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

Report for Task 6
Review of Traffic Factor Groups

Prepared by:

David Veneziano
Research Scientist II
Montana State University

Ahmed Al-Kaisy, Professor
Montana State University

Jerry Stephens, Professor
Montana State University

Western Transportation Institute
Montana State University

Prepared for
Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

January 2015

ABSTRACT

This task report documents an investigation of traffic factor grouping schemes conducted for the Montana Department of Transportation as part (i.e., Task 6) of a comprehensive project being done to assess the efficacy of MDT's traffic data collection program. All traffic flows on Montana's highways currently are viewed as fitting within one of eight traffic factor groups, with these groups being established based on highway functional classification, with an added group for recreation related routes. In light of changes in traffic patterns over time, it is important to periodically review a) the traffic factor groups being used, b) the assignment of segments along each highway route to a particular traffic factor group, and c) whether regional traffic patterns are being adequately represented.

This study evaluated three alternative traffic factor grouping schemes relative to the currently used system of eight functional classification based groups, namely, grouping by a) vehicle type, i.e., commercial versus non-commercial, and functional classification b) area of the state and its socio-economic environment, i.e., agriculture, recreation/tourism, rural and urban, and functional classification, and c) a simplified functional classification scheme treating interstate highways as one group and the remaining classifications, i.e. other arterials, collectors, and local roads in another group. The current and these hypothesized schemes for traffic factor groupings are all consistent with grouping strategies recognized in the Federal Highway Administration's Traffic Monitoring Guide, which does not promote any one scheme as necessarily better than the others.

The examination of the different groupings was accomplished using traffic count data obtained from MDT's Traffic Data Collection and Analysis Section. Data for each of the state's 37 WIM and 62 ATR sites 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 (when available) in a separate file. These data were used to calculate Average Daily Traffic (ADT) by day of week and month of year for each count station. These values were used to calculate site-specific traffic adjustment factors. These site adjustment factors were then aggregated according to each traffic factor grouping scheme examined in this study.

Examination of the various hypothesized traffic factor groupings was done using graphical analysis and quantitative statistics (i.e., intergroup standard deviations) to assess temporal variations in adjustment factors and the variation of factors within a group. The primary findings of these evaluations are as follows:

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 applications that are concerned with freight transportation (e.g. pavement design, weight enforcement, etc.).

2) The second grouping scheme, i.e., by area/region, proved to be somewhat impractical. The estimation of adjustment factors was reasonably accurate, but assignment of stations to a group is subjective. The main concern is the difficulty

with which to classify any existing or proposed station in one of the groups, as the nature of trips made may not be very clear to the user and of course different types of trips may occur at any particular site. Consequently, the "rural/other" category which is intended to include all stations that could not be classified in any of the other groups turned out to be the group with the largest number of stations (around 32% of stations included in analysis).

3) The third grouping scheme, fundamentally consisting of interstate and non-interstate, rural and urban, has a 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 saving in time and resources.

The study findings suggest that 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 (in use in the current grouping scheme) may be more appropriate for Montana conditions than the current grouping scheme.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

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. Inherent in such reviews is due consideration of the level of accuracy offered by various prospective groupings.

In this study, three alternative schemes for traffic factor groupings were investigated for possible use by the Montana Department of Transportation (MDT). The current traffic factor groupings are based 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 dominant economic activity, i.e., agriculture, recreation/tourism, rural and urban, 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. This work is part of a comprehensive evaluation being conducted by MDT of its traffic data collection program to assist in determining the future direction of this program. Other work being done as part of this project can be seen at http://www.mdt.mt.gov/research/projects/planning/wim.shtml.

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 brief description of the MDT's traffic data collection program that provides the information necessary to generate traffic adjustment factors by traffic factor group.

Background

As previously mentioned, one of the important uses of the continuous traffic data collected by permanent weigh-in-motion (WIM) and automatic traffic recorder (ATR) installations is to provide the data necessary to adjust traffic data collected from short term monitoring events to obtain reasonable estimates of annual average daily traffic (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 36-hour period) generally cannot simply be factored up based on their duration to obtain usable estimates of average annual daily traffic (AADT), as such an approach does not account for temporal (seasonal) 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 Traffic Monitoring Guide (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; and
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 the segment is assigned to.

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 in 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. This work is focused on traffic factor rather than weight groups.

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.

Current MDT Traffic Factor Groupings

Following the "traditional" traffic group factor approach, Montana currently uses nine traffic factor groups, generally consistent with the primary functional classifications mandated in the Federal Highway Performance Monitoring System (HPMS – FHWA, 2012). These groups are:

1) Rural Interstate
2) Urban Interstate
3) Principal Arterial - Rural
4) Principal Arterial - Urban
5) Minor Arterial - Rural
6) Minor Arterial - Urban
7) Major Collector - Rural
8) Collector - Urban
9) Recreational

Two of these groups are typically combined due to the low number of data collection sites within them, i.e., Minor Arterial - Urban and Collector - Urban, resulting in eight traffic factor groups. Thus, all traffic flows on Montana's highways are viewed as represented by one of the eight 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 using a three year average. Two sets of adjustment factors are available:

1) factors to adjust short term volume counts for a combination of axle and seasonal effects, and

2) factors to adjust short term classification counts for just seasonal effects.

In both cases, adjustment factors are determined for weekdays – specifically, Monday through Thursday, for Fridays individually, and for weekends - Saturday and Sunday. Consistent with practice in several states, MDT has found Friday travel to be non-typical, so short term counts generally are not conducted on Fridays, and "weekday" adjustment factors are calculated exclusive of Fridays.

Typical adjustment factors for each traffic factor group as determined by MDT are presented in Table 1 (http://www.mdt.mt.gov/publications/datastats/traffic_factors.shtml). The weekday adjustment factors in this table are plotted by month for an entire year for each traffic factor group in Figure 1. Referring to Figure 1, these adjustment factors clearly reflect seasonal trends in traffic operations across all traffic factor groups (and referring to Table 1, 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 1. Example of MDT Adjustment Factors

Montana Department of Transportation

MDT

Seasonal Day of the Week For Axle Counts

(SDOWF)

For Year: 2014

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Recreational												
Weekdays	1.95	1.81	1.65	1.39	1.01	0.71	0.53	0.58	0.76	1.14	1.54	1.84
Saturday	2.11	1.94	1.56	1.49	1.00	0.71	0.52	0.55	0.73	1.15	1.68	2.03
Sunday	2.29	2.08	1.70	1.54	1.00	0.68	0.50	0.53	0.72	1.17	1.78	2.25
Friday	2.20	1.96	1.65	1.45	1.01	0.70	0.51	0.55	0.73	1.12	1.67	2.23
Rural Interstate												
Weekdays	1.37	1.27	1.14	1.03	0.97	0.86	0.79	0.79	0.91	0.98	1.09	1.26
Saturday	1.40	1.25	1.06	1.05	0.99	0.87	0.77	0.78	0.94	0.99	1.14	1.24
Sunday	1.46	1.39	1.13	1.08	0.98	0.85	0.73	0.75	0.92	0.96	1.11	1.33
Friday	1.44	1.33	1.10	1.05	0.97	0.85	0.77	0.76	0.92	0.96	1.09	1.37
Rural Minor Arterial												
Weekdays	1.34	1.25	1.19	1.08	0.97	0.88	0.80	0.82	0.90	0.96	1.03	1.22
Saturday	1.46	1.27	1.19	1.14	0.97	0.86	0.78	0.78	0.87	0.98	1.13	1.33
Sunday	1.58	1.47	1.24	1.16	0.94	0.82	0.73	0.72	0.88	0.98	1.14	1.36
Friday	1.52	1.39	1.21	1.11	0.96	0.85	0.76	0.75	0.88	0.98	1.10	1.35
Rural Major Collector												
Weekdays	1.24	1.17	1.12	1.00	0.96	0.90	0.87	0.86	0.93	0.99	1.08	1.18
Saturday	1.32	1.20	1.07	0.99	0.96	0.87	0.88	0.85	0.91	1.02	1.17	1.24
Sunday	1.40	1.26	1.16	1.02	0.93	0.85	0.82	0.83	0.92	1.02	1.17	1.24
Friday	1.35	1.21	1.14	0.99	0.96	0.87	0.85	0.85	0.92	1.01	1.13	1.23
Rural Principal Arterial												
Weekdays	1.35	1.25	1.17	1.07	0.99	0.89	0.79	0.79	0.88	0.98	1.07	1.23
Saturday	1.47	1.28	1.16	1.10	0.98	0.89	0.78	0.77	0.85	0.97	1.16	1.30
Sunday	1.58	1.40	1.19	1.14	1.00	0.84	0.72	0.73	0.87	0.99	1.15	1.38
Friday	1.54	1.33	1.16	1.11	1.00	0.86	0.76	0.75	0.87	0.97	1.11	1.39
Urban Interstate												
Weekdays	1.20	1.15	1.08	1.00	0.97	0.91	0.85	0.86	0.95	0.99	1.06	1.15
Saturday	1.25	1.15	1.02	0.99	0.95	0.92	0.87	0.87	0.94	0.99	1.13	1.13
Sunday	1.33	1.24	1.09	1.03	0.95	0.86	0.79	0.81	0.94	0.99	1.11	1.19
Friday	1.30	1.19	1.07	1.00	0.95	0.89	0.83	0.83	0.94	0.99	1.09	1.19
Urban Minor/Collector												
Weekdays	1.08	1.01	0.98	0.97	0.95	0.97	1.06	1.03	0.99	0.97	1.04	1.09
Saturday	1.11	1.04	0.98	0.95	0.92	0.98	1.08	1.04	0.99	0.98	1.10	1.05
Sunday	1.14	1.05	1.00	0.96	0.92	0.95	1.00	1.02	0.98	0.99	1.06	1.11
Friday	1.13	1.03	0.98	0.97	0.92	0.96	1.05	1.01	0.99	0.98	1.07	1.08
Urban Principal Arterial												
Weekdays	1.12	1.06	1.02	1.00	0.99	0.95	0.94	0.93	0.96	0.98	1.03	1.08
Saturday	1.16	1.04	0.99	0.99	0.96	0.96	0.95	0.94	0.95	0.98	1.09	1.08
Sunday	1.19	1.11	1.03	1.02	0.95	0.92	0.88	0.89	0.95	1.00	1.08	1.12
Friday	1.17	1.08	1.02	1.01	0.96	0.93	0.92	0.91	0.94	0.99	1.07	1.11

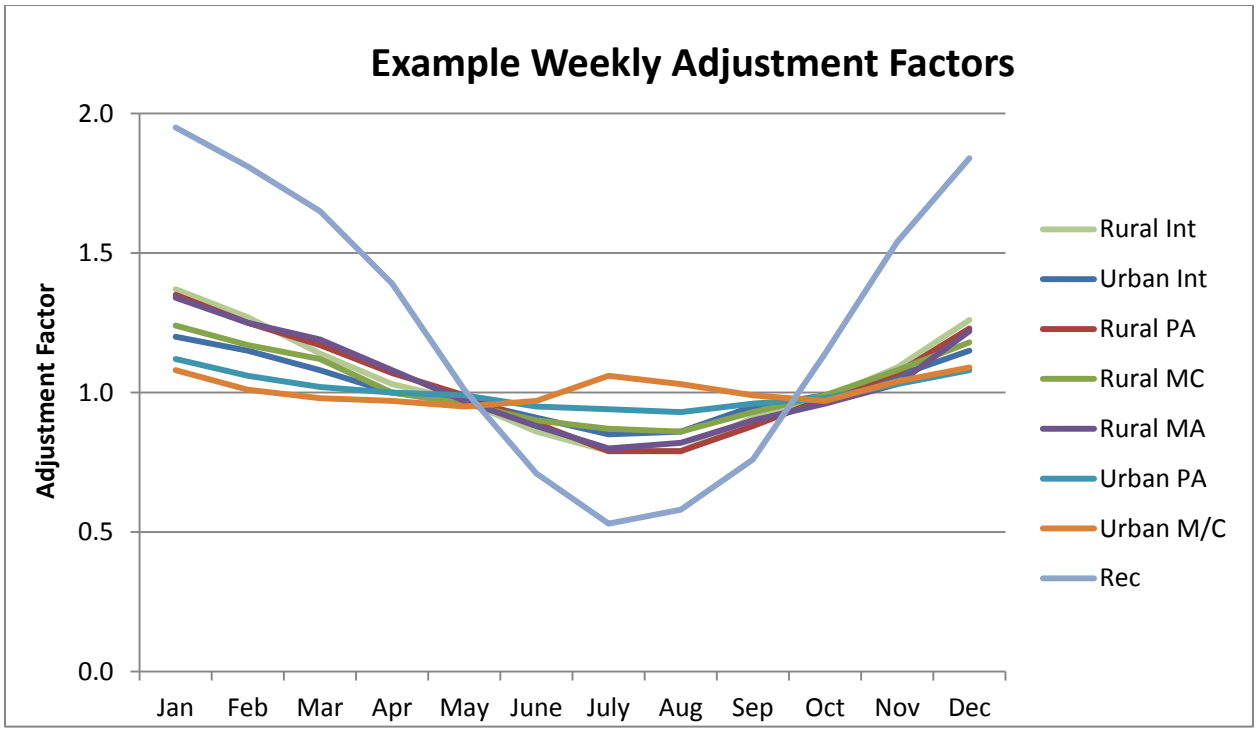

Figure 1 Example of weekday adjustment factors by month

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. Currently, there are 99 permanent stations (i.e. continuous count sites) collecting traffic data on a daily basis throughout the state, consisting of 62 ATR and 37 WIM sites. These stations are shown in Figure 2 with the intent of providing a sense of their general distribution across the state highway network. Additionally, MDT collects traffic data at approximately 5,800 active short-term traffic count sites statewide (MDT 2014). These counts, also known as coverage counts, make up the bulk of the MDT's traffic count program.

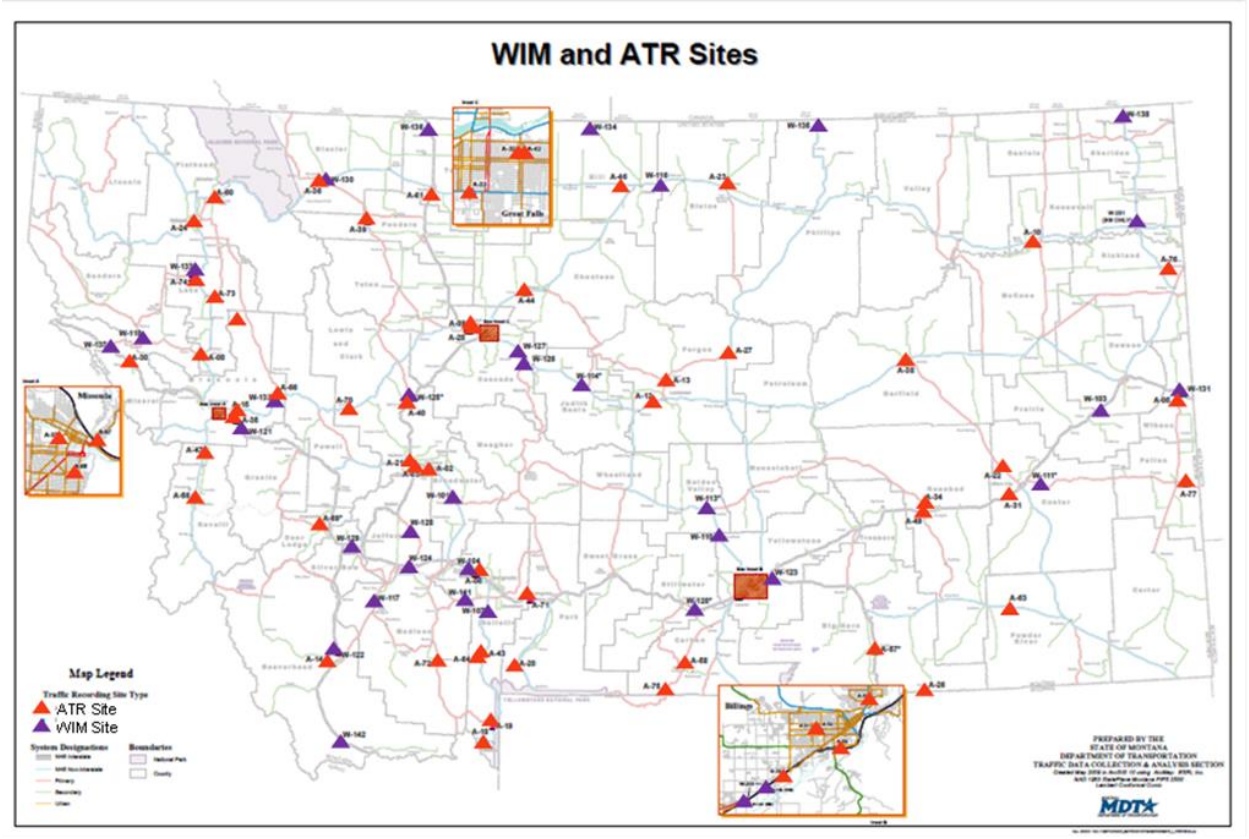

Figure 2 WIM and ATR sites (MDT, 2012a)

Table 2 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 2. This functional classification in most cases corresponds to the traffic factor group to which each site is assigned following MDT's current traffic factor grouping scheme. 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 2. 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

Table 2 cont'd. WIM and ATR Site Location Descriptions

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

Table 2 cont'd. WIM and ATR Site Location Descriptions

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

* site is included in the Recreation factor group

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 and functional classification, 2) geographical area/dominant economic activity and functional classification, and 3) simplified functional classification 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.

