short term sites) data

3. **Program planning/prioritization**
   Please explain
   a. **How were the locations of your current WIM and ATR sites determined?**
      Since 2006, ATR sites have been determined using a long range or ITS Deployment Plan based on traffic volume needs for design, growth, gaps in coverage. Original 12 WIM sites were placed near our static weigh stations as these weigh stations were closed or open during limited times only.

   b. **What methodology will you use for planning/prioritization of future WIM/ATR sites?**
      Based on needs, growth etc.
      If possible, please provide documentation on your process.
      Will continue to use and update the ITS Deployment Plan, listen to our stakeholder, customers.

Part II Data Collection Technology

1. **Current deployed WIM/ATR technologies (Brand, sensor type, communications, etc.)**
   - PEEK portable ADR and road tubes
   - Diamond Traffic portable volume counters and road tubes
   - Miovision Video technology
   - IRD WIM electronics and Kistler piezo sensors
   - PEEK permanent models ADR and loop and/or AXOR K piezo sensors

   Communication technology varies some fiber optic, some hard line telephone, some cellular. This fall we will be trying a test project at several WIM locations of IP addressable communications
2. **Are you testing any WIM/ATR technologies or are you aware of new technologies you would like to test but currently can't due to funding or resource limitations?**
   Yes, a traffic data sensor study is being performed by our Advanced Traffic Analysis Center (ATAC) which is a branch of the NDDOT and the North Dakota State University

Part III Traffic Data Collection, Analysis, and Presentation

1. **Types of traffic data currently being collected through WIM/ATR?**
   WIM – GVW/axle weights, spacing, number, speed, date/time.
   ATR – class, speed, date/time

2. **What format is your WIM and ATR collected in? (i.e. binned or individual vehicle records):**
   PVR – per vehicle record and binned

3. **Types of analysis performed on the traffic data collected (i.e. weight trend analysis, average speed by time of day, day of week, etc.):**

Weight trends, front axle and GVW weight, some speed analysis, time of day, day of week, class, volume

4. **How are the traffic data displayed/presented and accessed by users? (i.e. is your data available on the DOT's website? Upon request? etc.)**
   Yes, all portable traffic counts are available on NDDOT website
   no other traffic data Not at this time.
   On our website the user can view the traffic data. We serve our other customer's with traffic data - provided in several types of formats depending on their needs. Some examples are ArcGis/ArcMap shape files, pdf's, Excel

5. **What are your future goals regarding data collection, analysis, and presentation in regards to your WIM and ATR program?**
   Maintain/repair/upgrade of ATR and WIM network

Part IV Traffic Data Users

1. **Current traffic data users:**
   Please indicate which of the following are current users of your traffic data:

   Internal Users:
   Planning staff Yes
   Traffic Operations Yes
   Traffic Safety Yes
   Highway Design Yes
   Weight Enforcement Yes
   Speed Enforcement
   Others not listed:
   Camera images for traveler information system – this camera system that I believe you are referring to does not collect traffic data – the images available on our website are from our Environmental Sensor Station ESS or RWIS – road weather information camera/sites

   External users:
   FHWA Yes
   Colleges/Universities Yes
   Research Institutes Yes
   Consulting companies Yes
   Realty companies Yes
   Others not listed:

2. **Unmet data needs**
   Are you aware of any unmet needs of your data users? (i.e. enforcement customers needing speed data in a format or structure that you are not currently able to provide or quality vehicle classification data on certain roadways?) If so, please indicate the unmet data need and provide the reason you are not currently able to meet this need. none at this time

South Dakota's Survey Response

Part I Preliminary Questions

4. **General size of your current WIM and ATR traffic data collection program**
   a. **Number of WIM sites:**
      15
      Number of *functioning* WIM sites:
      14

   b. **Number of ATR sites:**
      62
      Number of *functioning* ATR sites:
      62
      Number of WIMs or ATRs owned or operated by data sharing partners outside of your DOT: (i.e. MPOs, cities, etc.)
      none

   c. **What other technologies are you currently using to collect traffic data year-round? (i.e. cameras, infrared sensors, in-road pucks such as Groundhogs, etc.):**
      WIM: using load cells, bending plates and Kister quart piezo.
      ATR: using Peek ADR 6000 system, piezo, wavetronic radar sensors and loops.

5. **Management and operation of your current traffic program**
   a. **Staffing composition and organizational structure of the traffic data collection unit in your DOT:**
      Transportation Division----Highways Section-----Traffic Monitoring Program
      6 permanent employees and 1 supervisor

   If possible, please provide a chart showing the organizational structure and size of the traffic collection unit in your DOT.

   b. **Number of personnel involved**
      - Indicate the number of FTEs responsible for each of the following WIM and ATR functions. If the work is contracted out, check the "Contracted out" box:

Functions	# of FTEs if done in house	Check the cell if contracted out
Installation	7 (maybe 1% of a working year)	
Maintenance	7 (maybe 1% of a working year)	
Repair	7 (maybe 1% of a working year)	
Calibration	7 (maybe 1% of a working year)	

Indicate number of FTEs responsible for processing, QCing, and analyzing WIM and ATR data:

1 collecting, 1 analyzing (50% of a working year)
Please check this box if these services are contracted out: ☐

c. **WIM calibration**
Please indicate how your WIMs are calibrated, even it is contracted out:
Method: Contracted with IRD for repairs and calibration using a SDDOT supplied class 9 semi (following the ASTM standard procedure, load cells (the most expensive, ±10%, bending plates ± 15%))
Cycle: Yearly during Summer time, doing it right now. Since at winter, the load frame doesn't work very well due to the frozen soil

d. **Annual ATR and WIM program costs. If these services are contracted out, please indicate if the contract is a set fee per year or by the volume of data or number of sites, etc.**

Services and Duties	Annual Cost ($)	
	Done in house	Contracted out
Installation	Combined cost of all the service and duties is estimated as the 5% of the total traffic monitoring staff salary, $15/hr, it is around 10,000.	
Maintenance		
Repair		
Calibration		
Traffic data collection from WIM and ATRs (i.e telephone, power, etc.)		WIM calibration costs around $20,000 yearly
Traffic data analysis		
Distribution (i.e. compiling/printing of monthly, annual publications, etc.)		

Note: since the permanent sites are operated automatically, most of the hrs and labor of traffic monitoring staff are spend on short-term traffic data collection, e.g. driving around the state to date collection sites.

6. **Program planning/prioritization**
Please explain
a. **How were the locations of your current WIM and ATR sites determined?**
Using FHWA TMG
b. **What methodology will you use for planning/prioritization of future WIM/ATR sites? If possible, please provide documentation on your process.**
Using FHWA TMG
Will add 1 more WIM site next year, then the permanent data collection system is well done, no plan to add more sites in the foreseen future. DOT is satisfied with the current system, which meets all the needs

Part II Data Collection Technology

3. **Current deployed WIM/ATR technologies (Brand, sensor type, communications, etc.)**
WIM: using IRD load cells, bending plates and Kistler quartz piezo.
ATR: using Peek ADR 6000 system, piezo, Wavetronix radar sensors and loops.
All the permanent sites have telephone line, and DOT use vendor specified software for data transmission or communication.

4. **Are you testing any WIM/ATR technologies or are you aware of new technologies you would like to test but currently can't due to funding or resource limitations?**
   No

Part III Traffic Data Collection, Analysis, and Presentation

6. **Types of traffic data currently being collected through WIM/ATR?**
   ATR - Traffic counting and classifying data WIM - Weight
7. **What format is your WIM and ATR collected in? (i.e. binned or individual vehicle records)**
   WIM: individual vehicle records
   ATR: binned

8. **Types of analysis performed on the traffic data collected (i.e. weight trend analysis, average speed by time of day, day of week, etc.)**
   Yes

9. **How are the traffic data displayed/presented and accessed by users? (i.e. is your data available on the DOT's website? Upon request? etc.)**
   Yes Reports are available for download in pdf format.

