Traffic and ESAL Summary for the MnROAD Mainline

(July 1994 – June 2011)

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Executive Summary

Since its construction in the early 1990s, the Minnesota Department of Transportation's MnROAD has been an important cold-weather pavement research facility on an international scale. Lessons learned from both concrete and bituminous pavement research projects have led to longer lasting and more cost effective designs in the transportation field. These designs are especially important to the construction of highway pavements, which help to ferry the largest volumes of passenger and commercial vehicles to their destinations. To this end, the MnROAD mainline serves as a highway test track on westbound Interstate 94 near Albertville, MN.

Many different types of sensory instrumentation exist at the facility, which in addition to forensic analysis techniques help researchers to better understand the data collected and why pavements fail. Unfortunately, the available instrumentation does not directly measure damage to the pavement as a function of loading or traffic volume on a per vehicle, daily, monthly, or yearly basis. This damage is often expressed as Equivalent Single Axle Loads (ESALs), which are important for pavement design and understanding the life span of pavements.

In order to determine the ESAL values for test pavements, traffic volume and loading data recorded by Weigh-In-Motion (WIM) sensors was used. Axle type and loading values were used along with volumes to estimate the amount of ESALs for each lane and day, when available. In some cases, the WIM was not operational or the data were not of good quality. To rectify these situations, vehicle volumes were estimated based on the Federal Highway Administration's vehicle classification system, Average Annual Daily Traffic (AADT) volumes for the location based on past WIM data, and seasonal adjustment factors developed by the Office of Transportation Data and Analysis. Estimated volumes were then used along with Mn/DOT's Pavement Manual to estimate ESALs for those days.

In the period July 15, 1994 – June 01, 2011, the MnROAD mainline experienced a traffic volume of approximately 112 million vehicles. Flexible ESAL values were found to be 9.37 million for the driving lane and 2.35 million for the passing lane. Rigid ESAL values were found to be 14.4 million and 3.65 million, respectively. Heavy commercial vehicles constituted 13.2% of all vehicles on the route. Further details are found in the Results and Conclusions section of this report.

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1.0 Introduction

The MnROAD mainline is a 3.5-mile stretch of road on westbound Interstate 94 located near Albertville, MN. It serves as a pavement test track with 32 separate cells consisting of differing materials, treatments, and construction methods.

Sensors embedded in the pavement help to measure the performance of individual test cells. This performance data is used to make improvements in the construction of concrete and bituminous pavements for future projects both at MnROAD and on other state, county, and municipal routes.

Unfortunately at this time, there are not cost-effective sensors for use in every test cell that are able to directly record Equivalent Single Axle Loads (ESALs), a measure of the amount of damage to the pavement incurred by vehicle loads. This figure is key to transportation construction projects, because roadways are often designed using an ESAL calculation which represents the approximate design life of the pavement. Determining the ESAL values for test pavements will help designers better understand and improve the life span of their projects.

MnROAD has possessed a Weigh-In-Motion (WIM) sensor in operation at the site which has recorded vehicle type, approximate weight, speed, and numerous other data since 1994. This data was used to estimate the amount of ESALs incurred on the mainline. This process involved use of both weight and vehicle classification data, and is detailed in Section *2.0 Procedure*.

Section 3.0 Results contains tables and figures put together during this study. Discussion of the findings is also present; it includes a traffic and ESAL summary, classification summary, comparison of ESAL estimation methods, and a summary of heavy commercial vehicles.

Statistics summarizing traffic volume, loading, and vehicle classification on the mainline are found in Section *4.0 Conclusion*. These values reflect the tables presented in the Section *3.0 Results* section of this report, as well as other data found in the Excel workbook. Figures are given as daily, annual, and totals for the period July 15, 1994 – June 1, 2011.

2.0 Procedure

This section describes the methods used to estimate the amount of ESALs incurred on the MnROAD mainline for the time period of July 15, 1994 – June 1, 2011.

2.1 Data Collection

All data tables used in this study were downloaded from an Oracle SQL database using the SQL Developer program. These tables, along with their connections, are listed in *Table 2-1*.