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 (ODOT), for example, determines seasonal adjustment factors for all vehicles, trucks and passenger vehicles (ODOT, undated).

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.

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, ODOT 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, while 10 were located on urban routes.

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, the Oregon DOT, for example, generates traffic adjustment factors for eleven traffic factor groups, from interstate urban, to agriculture, to recreational winter (Oregon DOT, undated).

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.

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 (Montana Department of Commerce, 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 3 and shown in Figure 3.

Table 3. 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

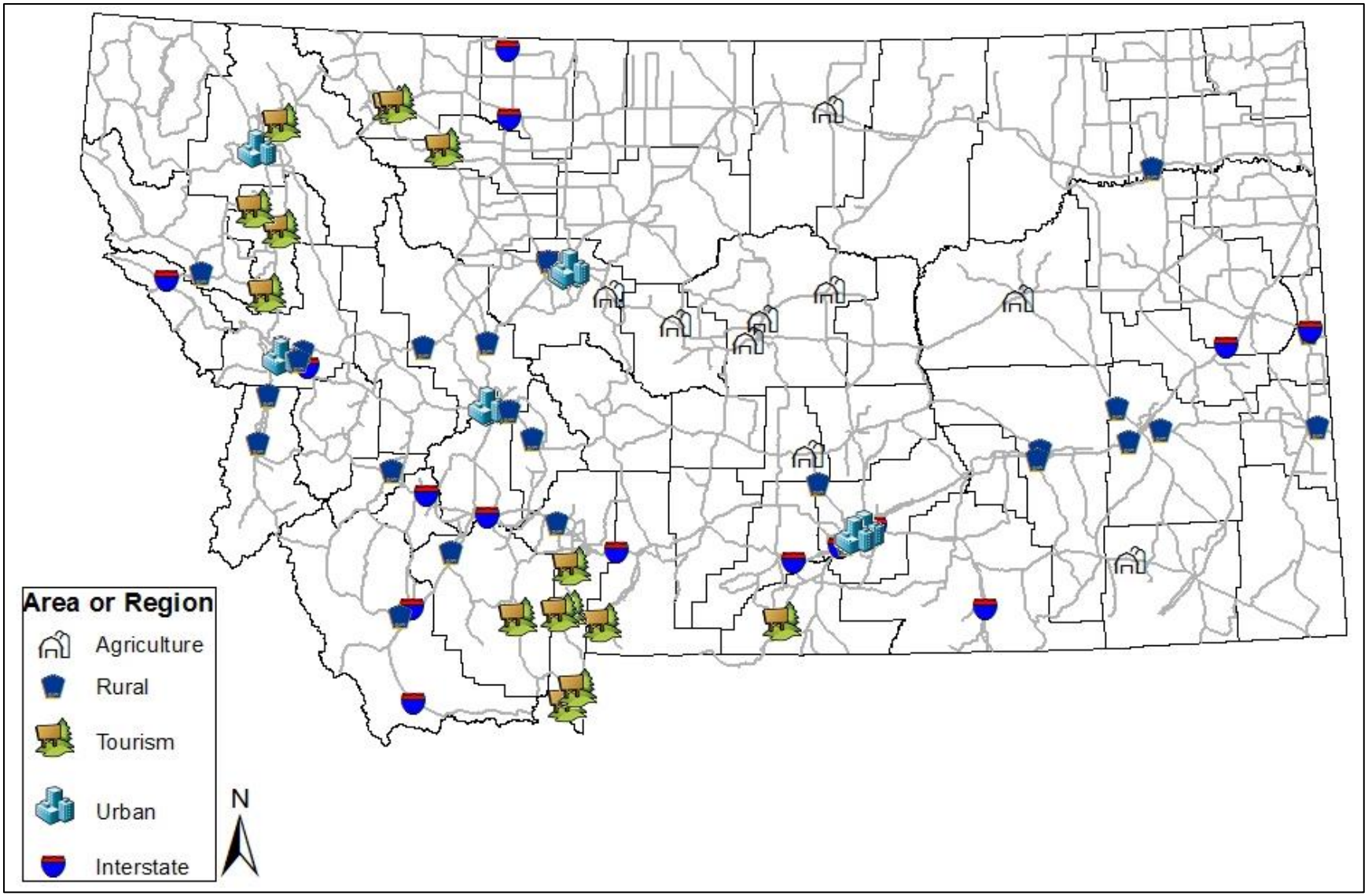

Figure 3 WIM and ATR sites by Area/Region Grouping

Grouping by Modified Functional Classification Scheme

The final grouping scheme considered in this study, presented in Table 3, 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 (FHWA 2013). 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 DOT, undated).

Table 4. 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

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.

Proposed Grouping Scheme

Counts from interstate WIM and ATR sites were assigned as urban or rural simply 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.

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.

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 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.

MDT had previously completed quality control checks to ensure that 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.

WIM and ATR Stations

As indicated, the data came from MDT's 37 WIM and 62 ATR sites distributed throughout the state as shown earlier in Figure 2. 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.

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.

Data Analysis

The data obtained from MDT was reformatted into new Excel spreadsheets which consisted of total counts by day as well as commercial vehicle counts to facilitate research-specific analysis activities. First, Average Daily Traffic (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.

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 4. Referring to Figure 4, 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.

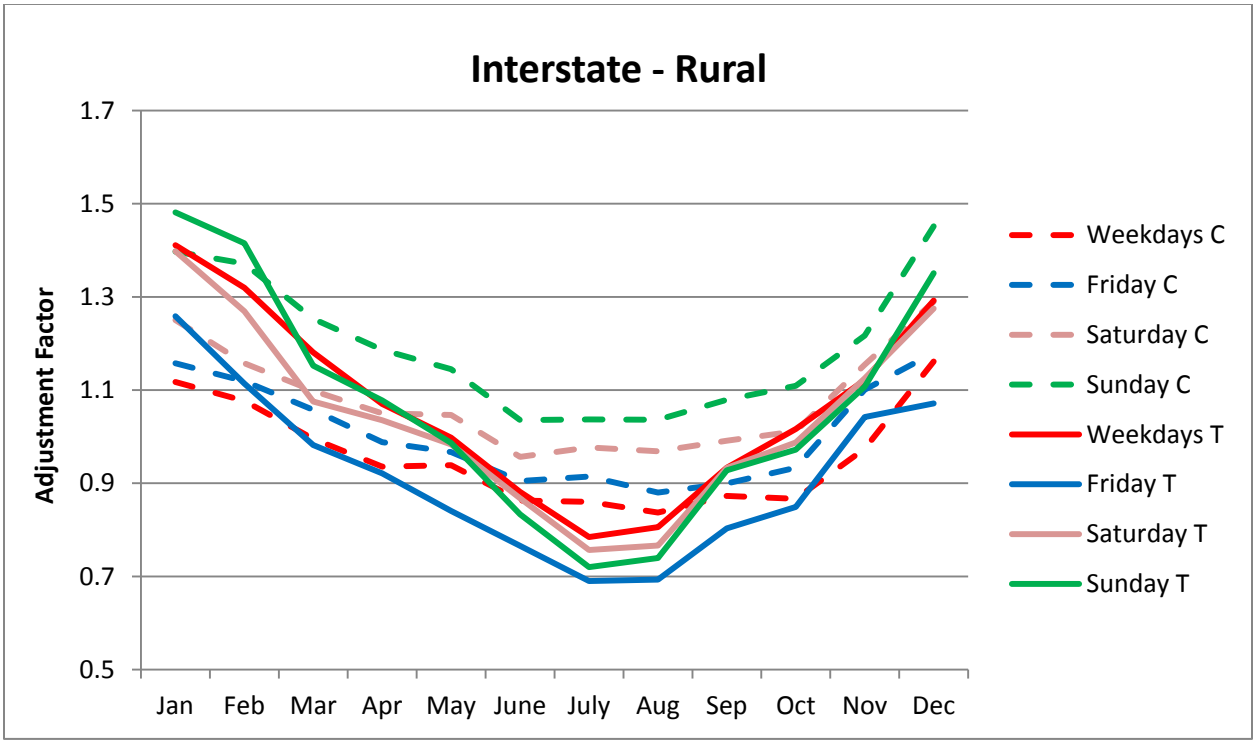

Figure 4 Rural interstate adjustment factor comparison, total vehicles versus commercial

A comparison of urban interstate adjustment factors between total and commercial vehicles is presented in Figure 5. 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.

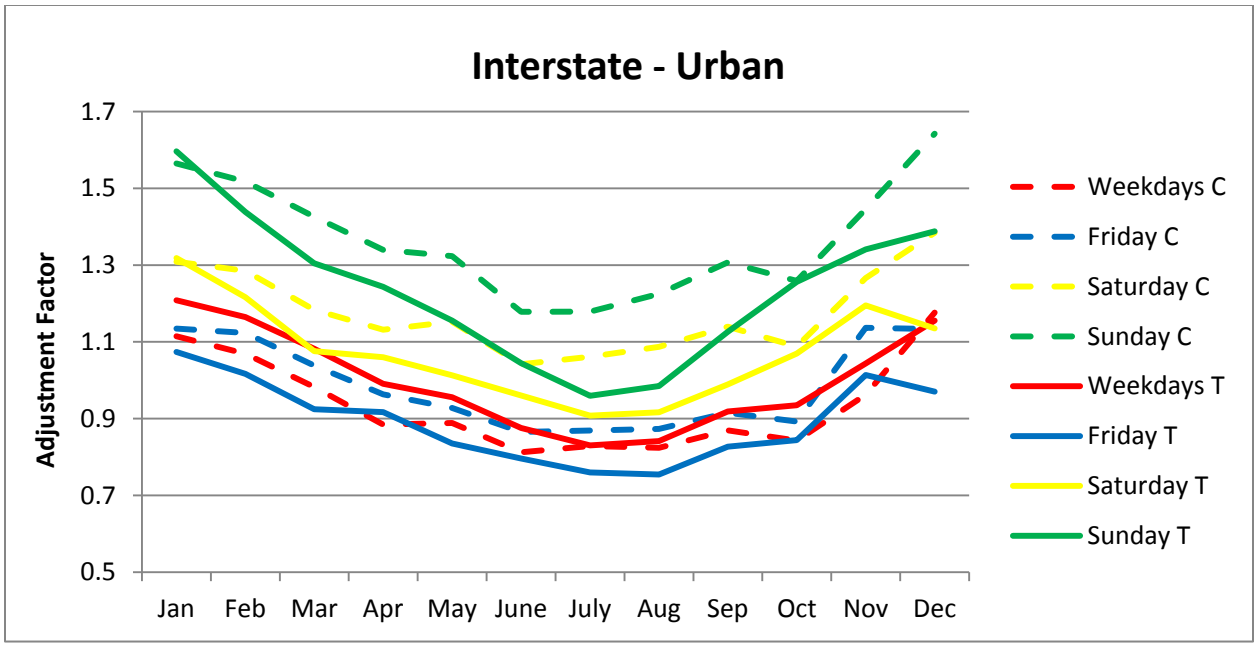

Figure 5 Urban interstate adjustment factor comparison, total vehicles versus commercial

For rural principal arterials, presented in Figure 6, 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.

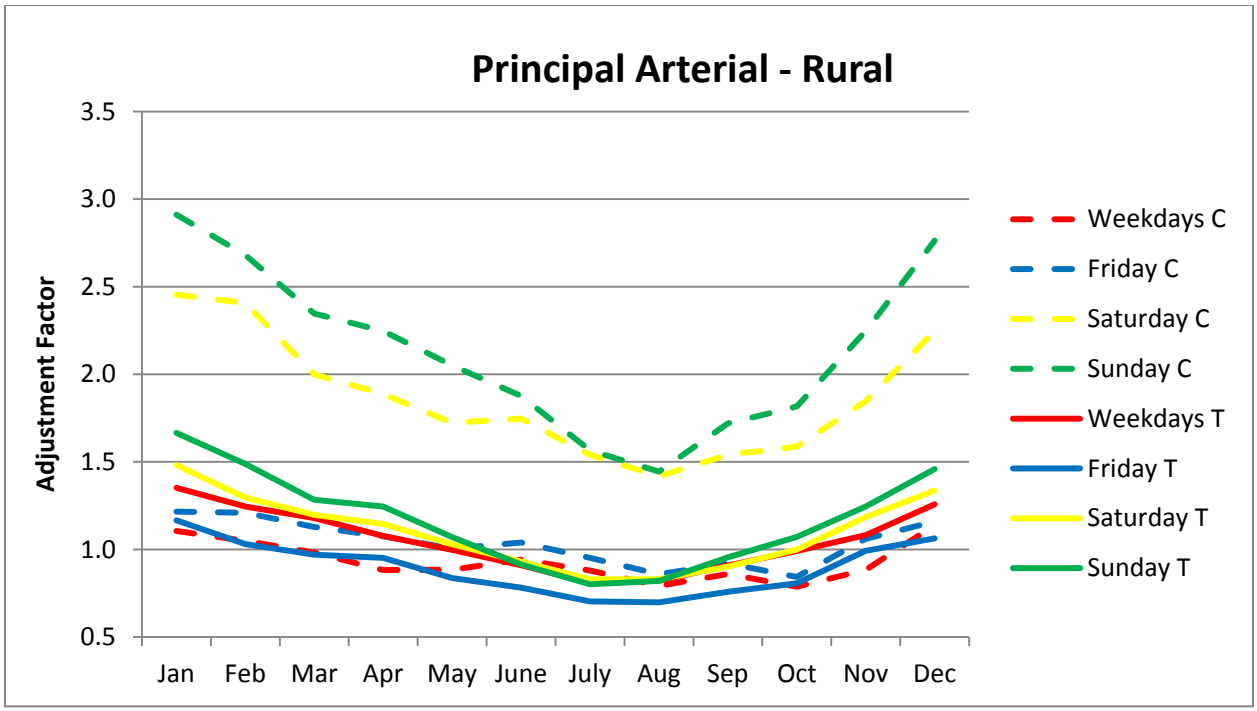

Figure 6 Rural principal arterial adjustment factor comparison, total vehicles versus commercial

Rural minor arterial adjustment factors for commercial and total vehicles are presented in Figure 7. 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.

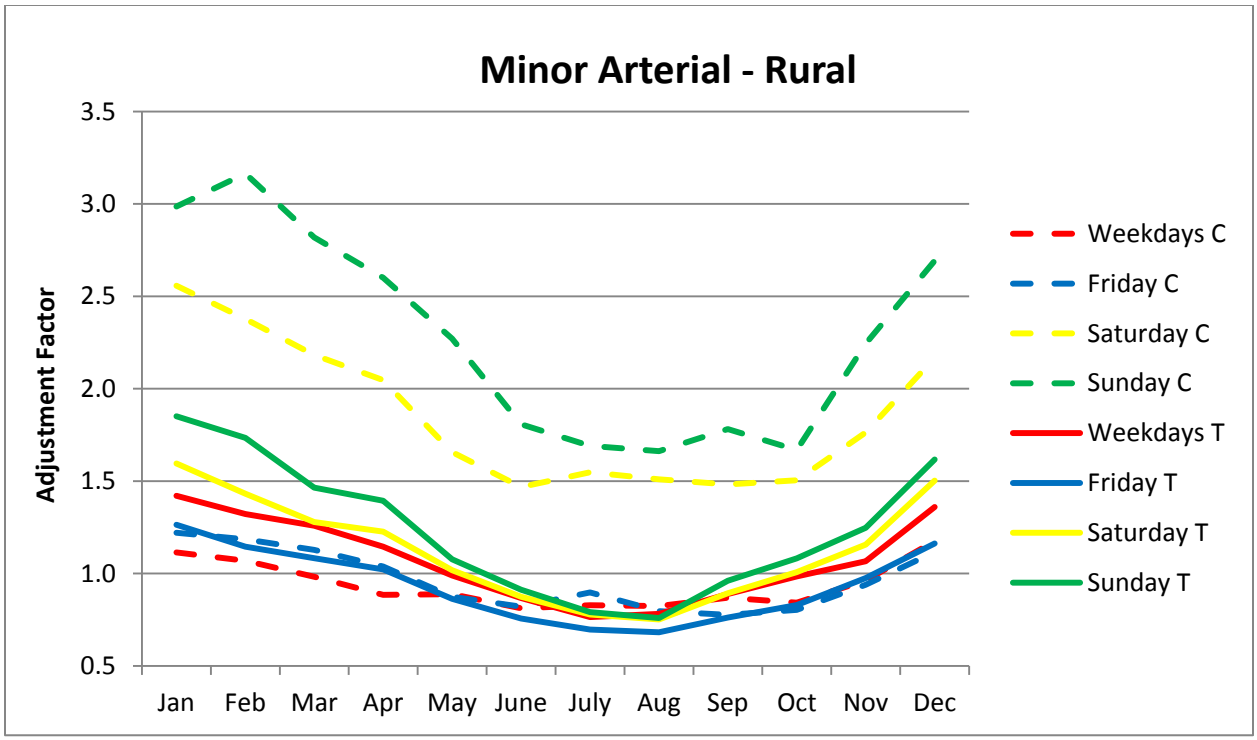

Figure 7 Rural minor arterial adjustment factor comparison, total vehicles versus commercial

Adjustment factors for commercial and total traffic on rural major collectors are shown in Figure 8. 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.