10. **What are your future goals regarding data collection, analysis, and presentation in regards to your WIM and ATR program?**
    Yes No intention to incorporate GIS for data display/presentation (only have GIS for internal use) , considering that the maintenance fee is expensive and that may limit the number of external users (if the users don't have GIS system)

Part IV Traffic Data Users

3. **Current traffic data users:**
   Please indicate which of the following are current users of your traffic data:

   Internal Users:
   Planning staff Yes
   Traffic Operations Yes
   Traffic Safety Yes
   Highway Design Yes
   Weight Enforcement No
   Speed Enforcement No
   Others not listed:
   Note: state legislation doesn't allow DOT to use weight data for weight enforcement, due to the strong farming and trucking lobby in SD. Even highway patrol is interested in weight data, but DOT is not allowed to provide such data.
   Since the FHWA does not require speed data, DOT doesn't pay much attention to speed data, not real-time speed data for traveler information system.
   External users:
   FHWA Yes

Colleges/Universities	Yes
Research Institutes	Yes
Consulting companies	Yes
Realty companies	Yes
Others not listed:	

4. **Unmet data needs**
   Are you aware of any unmet needs of your data users? (i.e. enforcement customers needing speed data in a format or structure that you are not currently able to provide or quality vehicle classification data on certain roadways?) If so, please indicate the unmet data need and provide the reason you are not currently able to meet this need.
   No

Maine's Survey Response

Part I Preliminary Questions

7. **General size of your current WIM and ATR traffic data collection program**
   a. **Number of WIM sites:**
      16
      Number of *functioning* WIM sites:
      9

   b. **Number of ATR sites:**
      69
      Number of *functioning* ATR sites:
      66

   c. **Number of WIMs or ATRs owned or operated by data sharing partners outside of your DOT: (i.e. MPOs, cities, etc.):**
      2

   d. **What other technologies are you currently using to collect traffic data year-round? (i.e. cameras, infrared sensors, in-road pucks such as Groundhogs, etc.):**
   Radar Cameras

8. **Management and operation of your current traffic program**
   Staffing composition and organizational structure of the traffic data collection unit in your DOT. If possible, please provide a chart showing the organizational structure and size of the traffic collection unit in your DOT.

   a. **Number of personnel involved**
      Indicate the number of FTEs responsible for each of the following WIM and ATR functions. If the work is contracted out, check the "Contracted out" box:

Functions	# of FTEs if done in house	Check the cell if contracted out
Installation	1	
Maintenance	1	
Repair	1	
Calibration		

We have one Technician who is responsible for installation, maintenance and repair of all volume and classification sites. There is one Senior Technician who oversees the WIM program. He performs some maintenance and repair work, but contracts out most of this as well as all installation activities.

Indicate number of FTEs responsible for processing, QCing, and analyzing WIM and ATR data
Please check this box if these services are contracted out: ☐
The data analysis is done in Transportation Analysis Division, not by traffic monitoring program. No FTEs are assigned to WIM data analysis, they all have other duties.

b. **WIM calibration**
Please indicate how your WIMs are calibrated, even it is contracted out:
Method: Calibrated truck
Cycle: once per year
It's done in-house. We use a Class 9 truck weighing 80,000 pounds; the threshold for error is 5%. Calibration is done in late fall or early spring due to availability of the truck

c. **Annual ATR and WIM program costs. If these services are contracted out, please indicate if the contract is a set fee per year or by the volume of data or number of sites, etc.**

Services and Duties	Annual Cost ($)	
	Done in house	Contracted out
Installation	ATR-$60,000	Wim $85-150,000 per site
Maintenance	ATR-$30,000 Wim-$35,000	
Repair	ATR-$10,000	Wim-$25,000
Calibration	Wim-$30,000	
Traffic data collection from WIM and ATRs (i.e telephone, power, etc.)	ATR - $35,000 Wim-$15,000	
Traffic data analysis		
Distribution (i.e. compiling/printing of monthly, annual publications, etc.)	ATR-$2,500 Wim-$1000	

9. **Program planning/prioritization**
Please explain
a. **How were the locations of your current WIM and ATR sites determined?**
The majority of the volume sites were located on the higher Federal Functional Classes and concentrated in the higher volume cities/towns. High priority was

given to the Interstate System. Most of the 16 counties were given at least one site. The permanent classification sites were placed in areas where the Bureau of Planning requested based on the major trucking routes and recreational traffic. Wim locations were selected to give a broad cross section of the interstate truck traffic using both major and minor routed highways.

What methodology will you use for planning/prioritization of future WIM/ATR sites? If possible, please provide documentation on your process.

New sites are generally based on the needs of the Bureau of Planning and on areas where significant development has occurred.

New WIM sites are selected based on the Bureau of Planning, and commercial weight law changes.

Part II Data Collection Technology

5. **Current deployed WIM/ATR technologies (Brand, sensor type, communications, etc.)**
   ATR Volume – Peek ADR counters, inductance loops
   ATR Classification – Peek ADT counters, Wavetronics Smart IQ Radar sensor, Measurement Specialties Brass Lingini Class 2 piezo sensors and inductance loops
   Communication – landlines (dial up @ 9600 Baud) and cellular communication
   Wim Equipment Primarily consists of Ecm Hestia 2 and 6 lane systems using Kistler instrument Quartz sensors, We also have 2 Mettlor Toledo systems using kistler sensors
6. **Are you testing any WIM/ATR technologies or are you aware of new technologies you would like to test but currently can't due to funding or resource limitations?**
   We are testing the Aldis Gridsmart camera for volume counting. No additional Wim system tests at this time.

Part III Traffic Data Collection, Analysis, and Presentation

11. **Types of traffic data currently being collected through WIM/ATR?**
    Traffic volumes, vehicle classification, speed, vehicle weights
12. **What format is your WIM and ATR collected in? (i.e. binned or individual vehicle records)**
    All ATR data is collected in binned data; all WIM data is collected in individual vehicle records
13. **Types of analysis performed on the traffic data collected (i.e. weight trend analysis, average speed by time of day, day of week, etc.)**
    AADT, Weekly Group Mean Factors is done by Traffic Monitoring within the Traffic Engineering Division. The majority of the analysis is accomplished by the Transportation Analysis Division of the Bureau of Planning. Please contact Ed Hanscom (207)624-3320 for further information.
    The analysis of WIM data is mainly for pavement design, including the calculation of ESALs for traditional design method, and developing seasonal variation and truck load distribution by vehicle type for MEPDG. (Mike Morin, (207)624-3285)
14. **How are the traffic data displayed/presented and accessed by users? (i.e. is your data available on the DOT's website? Upon request? etc.)**

Develop yearly images of traffic count data; the latest annual traffic count report by county and by Municipality is available online for download in pdf format. Data is scanned into the Department's electronic filing system and is available by request.

15. **What are your future goals regarding data collection, analysis, and presentation in regards to your WIM and ATR program?**
Hopefully, to develop a comprehensive software system to collect, analyze and store all types of data. Currently, in-house programs utilizing Microsoft Acces/Excel and Visual Basic Programming are used to process and store data. We would like to provide more information to the public online; AADT data would be available on a GIS system for easy retrieval.

Part IV Traffic Data Users

5. **Current traffic data users:**
Please indicate which of the following are current users of your traffic data:

Internal Users:
Planning staff Yes
Traffic Operations Yes
Traffic Safety Yes
Highway Design Yes
Weight Enforcement **Yes (share weight data with state police to facilitate enforcement)**
Speed Enforcement
Others not listed: Provides real time speed, highway images, and traffic condition map on major highways and turnpike for Traveler Information System

External users:
FHWA Yes
Colleges/Universities Yes
Research Institutes Yes
Consulting companies Yes
Realty companies Yes
Others not listed:
Other State Agencies, Legislative Branch

6. **Unmet data needs**
Are you aware of any unmet needs of your data users? (i.e. enforcement customers needing speed data in a format or structure that you are not currently able to provide or quality vehicle classification data on certain roadways?) If so, please indicate the unmet data need and provide the reason you are not currently able to meet this need.
Bureau of Planning needs more classification data in urban areas. Currently, there are few technologies that are able to provide this data and are expensive. The new federal requirements for speed data will create problems as we have no method for processing that data.