Table 2-1: Weigh-In-Motion Data Tables Used in this Study

Database Table / View	**Database Connection**
MNR.TRAFFIC_SWITCHES	MNROAD
WIM.WIM_ADMIN_ESAL_FACTORS	MNROAD
WIM.WIM_MNS04_ALL_DAYS	MNROAD
WIM.WIM_MNS04_SINGLE_AX_BINS	MNROAD
WIM.WIM_MNS04_STEER_AX_BINS	MNROAD
WIM.WIM_MNS04_TANDEM_AX_BINS	MNROAD
WIM.WIM_MNS04_TRIDEM_AX_BINS	MNROAD
WIM.WIM_MNS04_QUAD_AX_BINS	MNROAD
WIM.WIM_MNS25_ALL_DAYS	MNROAD
WIM.WIM_MNS25_SINGLE_AX_BINS	MNROAD
WIM.WIM_MNS25_STEER_AX_BINS	MNROAD
WIM.WIM_MNS25_TANDEM_AX_BINS	MNROAD
WIM.WIM_MNS25_TRIDEM_AX_BINS	MNROAD
WIM.WIM_MNS25_QUAD_AX_BINS	MNROAD
WIM.WIM_MNS37_ALL_DAYS	WIM_MGMT
WIM.WIM_MNS37_SINGLE_AX_BINS	WIM_MGMT
WIM.WIM_MNS37_STEER_AX_BINS	WIM_MGMT
WIM.WIM_MNS37_TANDEM_AX_BINS	WIM_MGMT

It should be noted that only a small amount of tridem and quadrem axle bin data was available in the database for WIM #37, so these tables were not used. Together, these axle types only account for only a small percentage of daily ESALs (1.93%) and since this data is only missing for WIM #37 (11.5% of all mainline days), the calculated ESAL values in this study are not significantly affected.

2.2 Data Processing and Validation

Before any calculations were to be performed, inspection of the data tables was necessary. Types of inspection performed included but were not limited to: checks for missing days and/or lanes of data, checks for double-counted and/or overlapping data, and checks for days of data with unusually low or high traffic counts. Some of these checks were done manually, while others required the creation of Visual Basic for Applications (VBA) macro code, which could be performed on the data tables within Microsoft Excel.

Data from WIM #04, 25, and 37 were combined in Excel into spreadsheets of the same type. For instance, all data from tables *WIM.WIM_MNS04_ALL_DAYS*, *WIM.WIM_MNS25_ALL_DAYS*, and WIM.*WIM_MNS37_ALL_DAYS* were combined into one spreadsheet, in this case named *Export Worksheet*. Columns of data from this particular worksheet that were determined to be significant for this study were then placed into another worksheet named *Main_Table*, where most of the data analysis in this study took place.

The data from the three WIM devices was collected from the following date ranges:

WIM #04: July 15, 1994 – September 08, 2001

WIM #25: August 20, 2000 – April 29, 2008

WIM #37: July 14, 2009 – June 01, 2011.

It was observed that there is an overlap of data between WIMs #04 and 25, between August 20, 2000 and September 08, 2001. Since simply combining the data from all tables resulted in double-counting vehicles in this range, it was determined to use only data from WIM #25 effective on its start date. Therefore, the additional data from WIM #04 past this date was not necessary, so the effective end of data from WIM #04 was decided as August 19, 2000 in this study.

2.2.1 Traffic Switches

MnROAD undergoes frequent traffic switches on the mainline due to construction, regular maintenance, and specialized testing. Because of these periods where there is no traffic (only maintenance vehicles) on the mainline, there appears to be many gaps in the WIM data. These traffic switches are detailed in the database table *MNR.TRAFFIC_SWITCHES*, and were manually placed into the Excel workbook in the tab *Traffic Switches*. Each day is represented in this tab for a total of 1,871 days in the range of this study.

In the case of data for WIMs #04 and 25, the WIM device was located on the mainline. Therefore, any time that a traffic switch occurred, the WIM would not record data. For WIM #37 however, it was placed before the split of the mainline and old WB I-94. This caused data to be recorded on the WIM even during traffic switches. It was decided to keep this data in the table, but not to use it for calculation of ESALs on the mainline.