In general and referring to Figure 6, Figure 7 and Figure 8, 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.

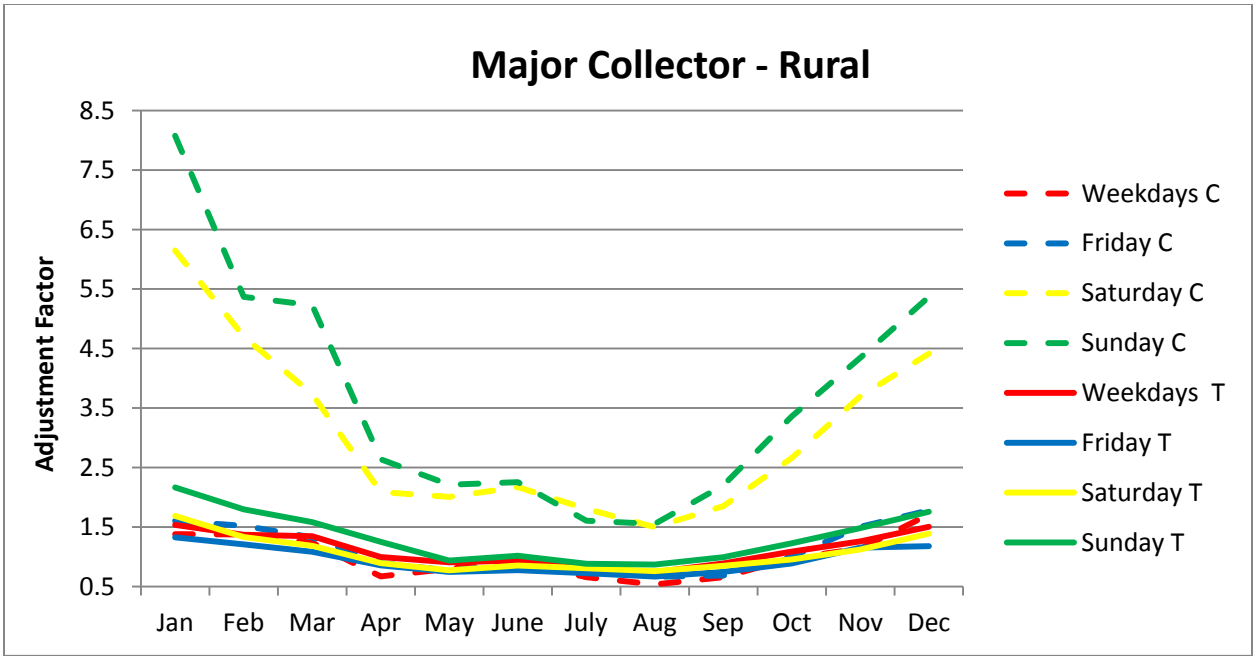

Figure 8 Rural major collector adjustment factor comparison, total vehicles versus commercial

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 5 and Table 6, 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 5. 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 6. Standard Deviations for Factors for Grouping by Vehicle Type Scheme – Commercial Vehicles

Interstate Urban												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
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

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 3.

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 9, Figure 10, Figure 11 and Figure 12 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 9 and Figure 10, 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.

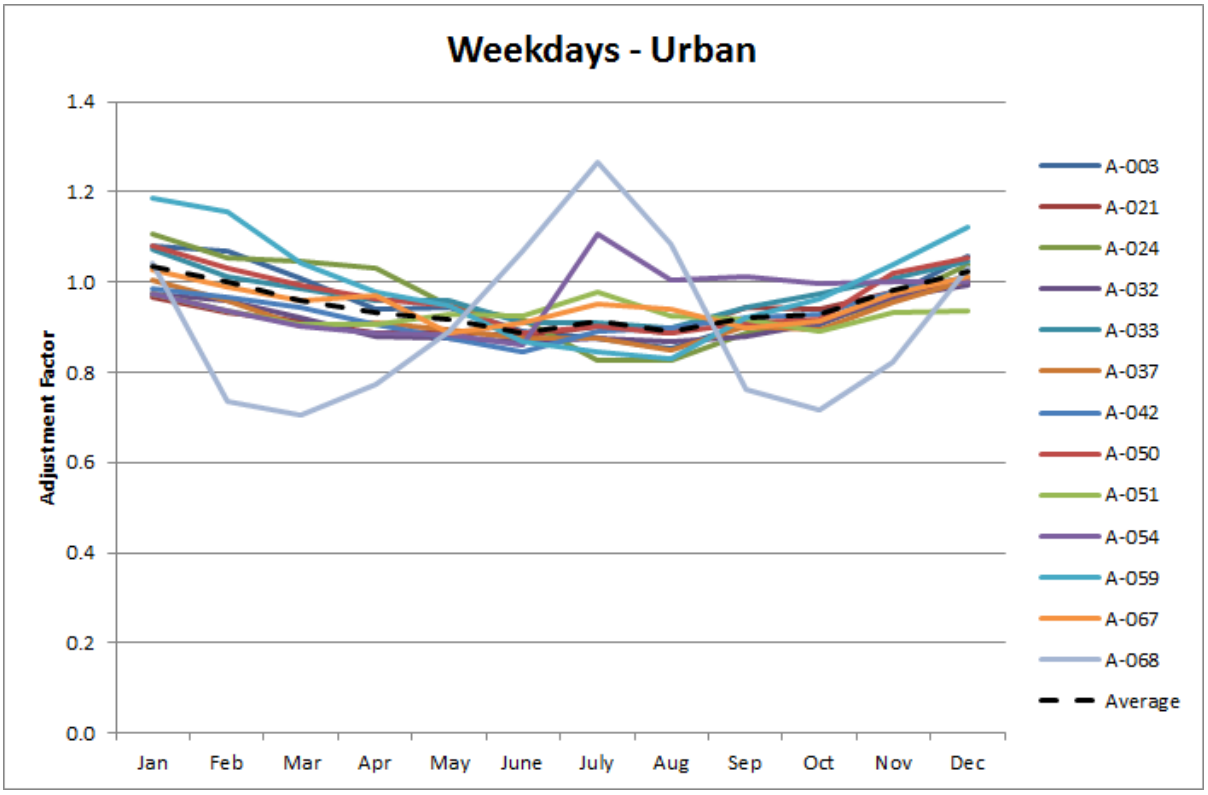

Figure 9 Urban count station adjustment factors, weekdays

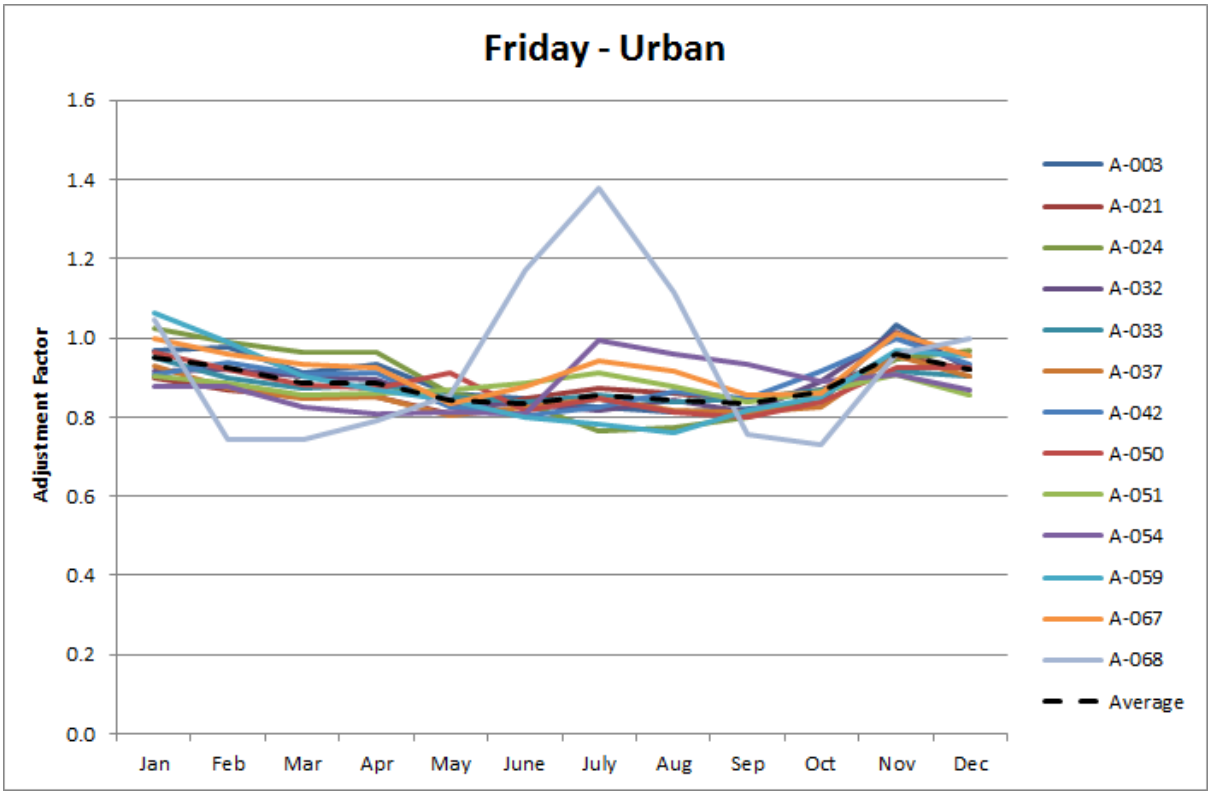

Figure 10 Urban count station adjustment factors, Friday

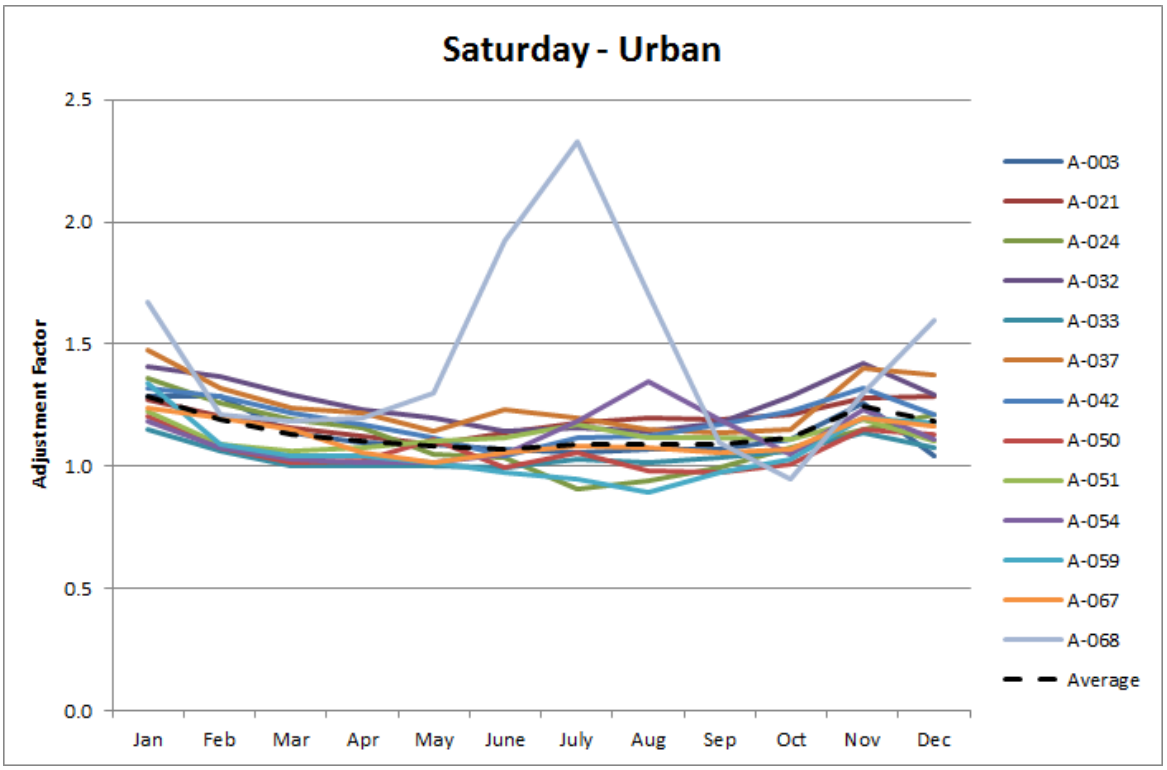

Figure 11 Urban count station adjustment factors, Saturday

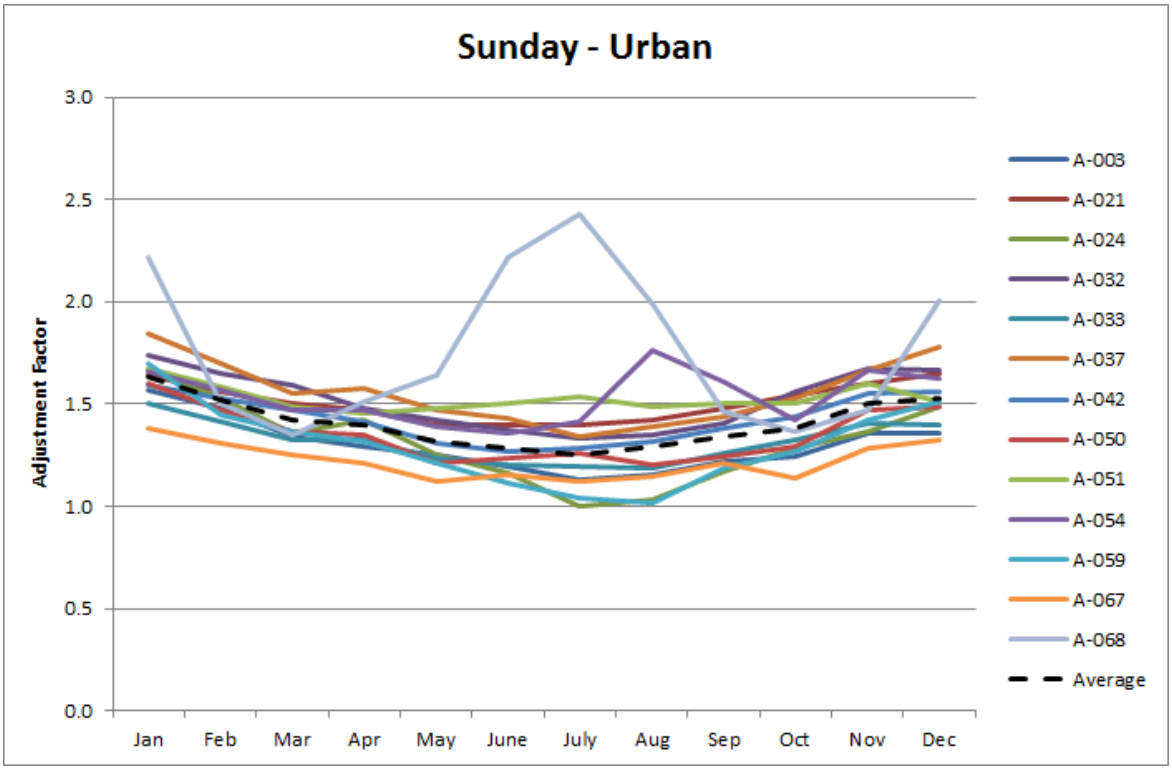

Figure 12 Urban count station adjustment factors, Sunday

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 13, Figure 14, Figure 15 and Figure 16 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.