APPENDIX B: ATR SITE WINTER MAINTENANCE

- Take GPS reading of site if needed
- Check Road Sensor Condition. (Piezos, Loops, Pull Boxes)
- Check General Site Condition
- Break and make terminal connections
- Record serial #'s for Modem and ATR
- Board versions
- Check batteries for corrosion, record voltages and do battery capacity test
- Check internal battery, record voltages and do battery capacity test
- If conditions are acceptable check output of:
  - Solar panel (Approx. 2 volts above battery given good sun)
  - Regulator output no load, also regulators with dual voltage outputs-14.2v and 7.5v
  - Note these values on ATR maintenance sheet
- Check for general wear and tear
- As needed:
  - Silicone / Tar cracks
  - Paint cabinets
  - Oil hinges
- Sensor Maintenance
  - Measure L, R, Q of loops and record results
  - Meg and Cap piezos and record results
- ATR Maintenance
  - Open box
  - Check Battery
  - Pull cards apart
  - Pull battery from card and drain caps
  - Replace cards
  - The unit should do a cold hard restart upon power-up.
  - Perform config and setup.
  - Call office to finish programming
- Run Calibration runs appropriate for site settings with office on phone

APPENDIX C: ATR & WIM SITE BASIC SELECTION CRITERIA

General site selection criteria applicable to both ATR and WIM locations:

- **<u>Roadway topography</u>**:
    - Roadway should be as level as possible.
        - No hills or sharp curves within ¼ mile of either end of the proposed site.
    - Need at least 600 feet of straight, flat pavement at proposed location. (300 feet minimum upstream and downstream of the proposed sensor location).
    - Available right-of-way must allow cabinet to be placed outside of the clear zone, typically a minimum of 30 feet from the edge of the nearest lane of travel. (Clear zone distances depend on traffic volume, posted speed, road topography, and shoulder slope characteristics, so the actual distance can vary.)
    - Available right-of-way must be accessible by service vehicles for installation and maintenance purposes.
- **<u>Utility availability:</u>**
    - Electrical power:
        - *For solar sites:*
            - Exposure to the sun must be adequate to accommodate solar panel requirements in all seasons. Southern exposure should not have any obstructions more than 15 degrees above the horizon from 110 degrees to 250 degrees (east to west) if possible to accommodate the track of the sun during the winter months.
        - *For A/C powered sites:*
            - A/C power must be accessible via power lines located within 150 feet of right-of-way fence on the side of the road where the cabinet is to be located. We do not want overhead power lines to be placed over the highway near our sites as they interfere electrically with the sensors in the road.
            - Power should be able to be delivered to the cabinet via underground service. Utility easements from adjacent private landowners must be obtainable in order to run underground serve to the cabinet.

- Communications:
    - *Cellular phone service:*
        - This is the preferred communications service if it is available. Signal type and strength is measured at the proposed cabinet location to determine the feasibility of cell service.
    - *Land-line phone service:*
        - Only used if cell service is not available. Land-line service access must be within the provider's specified hook-up range (varies by provider) so that no installation charges are applicable in order to keep costs down. Line quality must be able to handle data transmissions. DSL service is acceptable (and is becoming preferable).

- **Pavement conditions:**
    - *Rutting:*
        - Cannot be more than ¼ inch deep for WIM sensor installation.
        - Can be more than ¼ inch deep but should not exceed ½ inch deep for ATR sensor installation.
    - *Cracking:*
        - Transverse cracking is acceptable if the cracks are no more than ½ inch in width and have enough space between them to accommodate the sensor array. It is preferable to avoid pavement with transverse cracks as crack width varies with the seasons and new cracks can form at any time, including in the middle of the sensor array.
        - Longitudinal cracking is not acceptable at all as this means the cracks must be crossed by the sensors/sensor leads, and seasonal changes in crack sizes will damages sensors/sensor leads.
    - *Spalling:*
        - Pavement that is spalling (or scaling, chipping, flaking or generally breaking up) is not acceptable as the surface deterioration will lead to sensor damage.
    - *Lift adhesion issues:*
        - Any signs of overlay lift adhesion issues are unacceptable as the loose lifts will move with traffic and tear the sensors out of pavement.
    - *Chip seal adhesion issues:*
        - Loose or missing chip seal should be avoided if possible as it will continue to come loose over time and drive a need for more sensor maintenance than is normally necessary. Excessive grinding on sensor surfaces due to missing chip seal leads to premature sensor failure.

- **WIM specific criteria:**
  - *Calibration truck turn-around locations:*
    - For 4 lane installations, normal interstate exits are used. Exits should be at least 1 mile from the proposed site location and no more than 5 miles away if possible.
    - For 2 lane installations, turn-arounds should be at least 1 mile away and no more than 5 miles away if possible. 2 Lane turn-around locations have to be able to accommodate the size of the calibration truck, and have to provide adequate space to allow the truck to be driven safely out of the lanes of travel. Additionally, there has to be good visibility in both directions to allow the driver to safely return the truck to the lanes of travel. Unpaved turn-arounds are acceptable, but these have the limitation of being usable only in dry conditions as they typically will not support the weight of the calibration truck when wet. It is also highly preferable that all 2 lane truck turn-arounds are located within the highway right-of-way so as not to occur any liability issues when using private property.

APPENDIX D: CALCULATION OF COMMODITY FLOWS

Wheat - Data Source – Annual Production in Bushels: (USDA 2013)

Spring Wheat	95,700,000 Bu	60 lbs/Bu	2,871,000 t		
Winter Wheat	84,630,000 Bu	60 lbs/Bu	2,538,900 t		
Durum Wheat	14,420,000 Bu	60 lbs/Bu	432,600 t		
Total			5,834,000 t	25 t/trip	234,000 trips

Alfalfa/Hay – Data Source – Annual Production in tons: (USDA 2013)

Alfalfa	3,000,000 t		
Hay	1,120,000 t		
Total	4,120,000 t	25t/trip	165,000
trips			

Sugar Beets – Data Source – Annual Production in tons: (USDA 2013)

Sugar Beets			1,292,000 t	25t/trip	52,000 trips

Barley – Data Source – Annual Production in bushels: (USDA 2013)

Barley	41,870,000 Bu	48 lbs/Bu	1,005,000 t	25t/trip	40,000 trips

Cattle (beef) – Data Source – Annual Production in lbs: (USDA 2013)

Cattle (beef)			552,000 t	25t/trip	22,000 trips

Talc (Yellowstone Mine) – Data Source – Production in tons: (MDEQ 2004)

Talc			300,000 t	25t/trip	12,000 trips

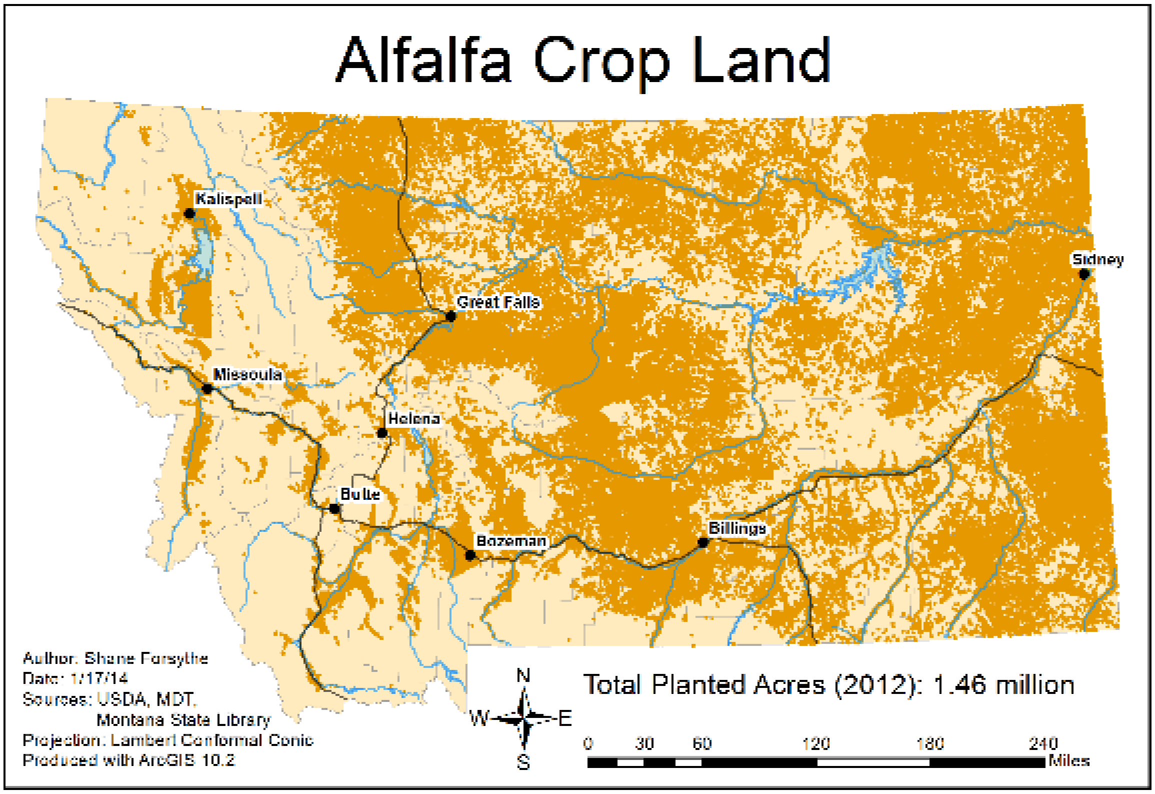
Timber – Data Source – Annual Production in board feet: (Morgan, et al 2012)