It was found that another study may have been done in the past, estimating traffic volumes and axle bins for days of missing data. Due to this, tables contained vehicle volumes (*ALL_DAYS*-type tables) as well as binned axle and weight data (*_AX_BINS*-type tables) for days of traffic switches, with another column designated as a "Replacement Day." Since none or a fewer than normal amount of vehicles were actually on the mainline for these days, these replacement volumes were inaccurate and needed deletion. This was done for the axle bins with the aid of the macro *N01_Fix_Traffic_Switches_Axle_Bins*, which searched the axle bin data for dates of traffic switches and removed this data. Volume data in the *Main_Table* tab was removed manually by deleting volumes for days filtered as "Traffic Switch=Yes" and "Traffic=vehicles off all day."

2.2.2 Estimate Days

Through inspection of data in the *Main_Table* sheet, it was determined that there were numerous days with unusually low traffic counts or high counts of unidentified or error vehicles on days where no traffic switches were in effect. In this study, an estimate day was defined as a day not under a traffic switch in which Lane 1 (the driving lane) experienced a total traffic volume of less than 5,000 vehicles or more than 2,500 combined Class 14 and Class 15 vehicles. This was chosen because either of these two situations occurring may indicate that a problem was occurring with the sensor. Volumes for these missing data days were required for ESAL calculations under several different methods, so these volumes would need to be estimated.

2.3 Adjustment Factors

In order to approximate vehicle volumes for estimate days, adjustment factors were both procured from the Office of Transportation Data & Analysis (TDA) as well as created using the WIM data in this study. These factors helped to estimate vehicle volumes in a more precise way than simply using past volumes, if available. Furthermore, the volumes required are only westbound volumes, not route volumes typically available from Average Annual Daily Traffic (AADT) data.

2.3.1 Seasonal Adjustment Factors

Seasonal adjustment factors were available through TDA's *Determination of Seasonal Adjustment Factors for Vehicle Class Counts*. The report details the creation of these factors. In this study, all factors used were based on 24-hour counts and classified as rural factors. Volume estimates for the year 2011 are based on 2010 factors, while estimates for years prior to 2007 are based on the "Previously Used Seasonal Adjustment Factors."

TDA's report lists factors in an 8-Class format, where in this study the 13-Class FHWA vehicle classification system was used. Therefore, some assumptions were made to convert these factors to the required format, listed in *Table 2-2*.

Table 2-2: Conversion of Factors

Body Type		Classes
CARS+PICKUP	=	1, 2, 3
2ASU	=	5
3+ASU	=	6, 7
3A Semi	=	8 (~35%)
4A Semi	=	8 (~65%)
5+A Semi	=	9, 10
TT/BUS	=	4
TWINS	=	11, 12, 13

2.3.2 Daily Adjustment Factors

Seasonal adjustment factors provided better volume estimates based on month and year, but it was decided to obtain more specific volumes. Under this method, every estimated day during any given month would provide the same volume for cars and trucks each time. Since commercial vehicles account for the largest portion of ESAL values and have a large fluctuation of volume between the middle of the week and weekends, it was determined that the creation of factors to describe this tendency would be the best way to estimate volumes and therefore calculate roadway loading.

It was decided that days involving traffic switches and days considered to be estimate days would not be included in the creation of the factors. This allowed the factors to be created based only on quality data involving traffic on the mainline for the entire day. Additionally, the data was required to be approximately equally representative of traffic during the entire year and for each day of the week, preventing certain seasons and weekdays from affecting the factors.

The year 2010 proved to match these attributes more closely than any other year or combinations of different years, and was chosen to represent factors for determining volumes on a day-of-week basis. The completed factors are shown in *Table 2-3*. The average weekday volumes from which these factors were created are found in *Appendix B, Table B-1*.

It should be noted that these factors are not to be applied towards AADT values through multiplication, but instead by dividing the AADT value by the factor. This method was chosen to be consistent with the same way that the seasonal adjustment factors are applied.

For example, to estimate the number of class 2 vehicles passing over the mainline on a Wednesday, the westbound AADT would be divided by 1.07.