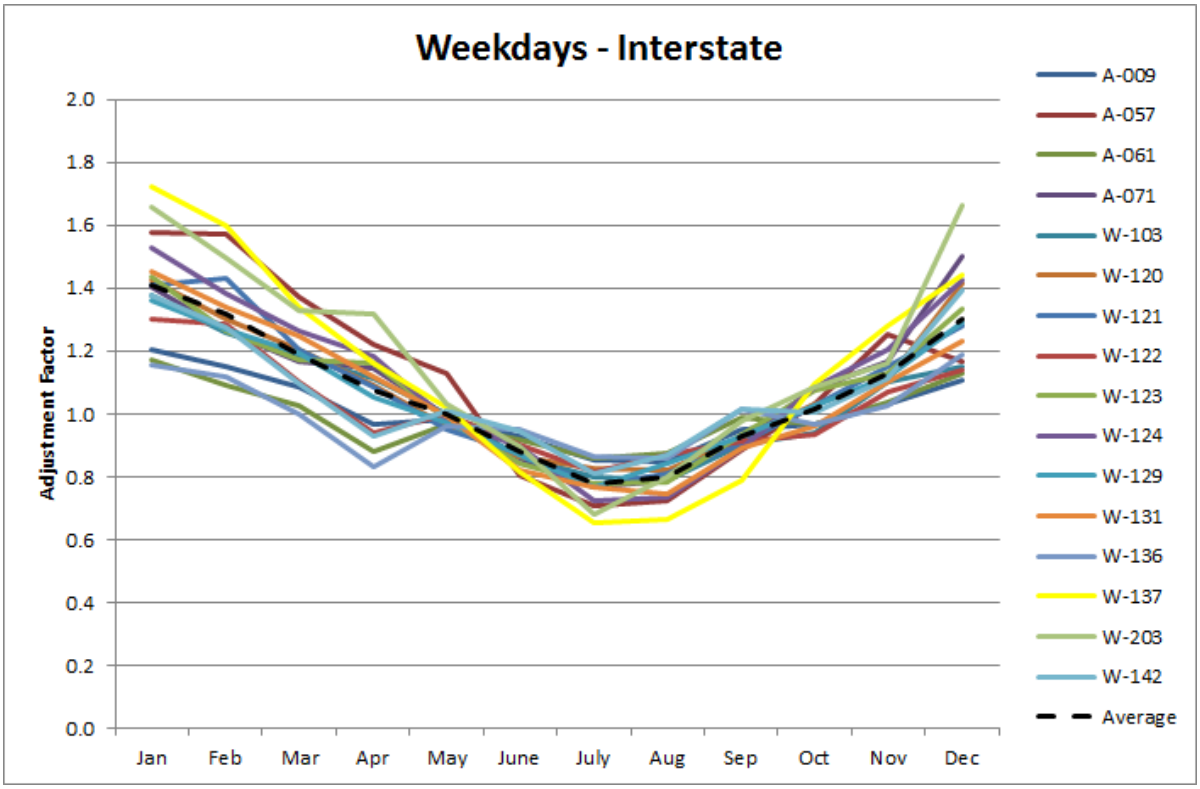

Figure 13 Interstate count station adjustment factors, weekdays

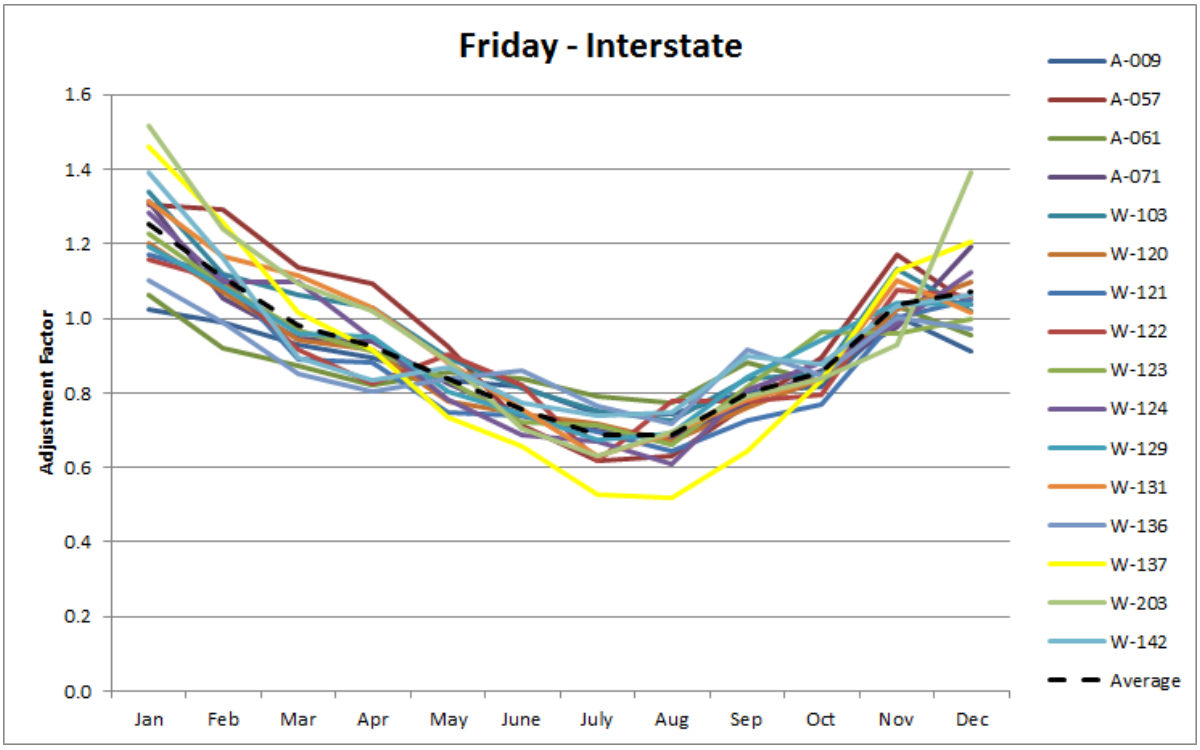

Figure 14 Interstate count station adjustment factors, Friday

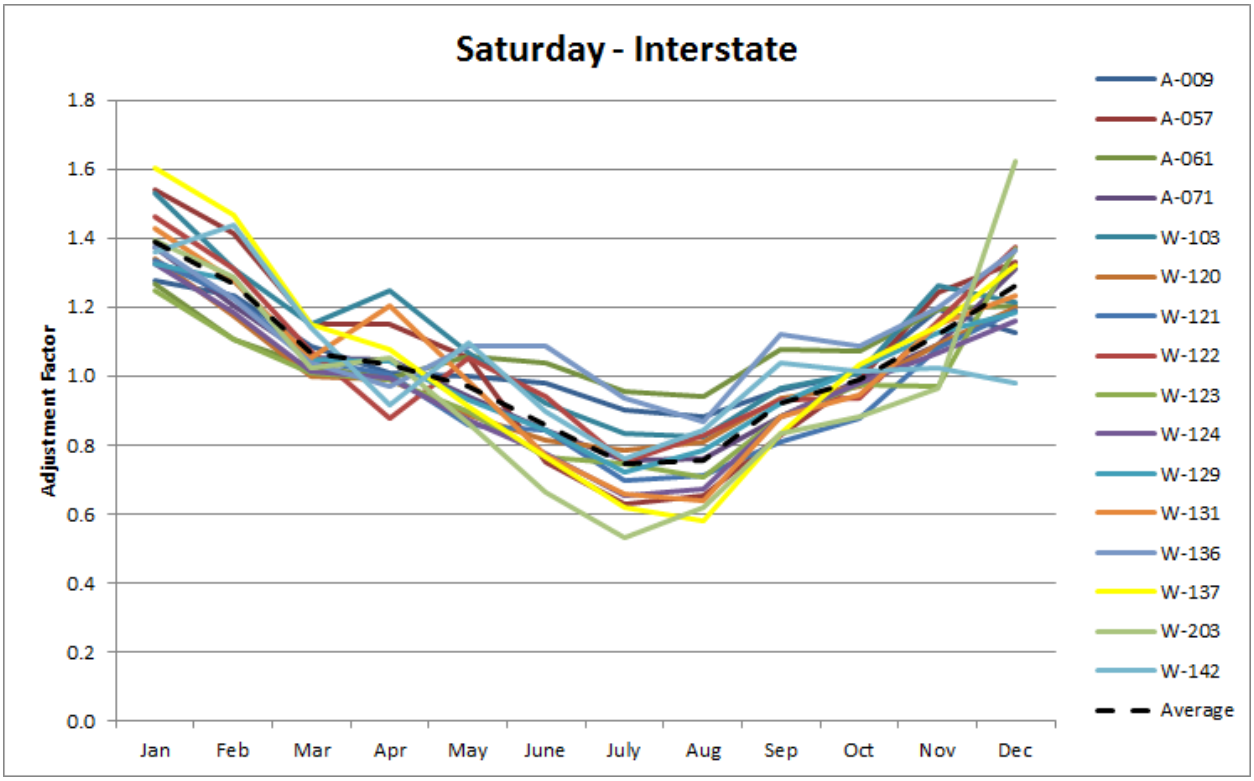

Figure 15 Interstate count station adjustment factors, Saturday

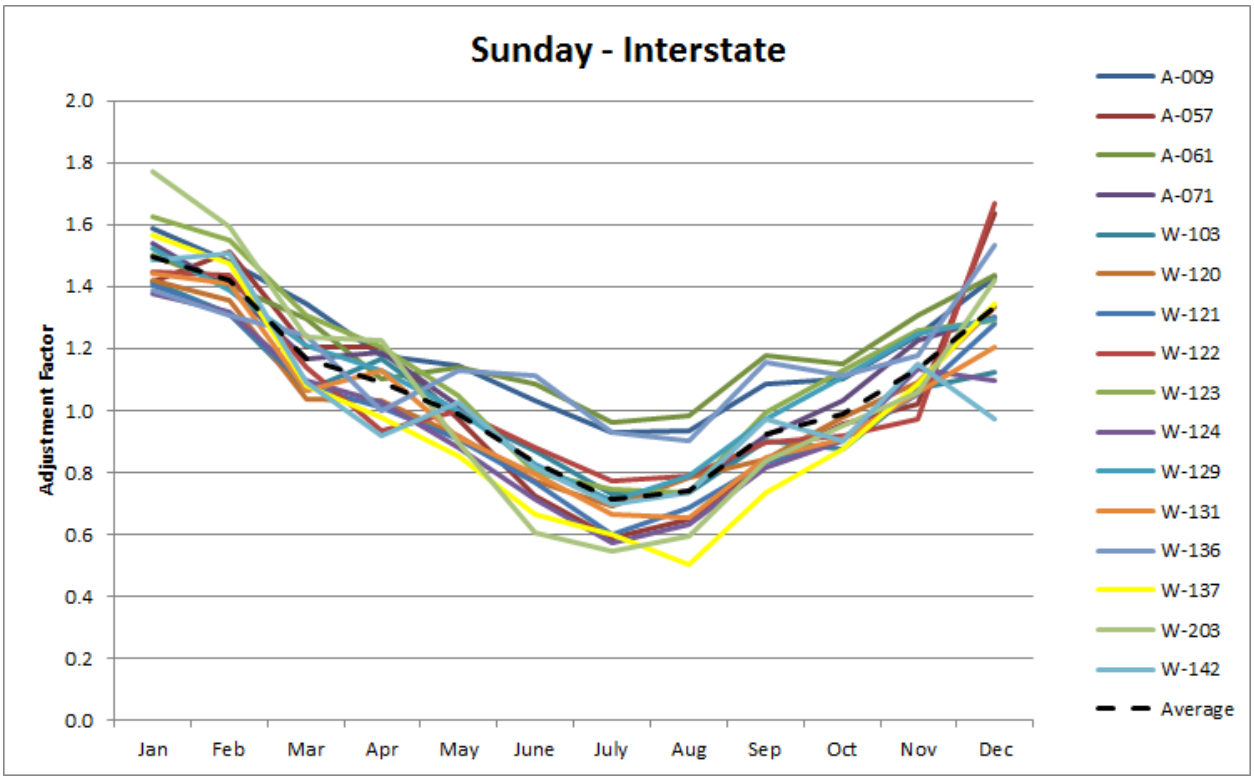

Figure 16 Interstate count station adjustment factors, Sunday

The next regional adjustment factor group evaluated was agricultural areas. The adjustment factor trends at these sites, shown in Figure 17, Figure 18, Figure 19 and Figure 20, 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.