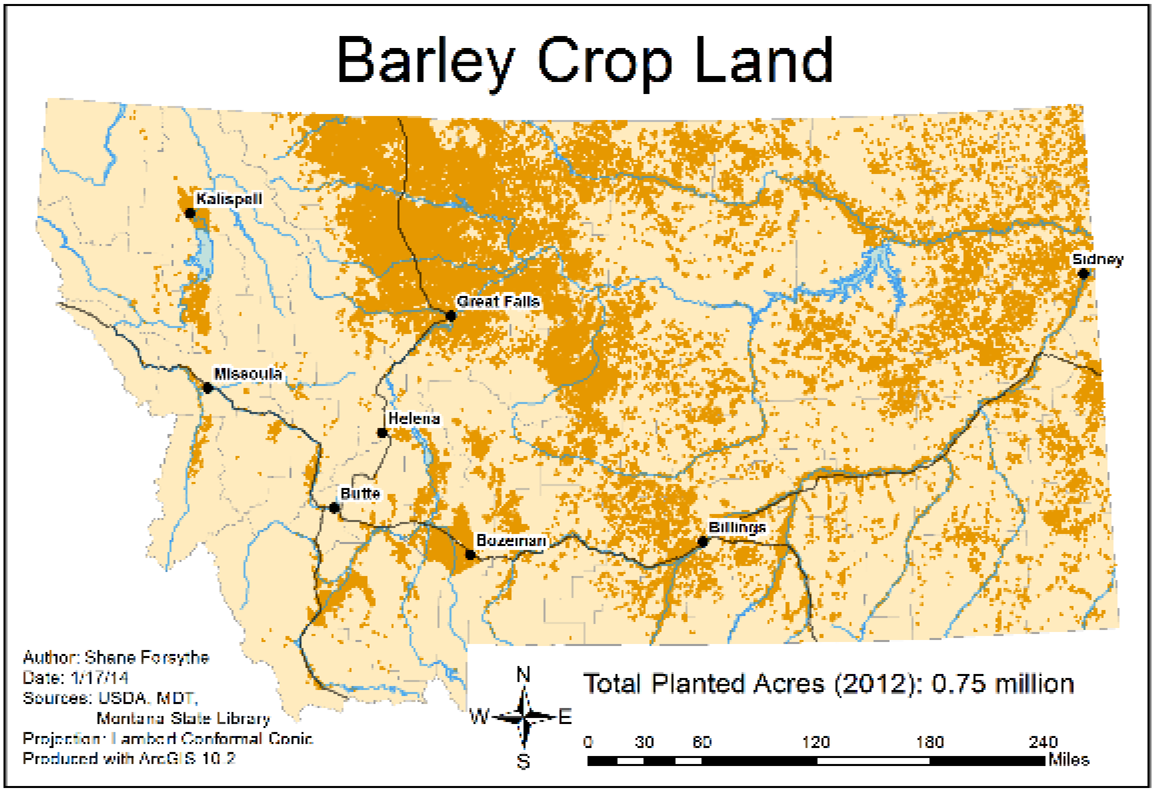
Timber	134,000,000 bd ft	5 t/ 1000 bd ft	670,000 t	25t/trip	27,000 trips

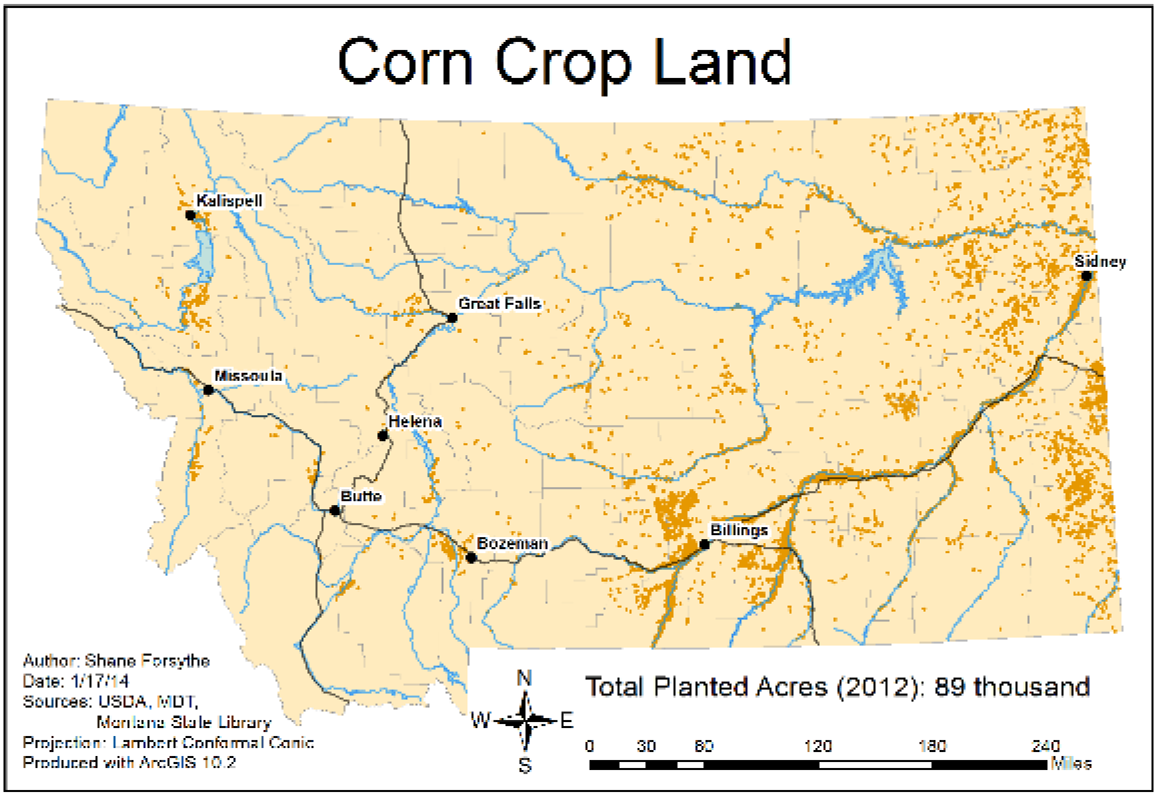
Tourism (Glacier National Park) – Data Source – Annual Visitors: (Nickerson 2010)