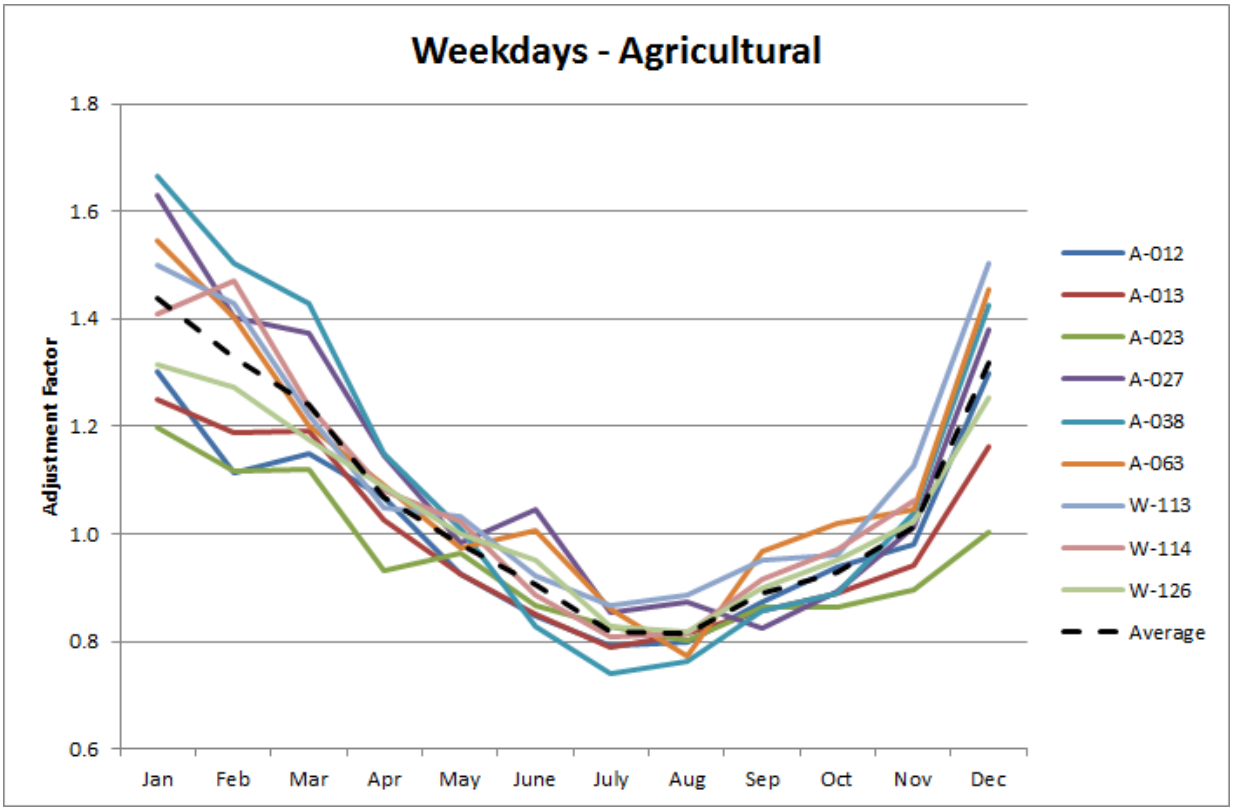

Figure 17 Agriculture count station adjustment factors, weekdays

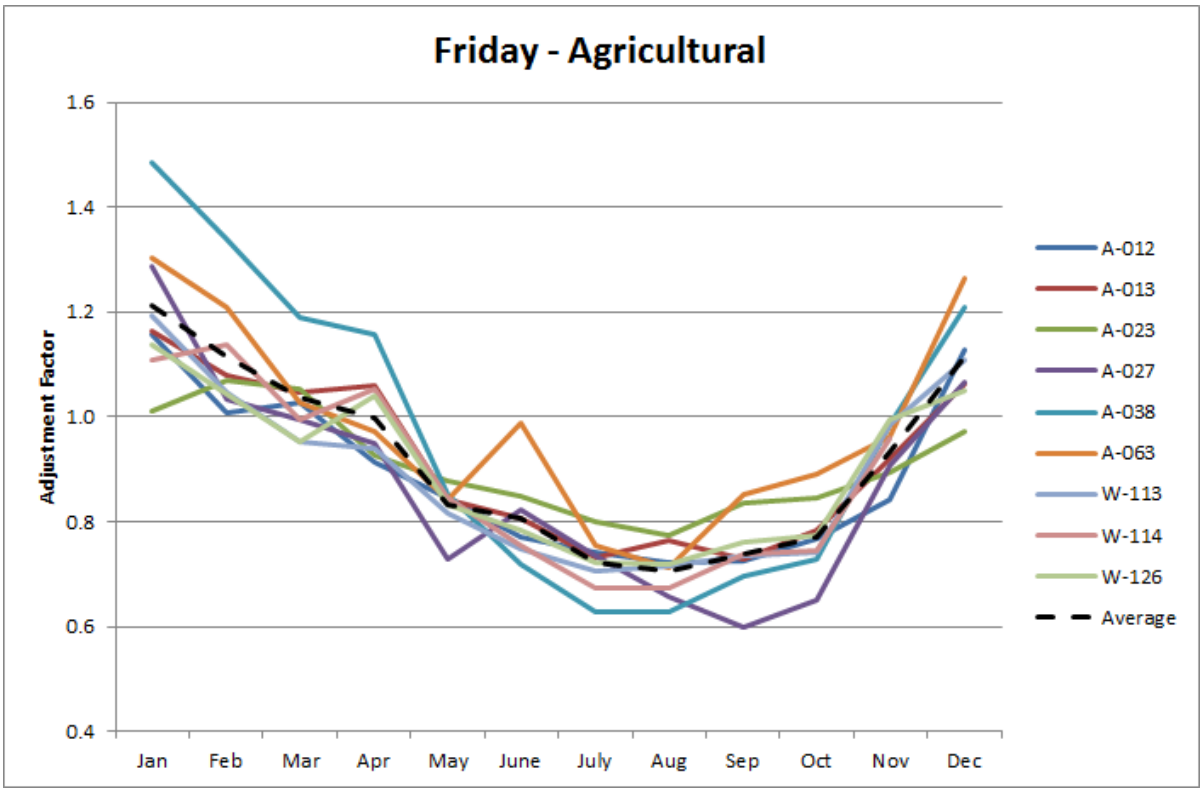

Figure 18 Agriculture count station adjustment factors, Friday

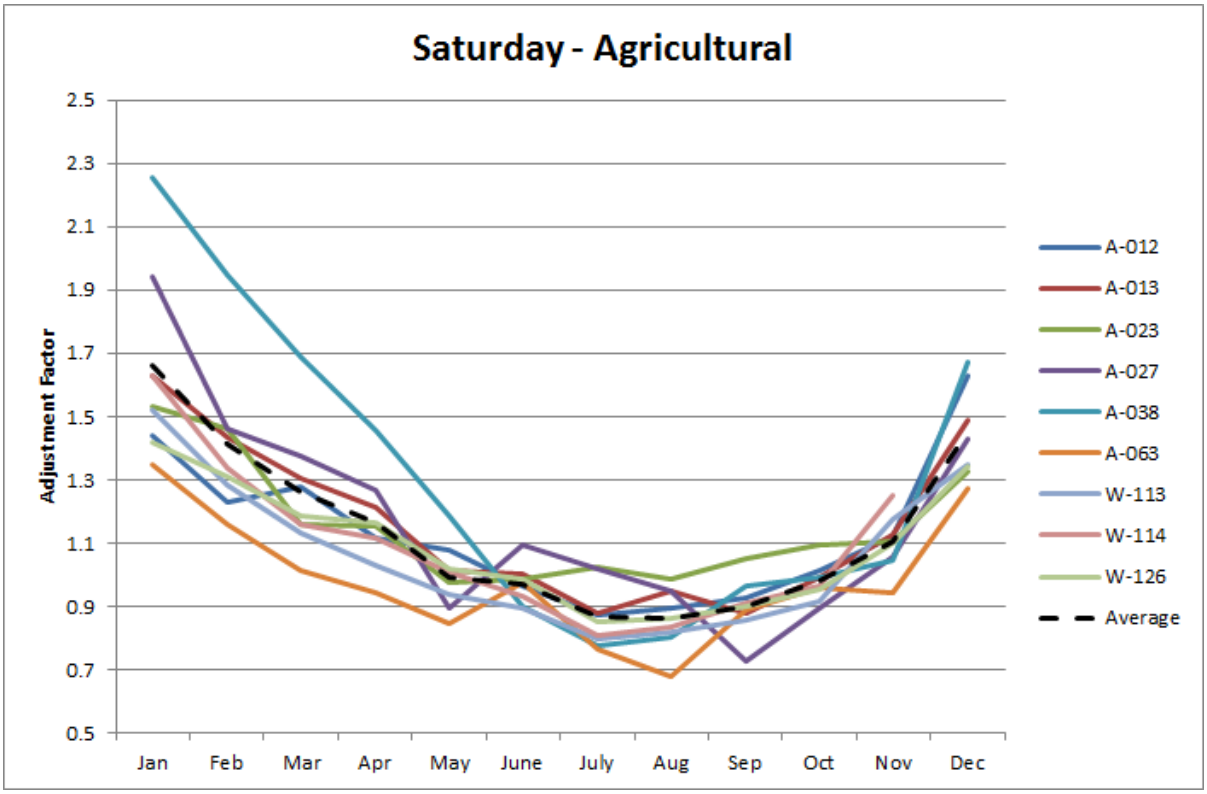

Figure 19 Agriculture count station adjustment factors, Saturday

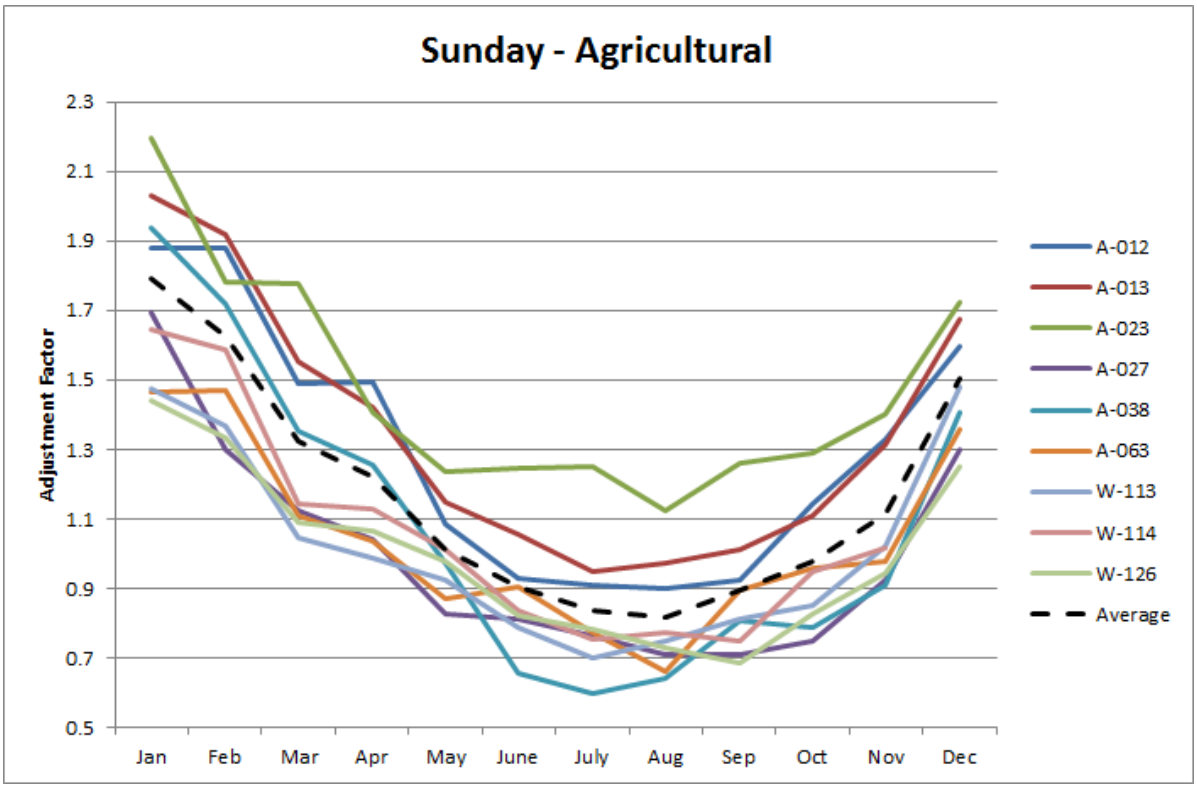

Figure 20 Agriculture count station adjustment factors, Sunday

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 21, Figure 22, Figure 23 and Figure 24 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.

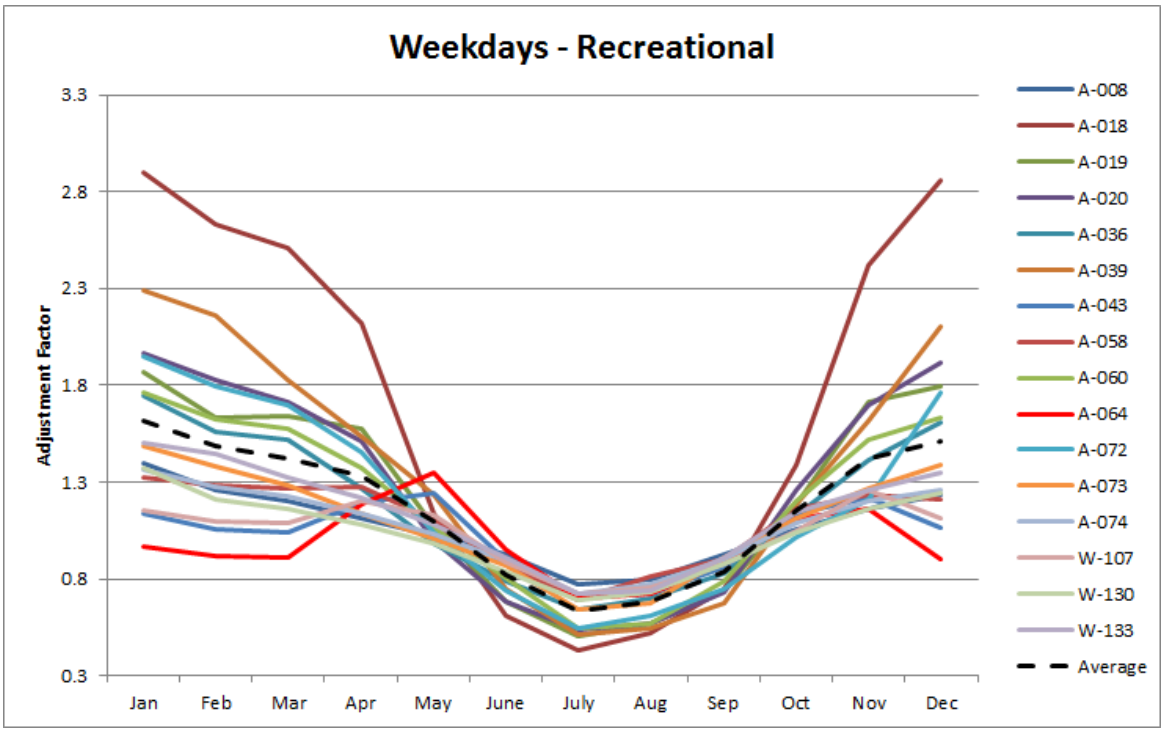

Figure 21 Recreation count station adjustment factors, weekdays

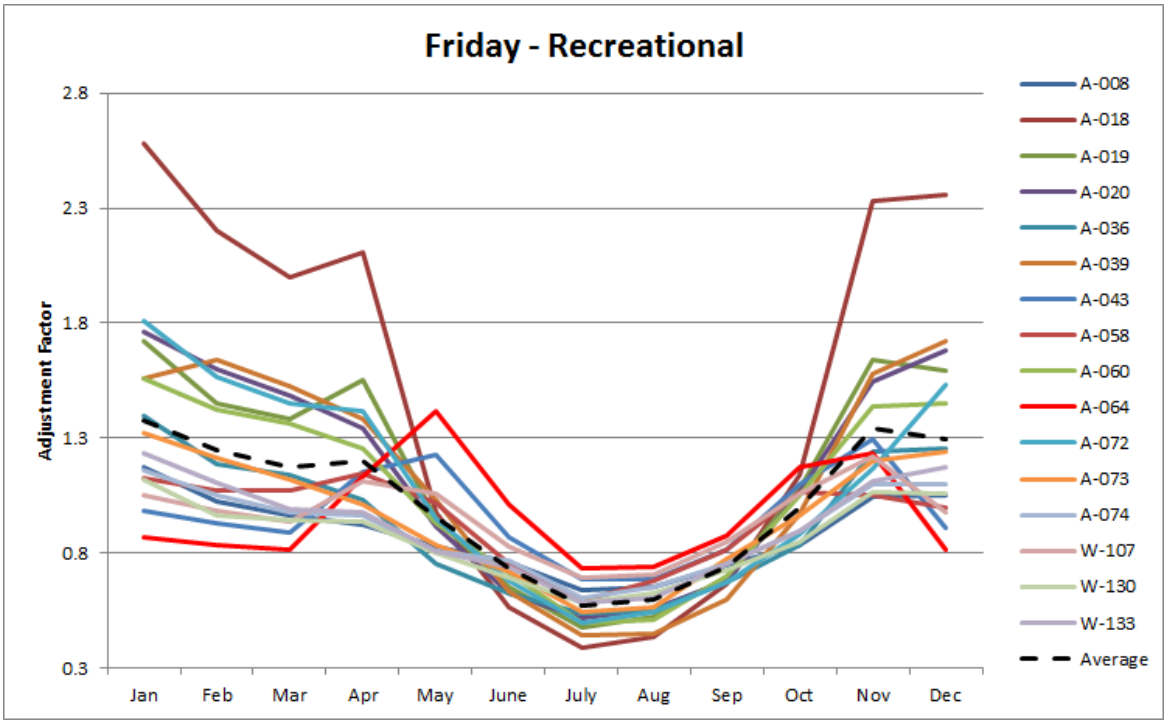

Figure 22 Recreation count station adjustment factors, Friday

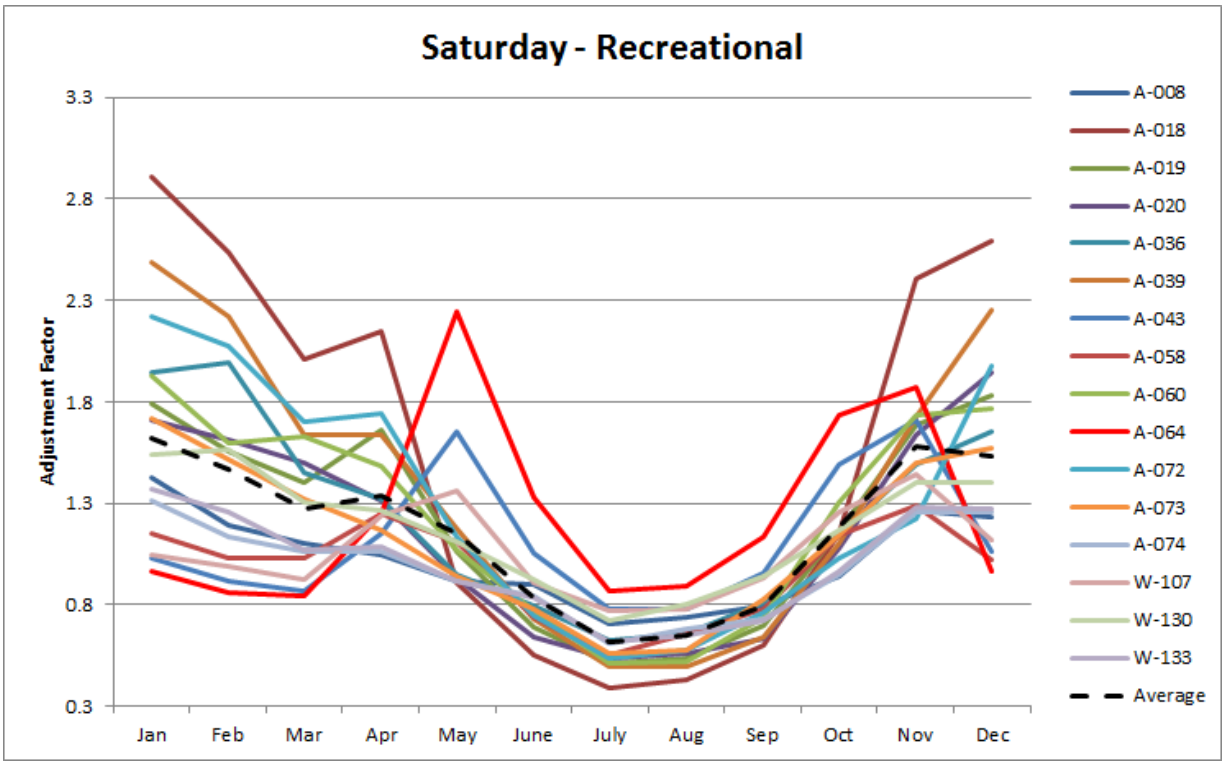

Figure 23 Recreation count station adjustment factors, Saturday

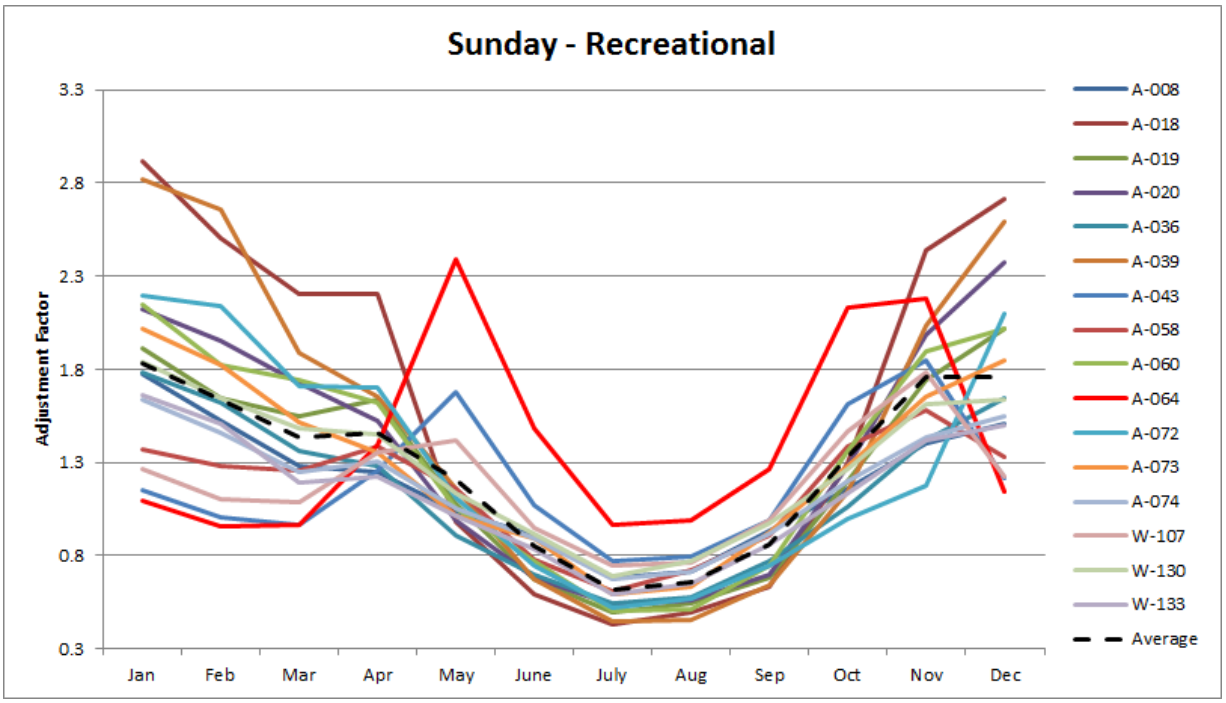

Figure 24 Recreation count station adjustment factors, Sunday

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 25, Figure 26, Figure 27 and Figure 28 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.

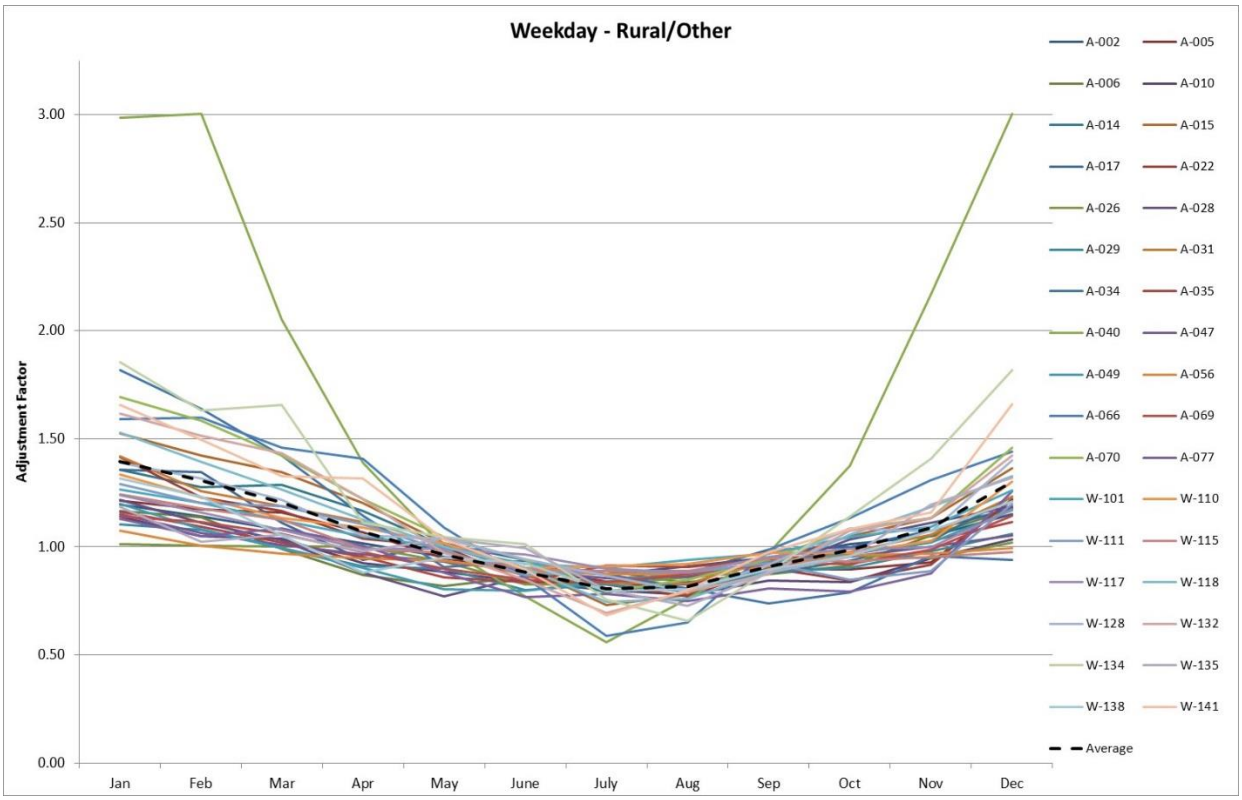

Figure 25 Rural/other count station adjustment factors, weekdays

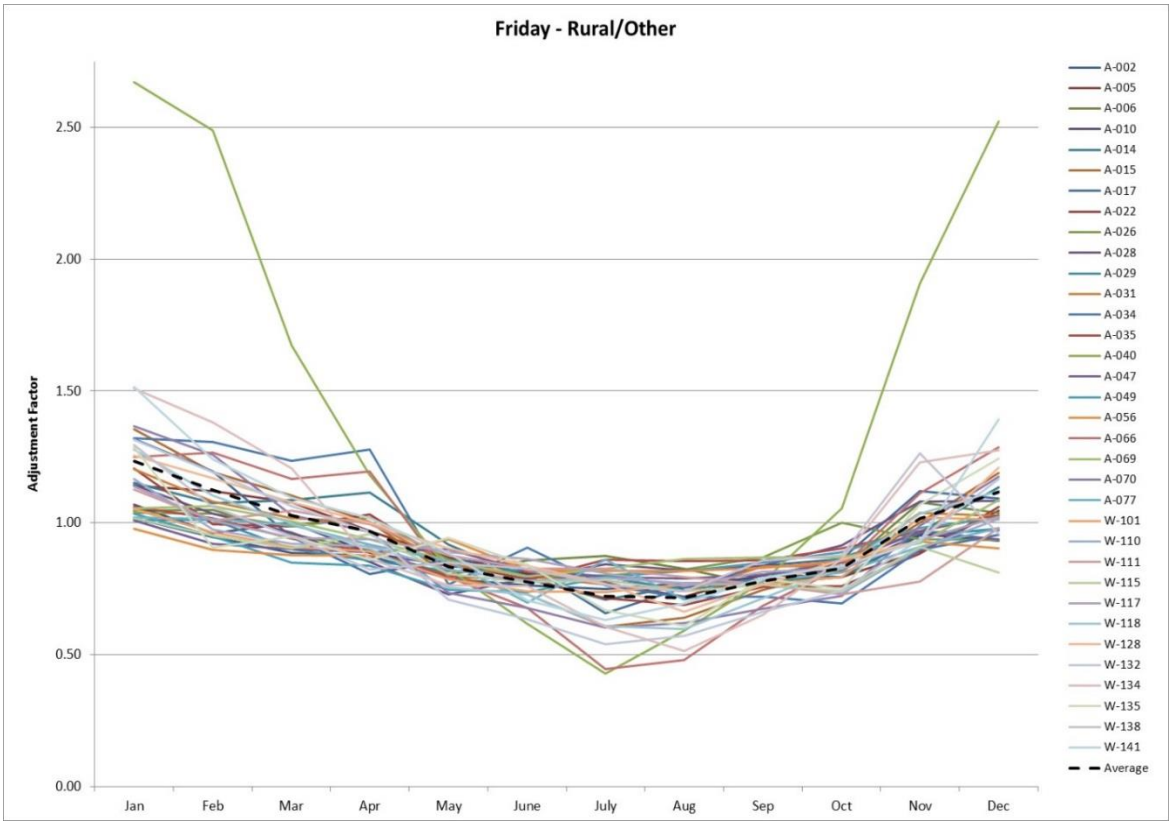

Figure 26 Rural/other count station adjustment factors, Friday

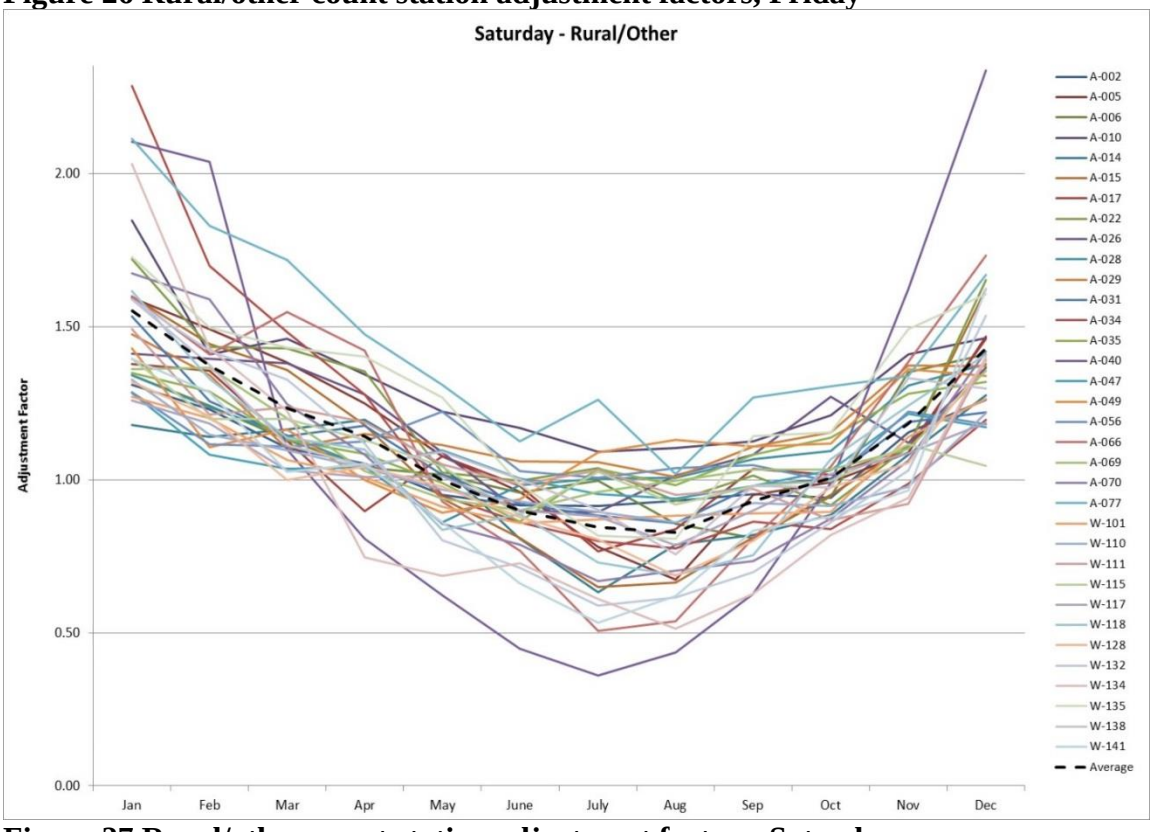

Figure 27 Rural/other count station adjustment factors, Saturday

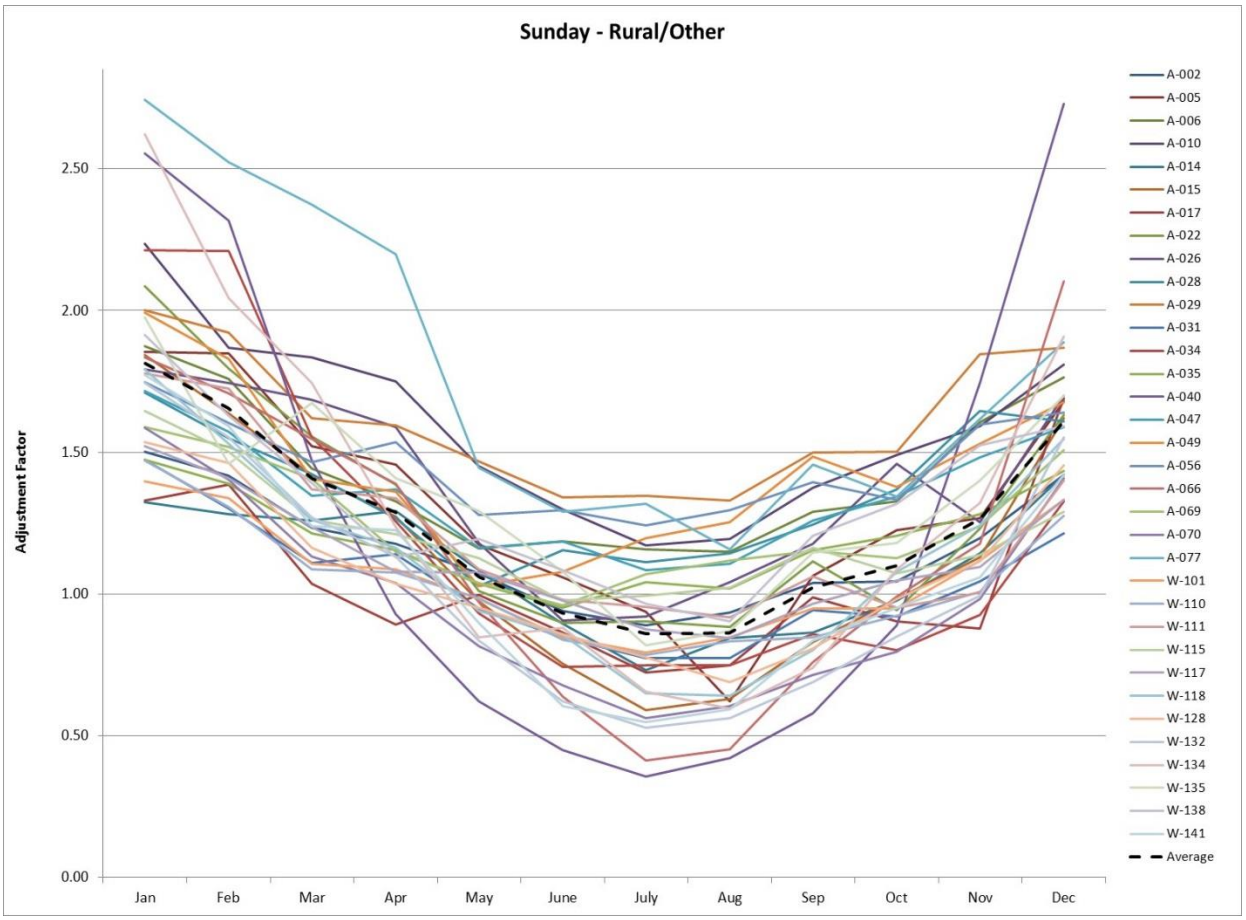

Figure 28 Rural/other count station adjustment factors, Sunday

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 7 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

Table 7. 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

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 5 and Table 7, 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.

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 29, Figure 30, Figure 31 and Figure 32, 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.