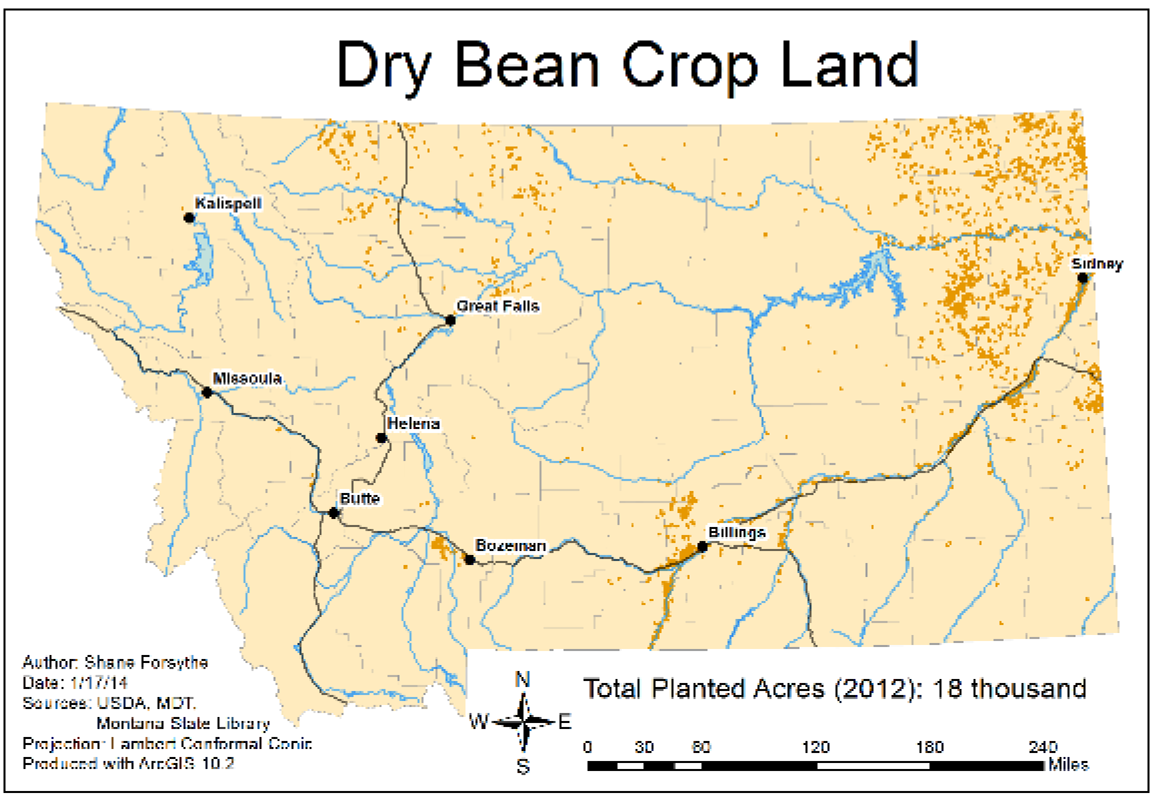
Visits	2,160,000 visitors			3 visitors/veh	721,000 trips

APPENDIX E: AREAL EXTENT OF MAJOR CROPS






Corn Crop Land
Kalispell
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Sidney
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 89 thousand
0
30
60
120
180
240
Miles