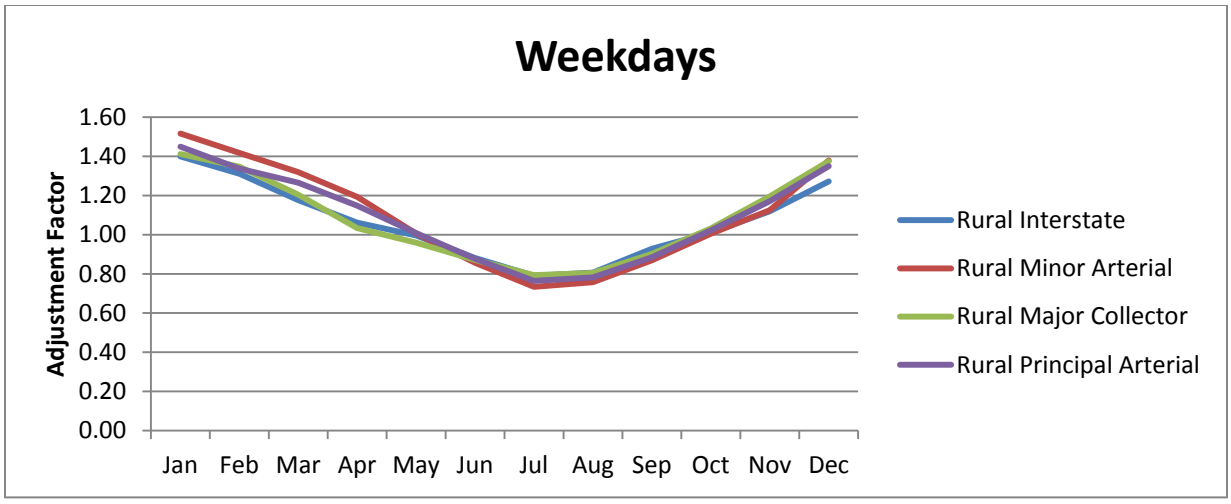

Figure 29 Rural route classification count station adjustment factors, weekdays

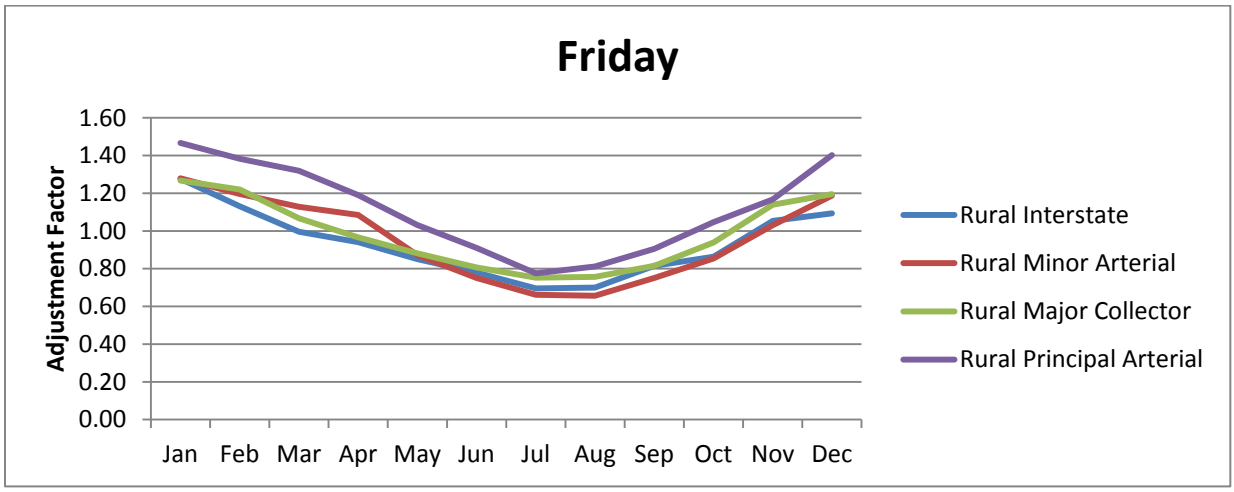

Figure 30 Rural route classification count station adjustment factors, Friday

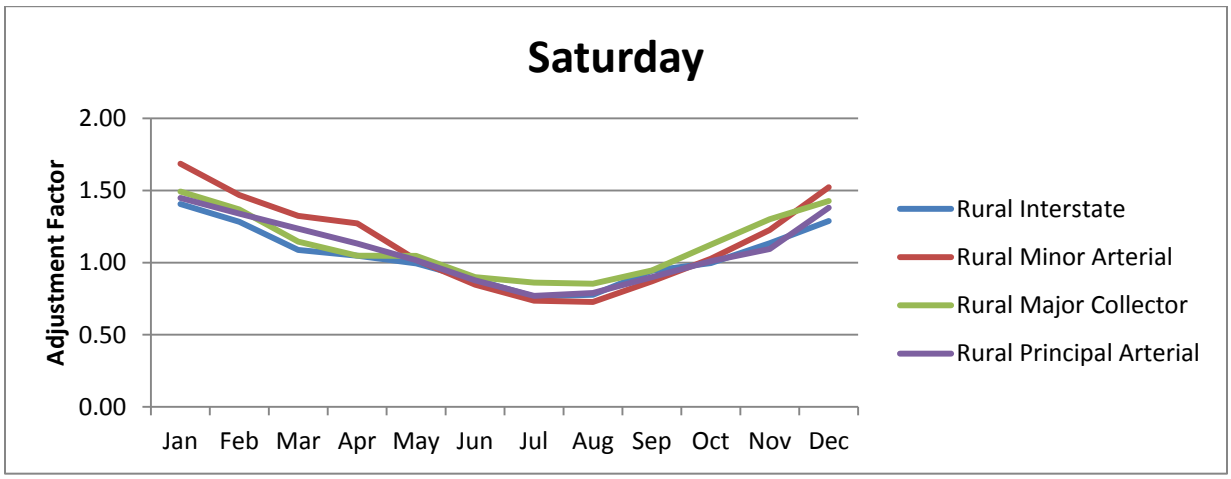

Figure 31 Rural route classification count station adjustment factors, Saturday

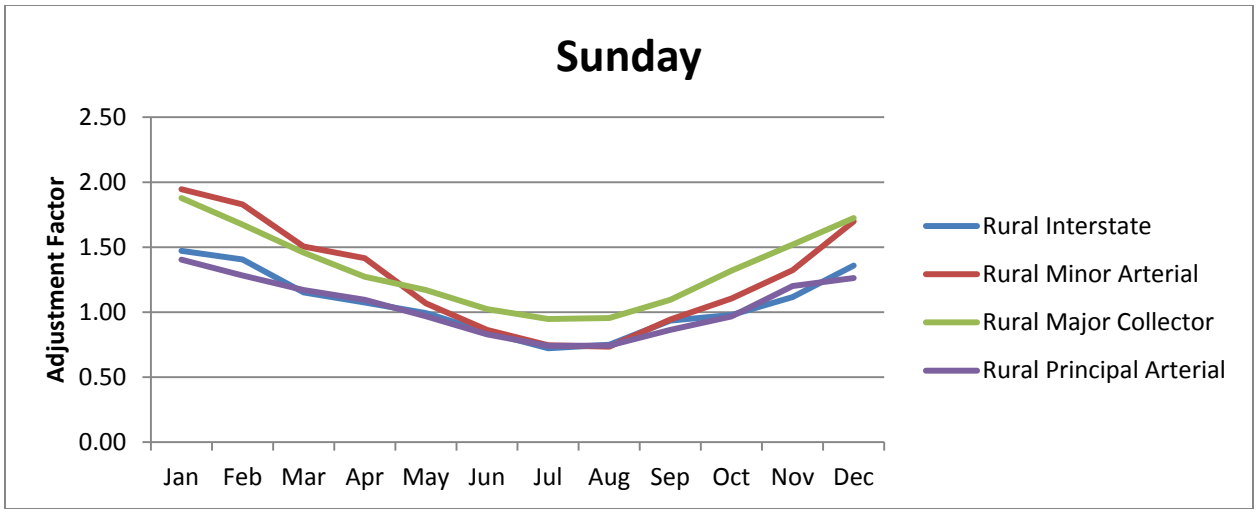

Figure 32 Rural route classification count station adjustment factors, Sunday

Adjustment factors for the urban highway groups currently used by MDT are presented in Figure 33, Figure 34, Figure 35, and Figure 36, 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.

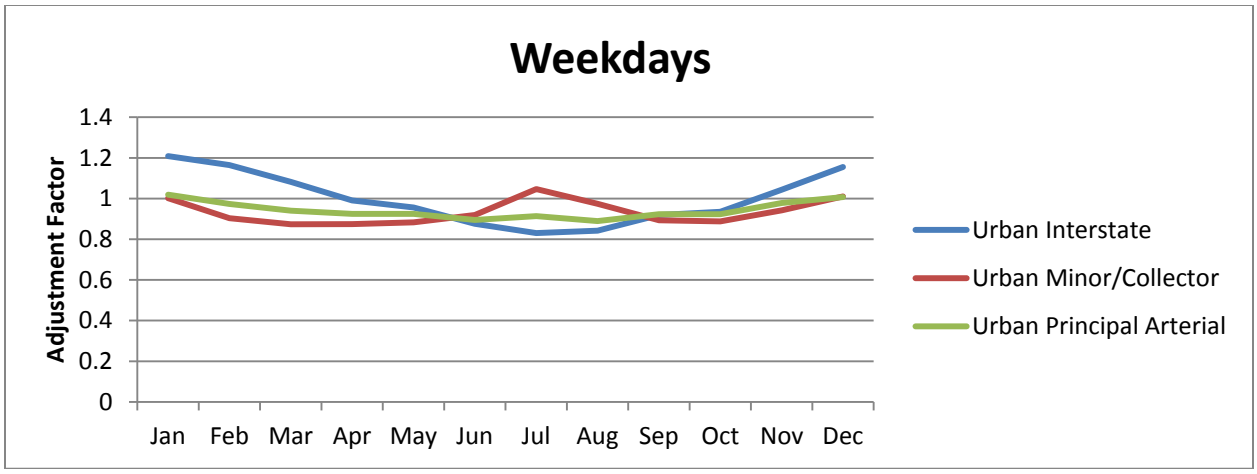

Figure 33 Urban route classification count station adjustment factors, weekdays

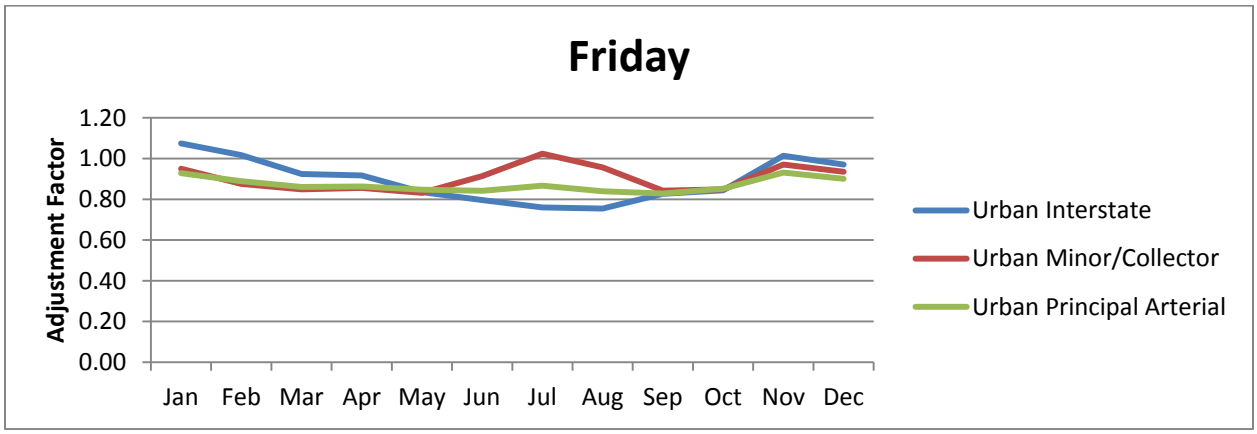

Figure 34 Urban route classification count station adjustment factors, Friday

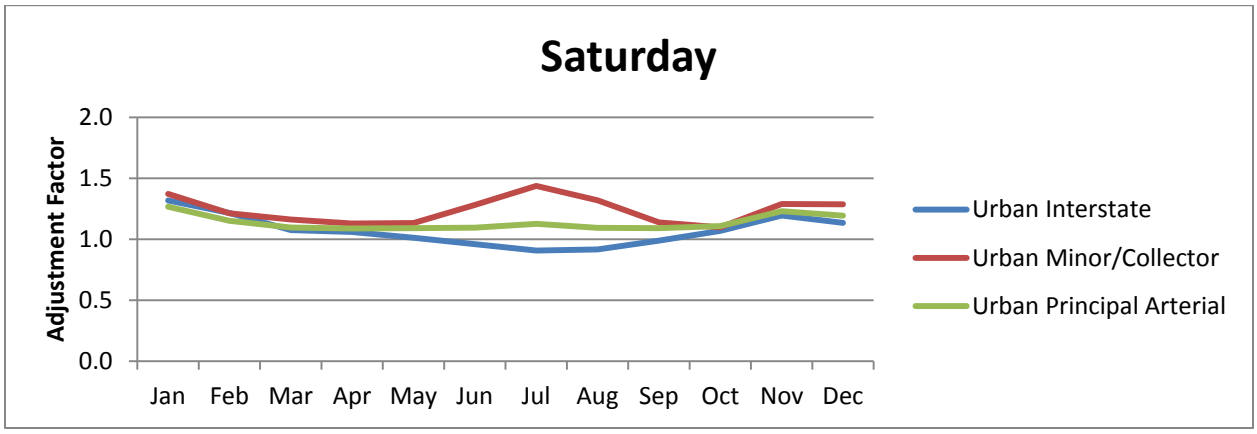

Figure 35 Urban route classification count station adjustment factors, Saturday

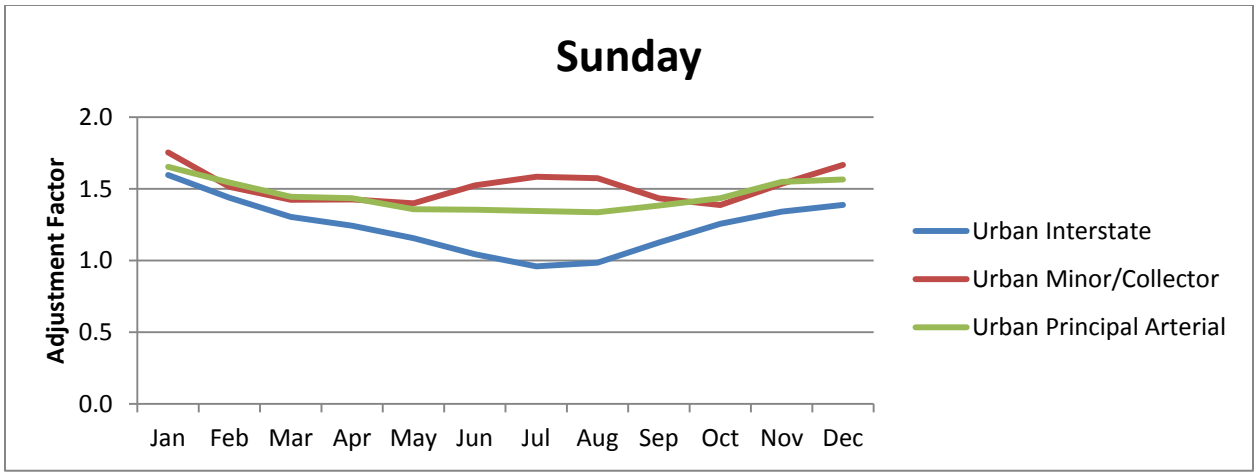

Figure 36 Urban route classification count station adjustment factors, Sunday

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 37, Figure 38, Figure 39 and Figure 40, 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.