Dry Bean Crop Land
Kalispell
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Sidney
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 18 thousand
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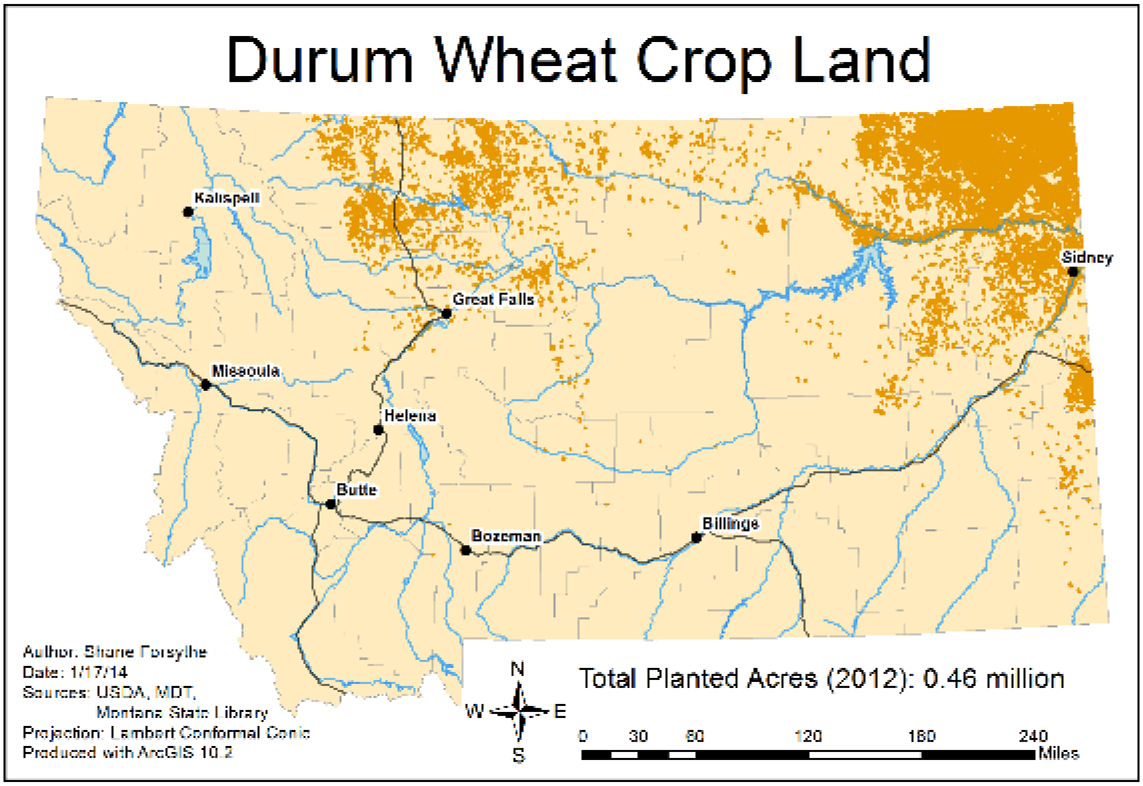
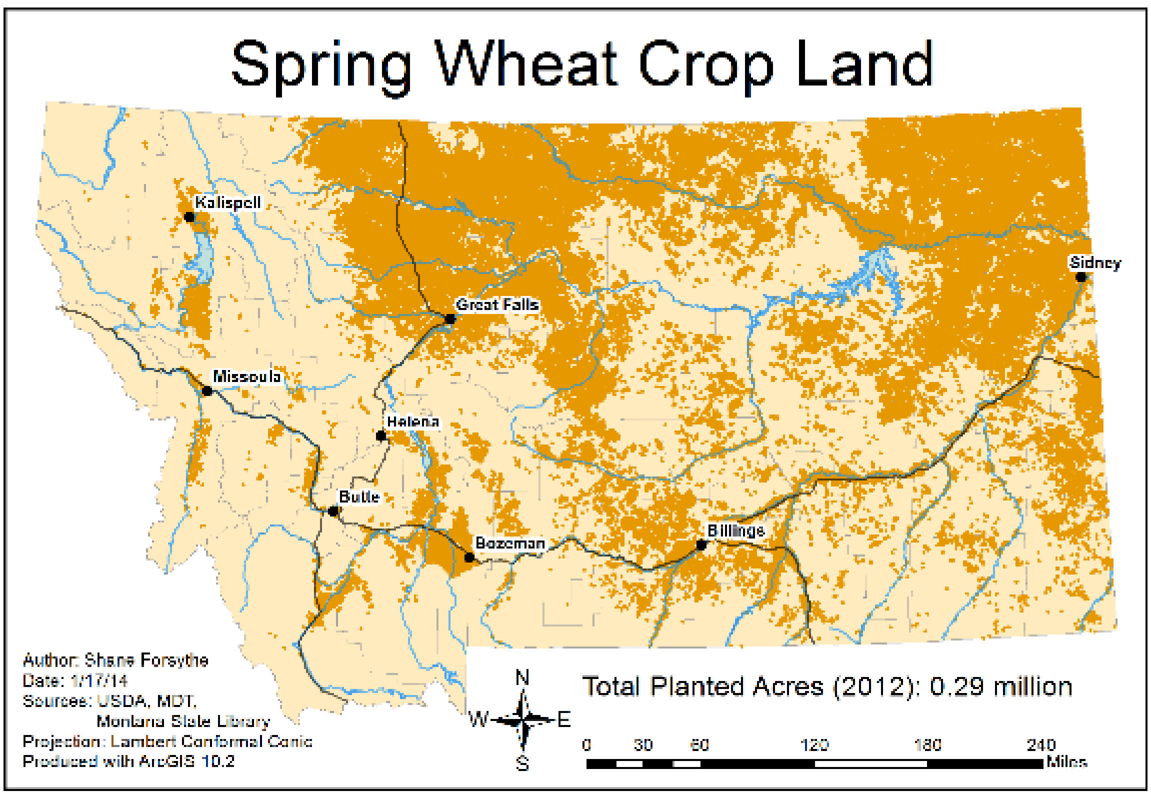
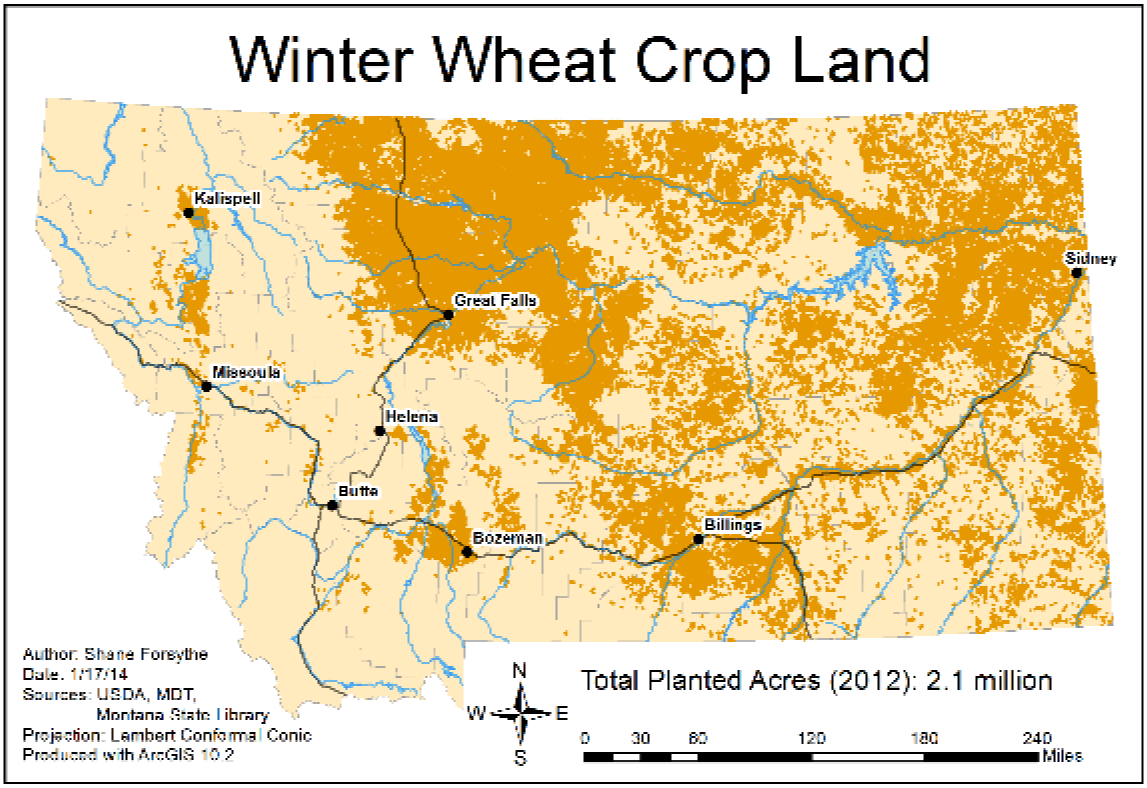
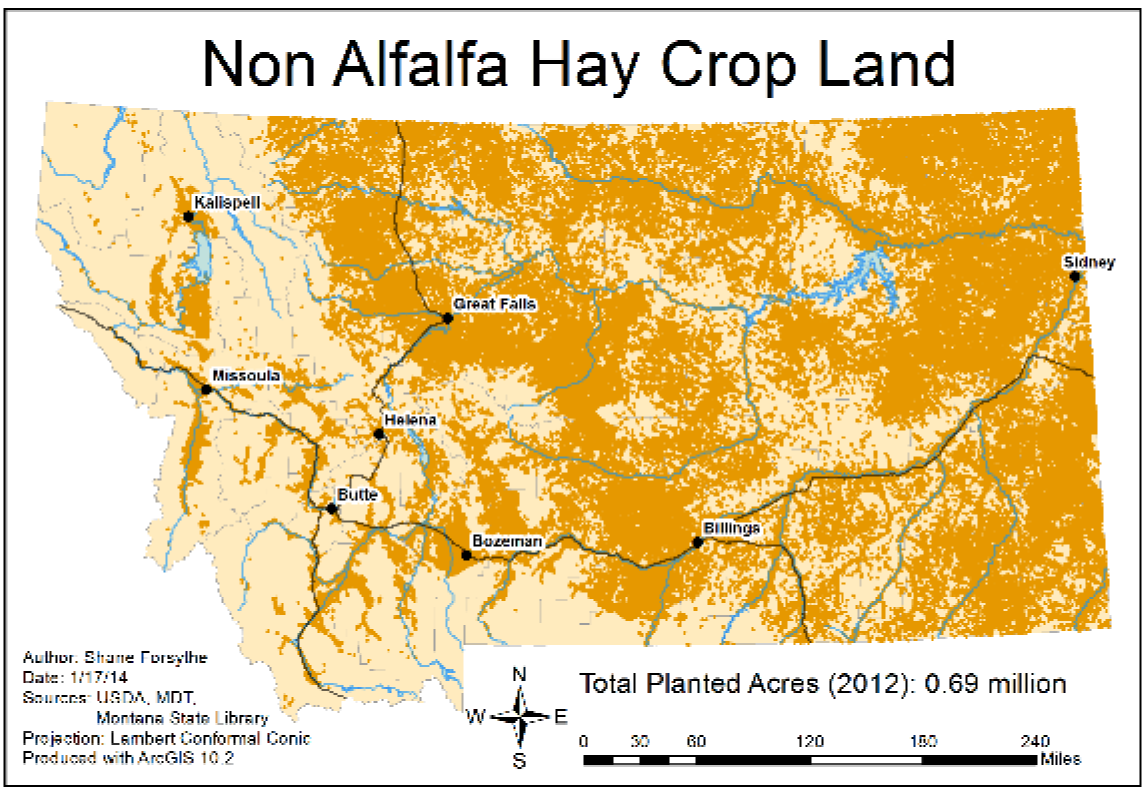
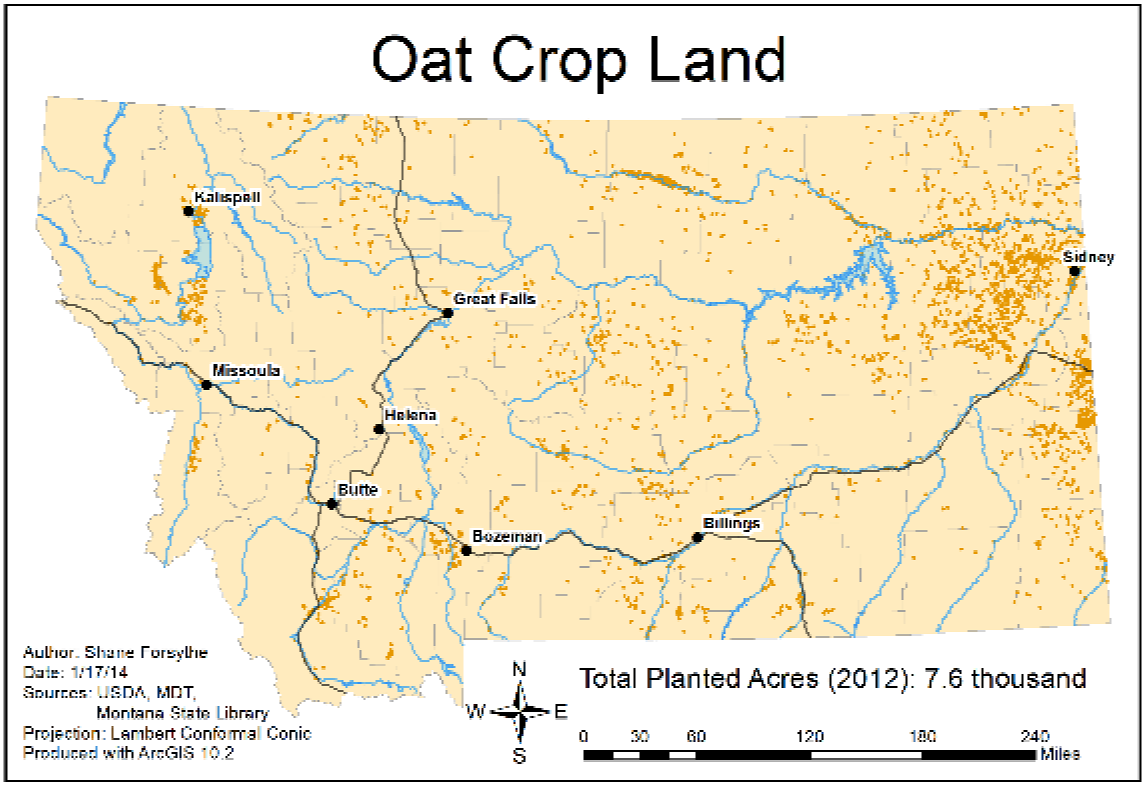
30
60
120
180
240
Miles

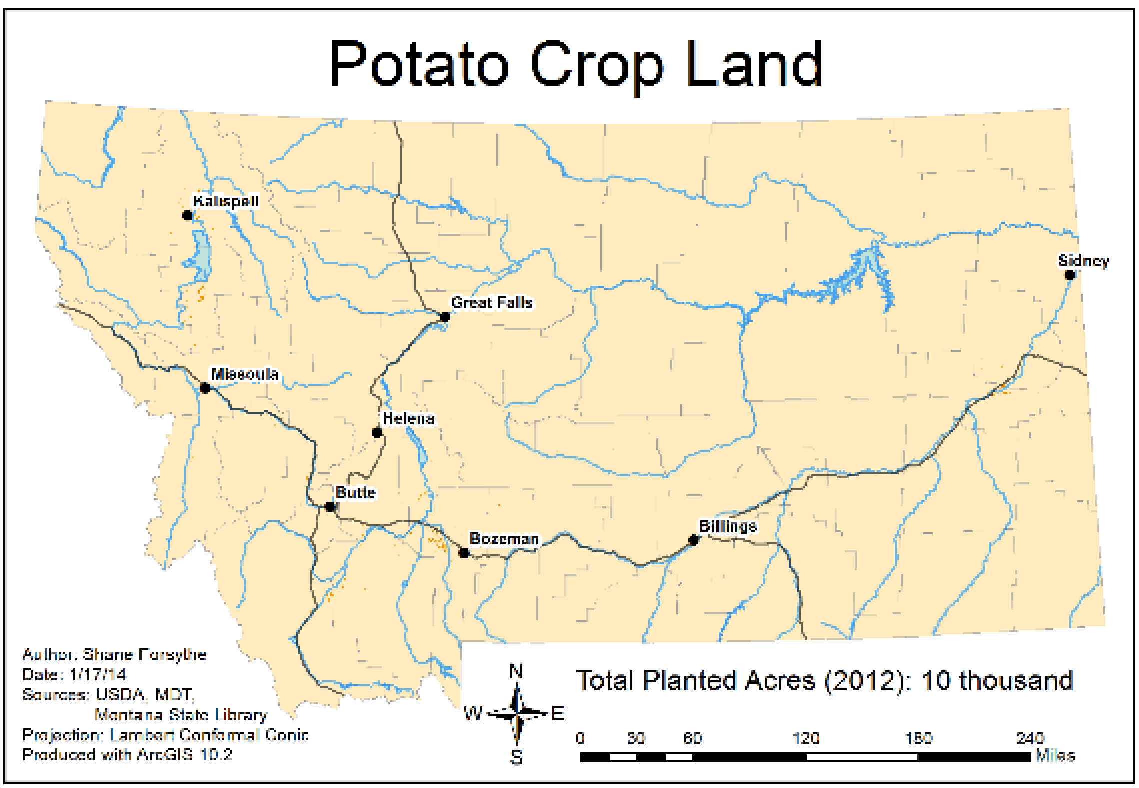

Durum Wheat Crop Land
Kalispell
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Sidney
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 0.46 million
0 30 60 120 180 240
Miles

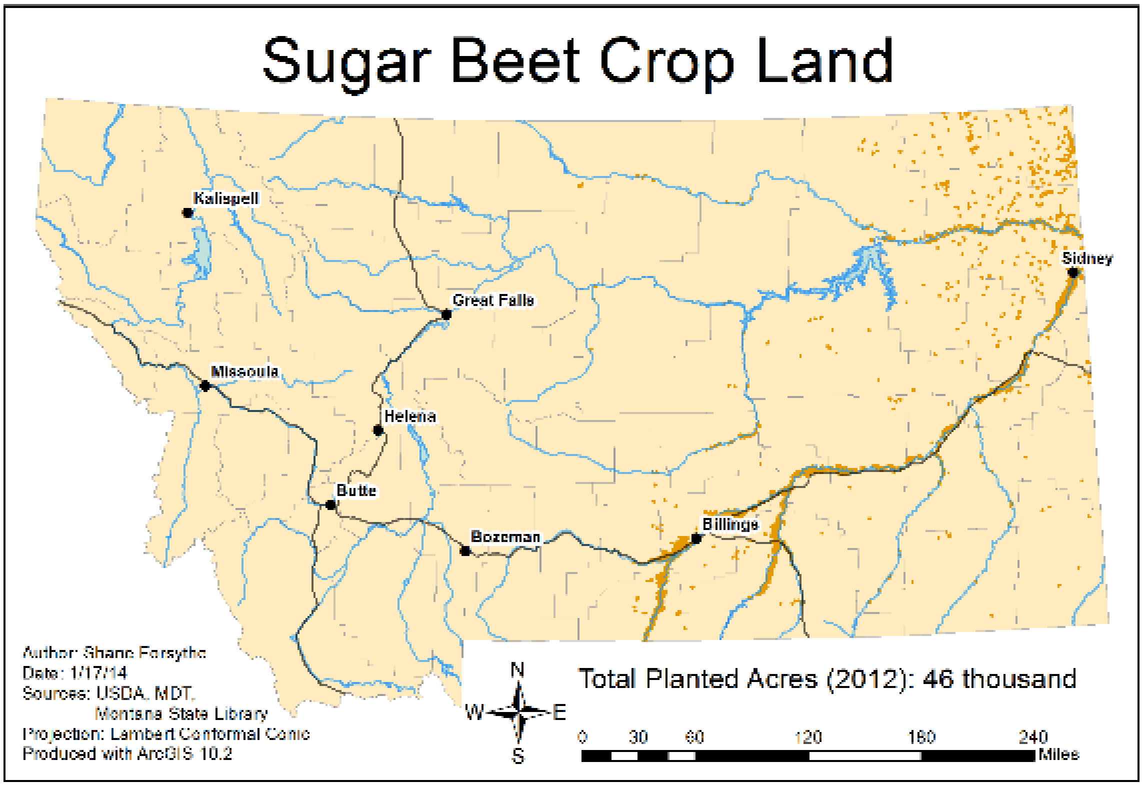

Spring Wheat Crop Land
Kalispell
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Sidney
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 0.29 million
0 30 60 120 180 240
Miles


Winter Wheat Crop Land
Kalispell
Great Falls
Sidney
Missoula
Helena
Butte
Bozeman
Billings
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 2.1 million
0 30 60 120 180 240
Miles


Non Alfalfa Hay Crop Land
Kalispell
Great Falls
Sidney
Missoula
Helena
Butte
Bozeman
Billings
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 0.69 million
0 30 60 120 180 240
Miles


Oat Crop Land
Kalispell
Sidney
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 7.6 thousand
0 30 60 120 180 240
Miles


Potato Crop Land
Kalispell
Sidney
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 10 thousand
0 30 60 120 180 240
Miles


Sugar Beet Crop Land
Kalispell
Great Falls
Sidney
Missoula
Helena
Butte
Bozeman
Billings
Author: Shane Forsythe
Date: 1/17/14
Sources: USDA, MDT,
Montana State Library
Projection: Lambert Conformal Conic
Produced with ArcGIS 10.2
N
W
E
S
Total Planted Acres (2012): 46 thousand
0 30 60 120 180 240
Miles

APPENDIX F: MDT USER SURVEY

1

Information to be Collected on Use of MDT Traffic Data -

Current and Potential Data Users – Current and Potential Data Products

Aptly named, the Traffic Data Collection and Analysis (TDCA) Section of MDT collects and makes available a wealth of information on the traffic carried by the state's highways by route, vehicle type (including in many cases configuration and weight), and time of day (often aggregated and reported by day, week, month and year). The TDCA Section has initiated a project through the Western Transportation Institute at Montana State University to review their Weigh-in-Motion (WIM) and Automatic Traffic Recorder (ATR) data collection programs to ensure that they are providing the best possible traffic information in the most cost effective manner to meet current and future data user needs. As part of this review, current and potential traffic data users are being contacted relative to their use (or potential use) of existing data available from the TDCA Section, as well as what new data and/or data products (i.e., aggregation/presentation schemes) are desired to better support their activities.

Your input is critical to this review, and will help the TDCA Section to better support your activities in the future. Thank you for taking the time to provide the following information (anticipated completion time is up to 20 minutes, depending on your use/need for traffic data). The survey has three sections Background, Data Use and Closing Questions. If you have any questions, please contact Jerry Stephens at WTI/MSU (406-994-6113, jerrys@ce.montana.edu).