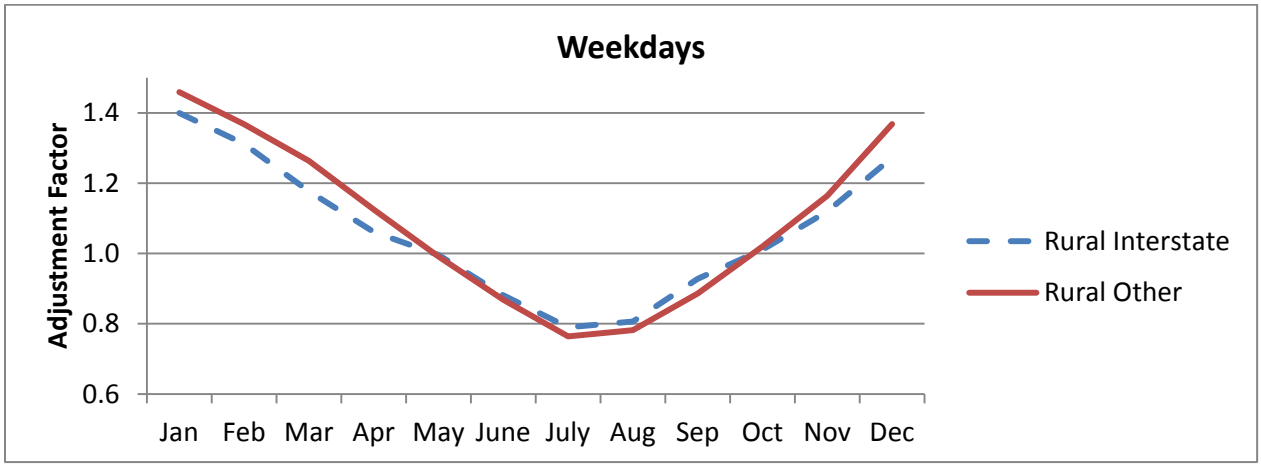

Figure 37 Rural Interstate and all other route adjustment factors, weekdays

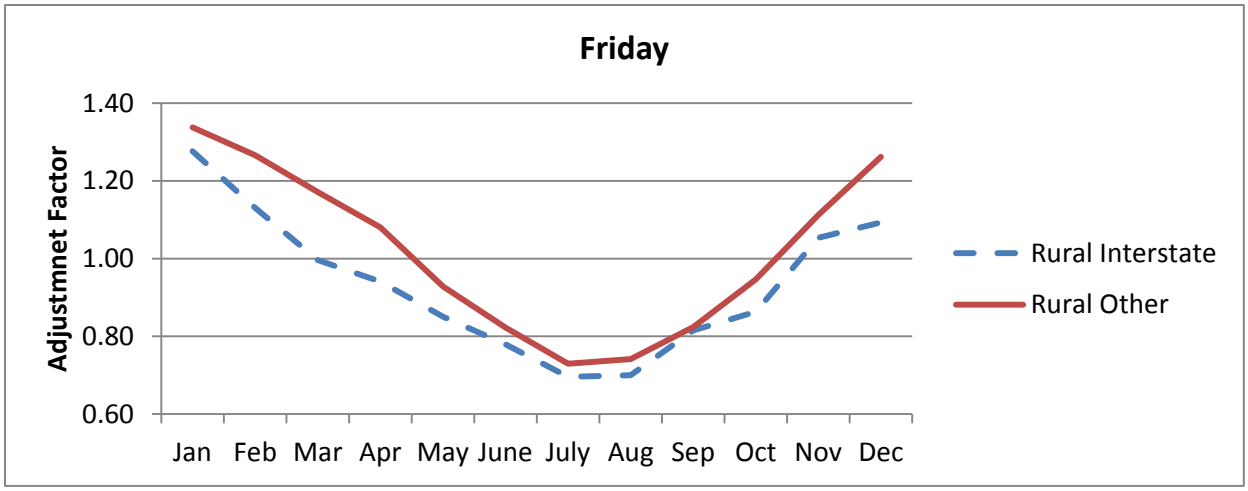

Figure 38 Rural Interstate and all other route adjustment factors, Friday

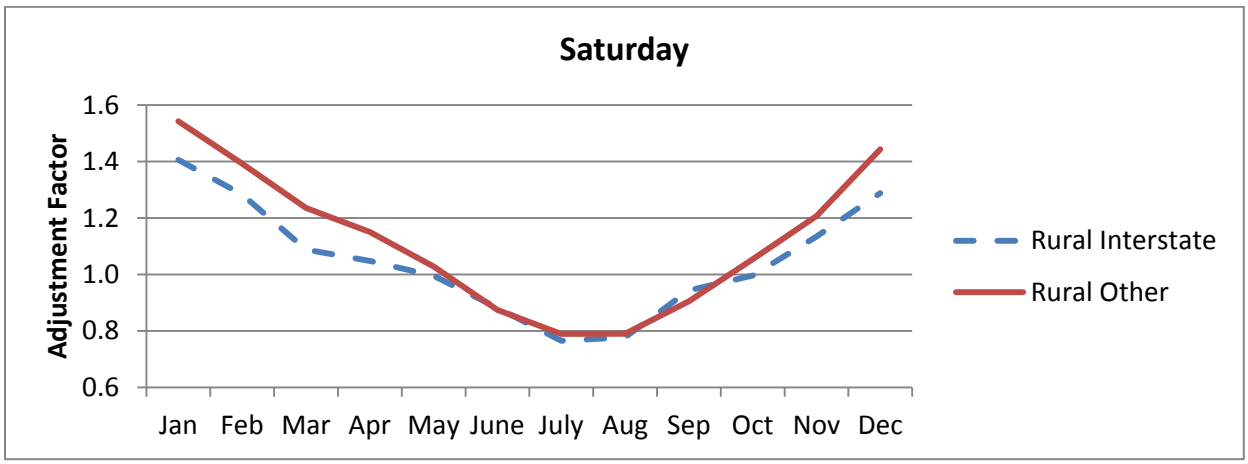

Figure 39 Rural Interstate and all other route adjustment factors, Saturday

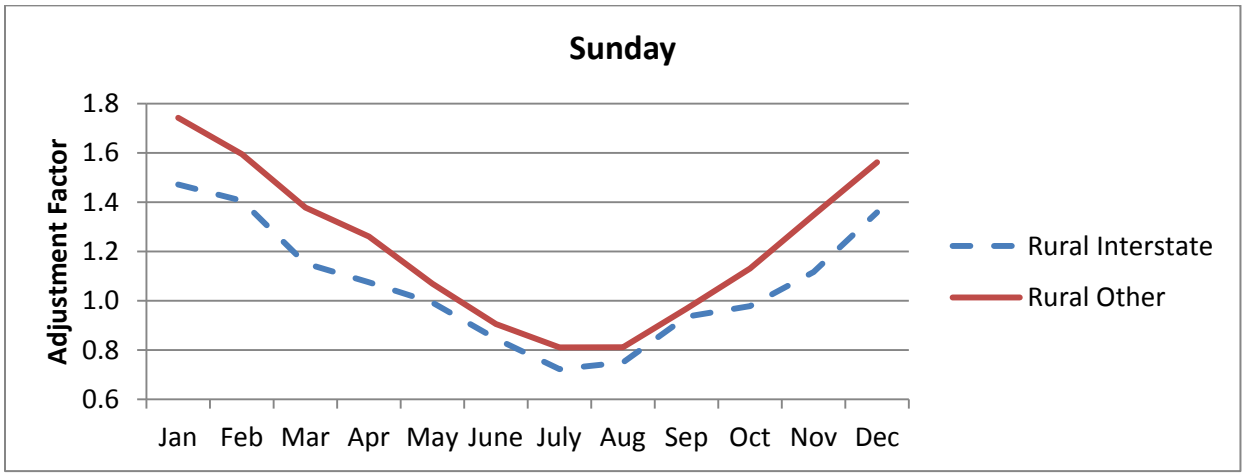

Figure 40 Rural Interstate and all other route adjustment factors, Sunday

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 41, Figure 42, Figure 43 and Figure 44, 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.

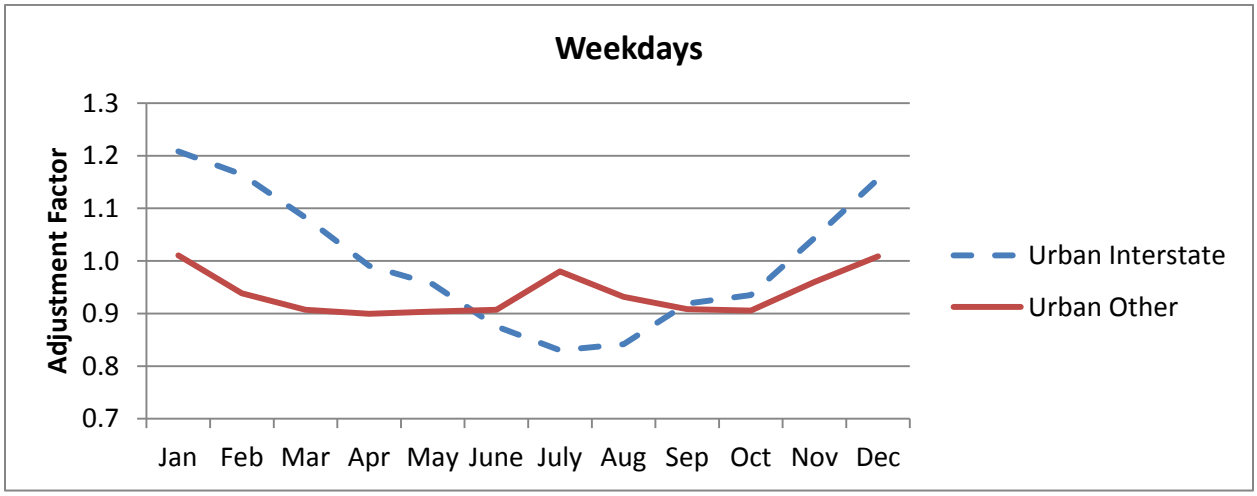

Figure 41 Urban Interstate and all other route adjustment factors, weekdays

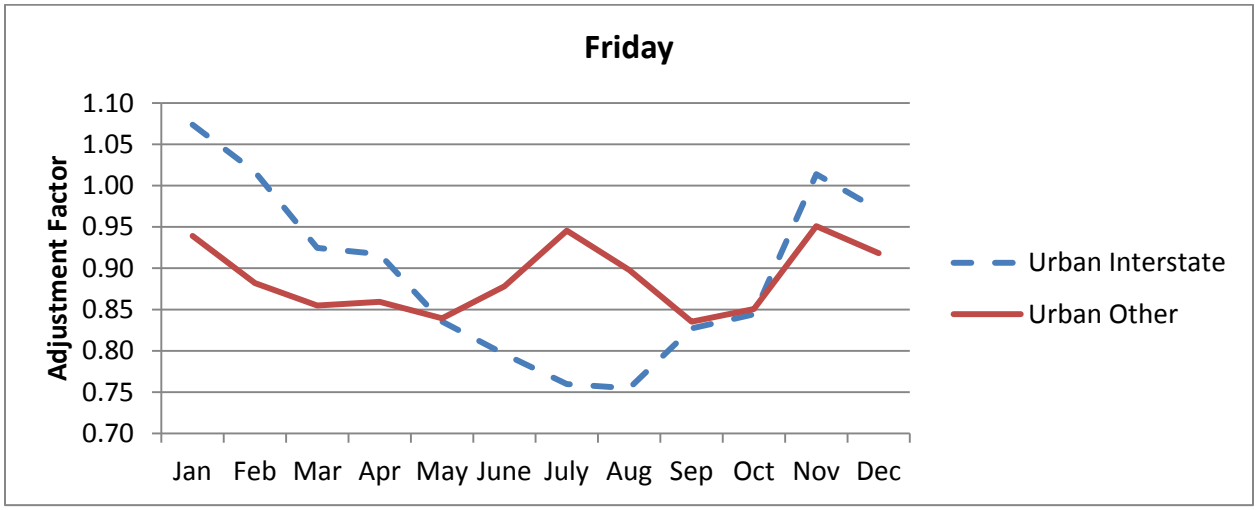

Figure 42 Urban Interstate and all other route adjustment factors, Friday

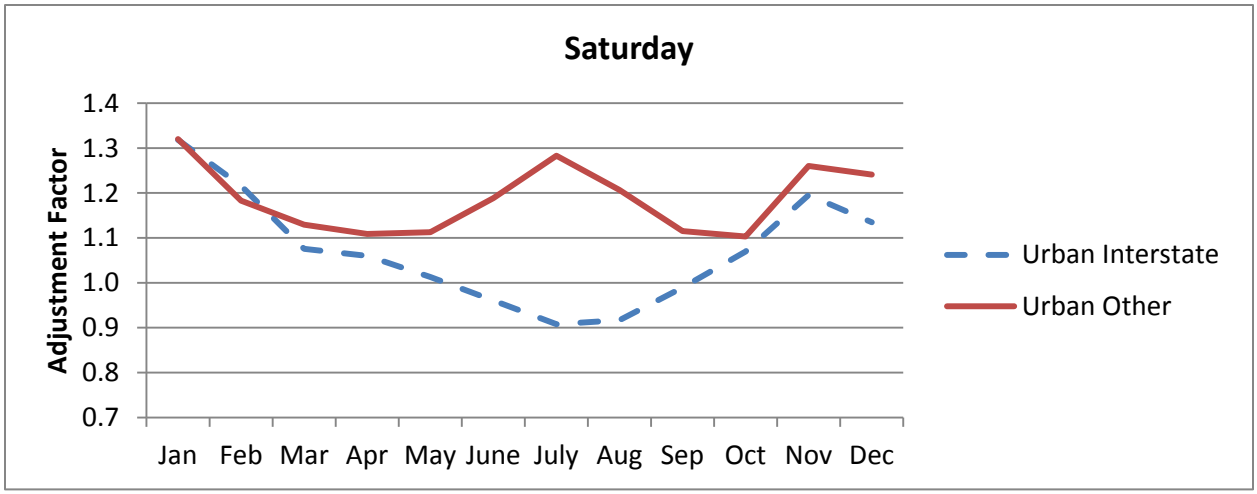

Figure 43 Urban Interstate and all other route adjustment factors, Saturday

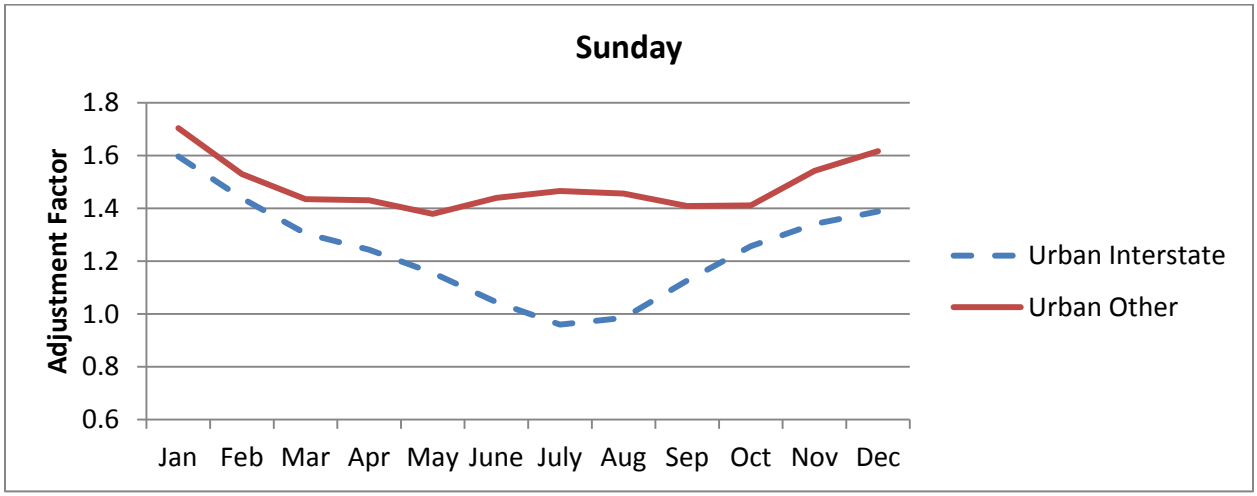

Figure 44 Urban Interstate and all other route adjustment factors, Sunday

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 8. Standard deviations for the expanded traffic factor groups currently used by MDT are presented in Table 9.

Table 8. 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 9. 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 8 and Table 9, 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 9). This is similar in trend to what was observed for the rural "other" category in the modified grouping scheme (see Table 8), 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 Tables 8 and 9, , 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 9 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 33, Figure 34, Figure 35 and Figure 36. 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 follows:

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

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 10 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 10. 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 11 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 11. 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 12 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 12. 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.

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 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 applications that are 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 modified 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
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.

WORKS CITED

FHWA (2012), WIM Data Analyst's Manual, 2010.

FHWA (2013), Traffic Monitoring Guide, Washington D.C., September 2013. http://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/, last accessed December, 2014.

FHWA (2012), *Highway Performance Monitoring System: Field Manual*, U.S. Department of Transportation, http://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/, last accessed November, 2012.

Indiana Department of Transportation (undated), Adjustment Factors, Traffic Statistics, Indianapolis, Indiana, http://www.in.gov/indot/3000.htm, last accessed January, 2015.

Montana Department of Commerce (undated), Census & Economic Information Center Industry Dashboard, Montana Department of Commerce, Helena, Undated. http://ceic.mt.gov/Economics/IndustryDashboard.aspx, last accessed August, 2014.

MDT (2012), *Traffic Adjustment Factors*, Montana Department of Transportation, Helena, MT. http://www.mdt.mt.gov/publications/datastats/traffic_factors.shtml, last accessed November, 2012.

MDT (2012a), *ATR and WIM Map*, Montana Department of Transportation, Helena, MT. http://www.mdt.mt.gov/publications/docs/datastats/atr/atr_wim_sites.pdf, last accessed October, 2012.

MDT (2014), Traffic Data, Montana Department of Transportation, Helena, MT. http://www.mdt.mt.gov/publications/datastats/traffic.shtml, last accessed December, 2014.

Ohio Department of Transportation (undated), Seasonal Adjustment Factors, Division of Planning, Office of Technical Services, Columbus, Ohio, http://www.dot.state.oh.us/Divisions/Planning/TechServ/traffic/Pages/SeaAdjFctrs.aspx , last accessed January, 2015.

Oregon Department of Transportation (undated), Transportation Development – Planning, Seasonal Trend Table, Salem, Oregon, http://www.oregon.gov/ODOT/TD/TP/Pages/Data.aspx , last accessed January, 2015.

Sheskin, David (2000), "Handbook of Parametric and Nonparametric Statistical Procedures, 2nd ed.," Boca Raton, Florida: Chapman & Hall, 2000.