Information on Use/Potential Use of MDT Traffic Data -

Background:

Division/Program/Bureau or District: Date:

Name:

Position:

Direct data user and/or administrator of personnel that use traffic data:

<u>Data Use - 1</u> (this section repeated as necessary for each individual data use)

1) Is this a current or potential data use – Circle One – Current   Potential

2) Description of basic task that requires traffic data:
(e.g., pavement design)

3) Specific traffic data and related parameters used/needed for this work:
(e.g., current annual ESALs. AADT, VMT)

4) Importance/benefits of high quality traffic data to this work:
(e.g., Traffic data is essential to cost effective pavement design. Both under- and over-designing the state's highways results in less than optimum use of limited resources. A ½ inch thickness of asphalt pavement costs $XYZ/lane mile, Montana paves approximately KK lane miles/yr at a cost of WVU million dollars.)

5) Is the traffic data you need currently available to accomplish this task?

a) Circle one: Yes   No   Don't know

b) If No, how are you currently completing this work without TDCA providing the necessary traffic data?
(e.g. utilizing statewide or regional estimates, task is not being done)

6) What is your current/desired method of accessing this traffic data:

(e.g., A direct request (traffic request form, email, telephone) is made to TDCA for project location specific information, consisting of current ESALs per year. These values are multiplied by appropriate growth factors from the planning division and the results modified as appropriate based on expert judgment to determine design pavement demands.)

a) Does this current method of accessing/requesting traffic data meet your needs?

Circle: Yes 5 4 3 2 1 No

b) If No, or a response of 1through 5, what would be the desired/most efficient method to access, request and receive this type of traffic data?

(e.g. using statewide or regional estimates)

7) If traffic data is already being used for this task, how could this data or its presentation be improved to better support your work?

(e.g., Basic data is available and adequate. If transition to the MEPDG pavement design method, load spectra will be required.)

<u>Data Use - 2</u> (this section repeated as necessary for each individual data use)

1) Is this a current or potential data use – Circle One – Current Potential

2) Description of basic task that requires traffic data:
(e.g., highway capacity assessment/design)

3) Specific traffic data and related parameters used/needed for this work:
(e.g., peak hourly volume, split of passenger cars vs. commercial vehicles)

4) Importance/benefits of high quality traffic data to this work:
(e.g., Determining the correct number of lanes and traffic control strategies is essential to optimize the operating capacity of a roadway. Both over- and under-capacity roadways result in less than optimum use of limited resources. The estimated cost of one lane of urban arterial is $xxx/mile.)

5) Is the traffic data you need currently available to accomplish this task?

a) Circle one: Yes No Don't know

b) If No, how are you currently completing this work without TDCA providing the necessary traffic data?
(e.g. utilizing statewide or regional estimates, task is not being done)

6) What is your current/desired method of accessing this traffic data:
(e.g., The required traffic data is available in the yearly ATR Profiles.)

a) Does this current method of accessing/requesting traffic data meet your needs?
Circle: Yes 5 4 3 2 1 No

b) If No, or a response of 1through 5, what would be the desired/most efficient method to access, request and receive this type of traffic data?
(e.g. using estimates)

7) If traffic data is already being used for this task, how could this data or its presentation be improved to better support your work?
(e.g., Basic data is available and adequate)

Closing Questions

8) Have you visited the Traffic Data Collection and Analysis website?

http://www.mdt.mt.gov/publications/datastats/traffic.shtml

Circle: Yes No

If you have visited the website:

a) What were you trying to do?

b) How useful did you find the website? Circle: Useful 5 4 3 2 1 Not Useful

(if response is anything other than Useful, provide examples, i.e. not user friendly, slow response time, etc.)

c) What specific features of the website would you change/add/delete?

9) More specifically, have you used any of the Traffic Maps? (If already covered in Questions 1-8, skip this question.)

Circle: Yes No

a) If you have used the maps, which maps did you use?

b) What were you trying to do/what information were you looking for?

c) How useful did you find the maps Circle: Useful 5 4 3 2 1 Not Useful

(if response is anything other than Useful, provide examples, i.e. not user friendly, slow response time, etc.)

d) What specific features of the map(s) would you change/add/delete?

e) What other traffic related maps would you like to see on the site?

10) Have you used any of the monthly or annual traffic reports available on the site? (If already covered in Questions 1-7, skip this question.)

Circle: Yes No

a) If you have used the reports, which report did you use?

b) What were you trying to do/what information were you looking for?

c) How useful did you find the report? Circle: Useful 5 4 3 2 1 Not Useful
(if response is anything other than Useful, provide examples, i.e. not user friendly, slow response time, etc.)

d) What specific features of the reports(s) would you change/add/delete?

e) What other traffic reports/data would you like to have available on the site?

11) If you have been involved in trials of TDCA's new online Traffic Count Database System – TCDS – on the MS2 website, please answer the questions below, otherwise proceed to Question 12.

Have you used the TCDS?

Circle: Yes No

If you have used the TCDS,

a) What were you trying to do?

b) How useful did you find this system? Circle: Useful 5 4 3 2 1 Not Useful
(if response is anything other than Useful, provide examples, i.e. not user friendly, slow response time, etc.)

c) What specific features of the system would you change/add/delete?

12) Other comments:

Summary of selected data currently available from TDCA Section:

Traffic by Sections Report:

Annual Average Daily Traffic (AADT), and the daily vehicle miles travelled (DVMT) for all vehicles, with sub-breakdowns by various vehicle groupings (e.g., commercial vehicles (Class 5 -13), small trucks (Class 5-7) and large trucks (Class 8-13), etc.). The road sections used are based on a) major intersections that cause changes in traffic, b) political boundaries such as county lines, and c) for interstates, every interchange. http://mdt.mt.gov/other/traffcount/external/TRAFFIC_REPORTS/TBS-ON-SYSTEM_FINAL_6-12-13.PDF

Annual and Monthly ATR/WIM Reports

Data collected by the permanent automatic traffic recorder (ATR) and weigh-in-motion (WIM) sites throughout Montana on daily and peak hourly traffic volumes. Four types of reports are available with monthly ATR/WIM data. Three of the reports are similar in presentation and provide traffic data on different vehicle groupings: commercial vehicles, large truck, and all vehicles. These three reports provide monthly ADT and the change in traffic volume from year to year sorted by ATR/WIM site ID. The fourth report type is the Monthly Calendar Report which presents the traffic volume in calendar format by day, direction, and month for each ATR/WIM site. http://mdt.mt.gov/publications/datastats/traffic_atr.shtml

Traffic Adjustment Factors

Two types of Traffic Adjustment Factors are published each year. Combined Axle and Seasonal factors are used to expand short-term volume counts to AADTs, while the Seasonal Day of Week for Axle Count factor does the same for short-term vehicle classification counts. Each adjustment factor report, regardless of whether it is for volume or classification counts, gives a factor for weekdays (Monday – Thursday), Friday, Saturday, and Sunday for each traffic factor grouping for each month of the year (total of 384 individual factors). http://mdt.mt.gov/publications/datastats/traffic_factors.shtml

Traffic Maps (GIS)

The online interactive map-based GIS tool made available by MDT allows users to select a highway section and retrieve selected traffic data for it. The map allows a user to select a route segment using a mouse, or to search by address, signed route name, or place. Available traffic information on the selected segment includes, as available, historical AADT and percent commercial vehicles. http://mdt.mt.gov/publications/datastats/traffic_maps.shtml

Traffic Count Database System (TCDS)

The Traffic Count Database System (TCDS) is a subscription based software and database service offered by Midwestern Software Solutions (MS2, Ann Arbor, MI). In June of 2014 MDT selected MS2 as its new traffic software vendor. The web-based site will allow for timely access to traffic data (TCDS is made available internally and to other data customers (i.e. MPO's, local governments, consultants, etc.), but is not currently available to the public. TCDS produces a variety of traffic statistics, from daily volume to individual vehicle records. A large selection of report types are also made available or can be developed based on user needs/requests. http://mdt.ms2soft.com

Equivalent Single Axle Load (ESALs)

The ESAL value represents a mixture of different axle configurations and loads converted into an equivalent number of 18,000 lb. single axle loads that are expected to traverse a segment of roadway. ESAL values are available upon request for project specific pavement design, and more broadly at the network level for planning analyses.

For additional information on available traffic data, contact Becky Duke, Supervisor of the Traffic Data Collection and Analysis Section, MDT, 444-6122.