Table 2-3: Daily Adjustment Factors by Weekday and FHWA Classification for Year 2010

PCT OF AVG DAY CLASS VOLUME FOR YR 2010, TRAFFIC ALL DAY, ESTIMATE DAYS = NO								
Vehicle Class	**SUN**	**MON**	**TUE**	**WED**	**THU**	**FRI**	**SAT**	**AVG DAY**
C1	1.22	0.89	0.99	0.97	0.94	1.10	0.96	1.00
C2	1.04	1.12	1.11	1.07	0.99	0.81	0.95	1.00
C3	1.12	1.13	1.11	1.05	0.96	0.77	0.99	1.00
C4	1.67	1.40	1.15	1.02	0.63	0.66	1.48	1.00
C5	2.48	0.88	0.85	0.84	0.79	0.79	1.92	1.00
C6	3.05	0.84	0.79	0.79	0.78	0.85	2.13	1.00
C7	2.63	1.04	0.68	0.80	0.85	0.83	1.92	1.00
C8	1.93	0.89	0.86	0.81	0.79	0.87	1.92	1.00
C9	2.21	0.92	0.81	0.77	0.80	0.90	1.90	1.00
C10	4.31	0.86	0.74	0.73	0.72	0.89	2.97	1.00
C11	5.63	1.26	0.72	0.69	0.75	0.81	1.73	1.00
C12	2.85	1.26	0.84	0.75	0.76	0.83	1.29	1.00
C13	2.23	1.42	0.78	0.86	0.67	0.83	1.48	1.00
C14	1.46	1.11	0.97	0.96	0.89	0.77	1.11	1.00
C15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Count of DAY_OF_WEEK	43	43	45	45	45	46	45	N/A

2.4 Vehicle Volumes for Estimate Days

Vehicle volumes were estimated based on the following factors: year, month, weekday, vehicle class, and lane. The year, month, and weekday contributed adjustment factors based on data previously discussed. These factors were then applied toward individual vehicle class AADTs for each year and lane at MnROAD. Vehicle class AADTs for each year and lane are be found in *Appendix B, Figure B-1*. These values were compiled using only days in which no traffic switches took place and were not considered to be estimate days.

Having the daily adjustment factor (F_D), seasonal adjustment factor (F_S), and AADT based on year, lane, and FHWA class ($AADT_{YLC}$), the vehicle volume ($V_{FHWA\ Class}$) was calculated by the following formula:

$$V_{FHWA\ Class} = AADT_{YLC} \div F_S \div F_D$$

Since this calculation is required to be performed 15 times for every lane-day designated as an estimate day, a macro was written to perform this action, named *N08_Volume Estimate*.

Volume estimates were not performed for traffic switch days except in the case that WIM #37 was the active device at the time *and* the other regular conditions for an estimate day were incurred, as described in section *2.2.2*. These days' volumes were estimated for the reason that the data should be available to users desiring WIM data, but were not used for ESAL calculations because the traffic was not on the mainline.

2.5 ESAL Calculation Methods

Three types of ESAL calculations were performed in this study, including Representative Cell, the Mn/DOT Pavement Manual method, as well as a method published by the FHWA. These three different calculations of ESAL values were then available for analysis along with the value recorded by the WIM device, called the IRD_ESALS value.

2.5.1 IRD_ESALS value (International Road Dynamics, Inc.)

This value is directly recorded by the WIM software. Every time a vehicle drives over the WIM, weight and axle type are recorded. This individual vehicle data is put together to produce an ESAL value for each day, and recorded as a data column named *IRD_ESALS* in the *_ALL_DAYS*-type database tables.

This value is not signified as a flexible or rigid ESAL value in the database, but is calculated based on adjustable settings in the software. Until the installation of WIM #37 in 2009, the ESAL values more closely matched flexible values found by other calculation methods than rigid ones. This is seen in *Figure 3-1* of the *Results* section of this document.

2.5.2 Representative Cell (Cell 12 / Cell 16)

This method of ESAL calculation used recorded axle-type bins (i.e. *WIM.WIM_MNS25_SINGLE_AX_BINS*) along with ESAL factors as listed in the *WIM.WIM_Admin_ESAL_Factors* database table. These ESAL factors were created for various test cells on the MnROAD mainline at different points in construction, from which the values from the most recent construction (07/15/1994) were used. This date also set the beginning point for the ESAL summary in this report.

Cell 12 and Cell 16 were chosen to be cells representative of concrete (rigid) and asphalt (flexible) pavements, respectively. Each of these cells has three sets of ESAL axle-type factors for each lane: single, tandem, and tridem. The single axle-type factors contain a range of 52 individual factors for various load ranges; these factors were used for the calculation of steer axles as well. Tandem and tridem factors include a range of factors for 92 different load values. Quadrem ESALs were calculated using tridem factors.

This method calculated ESALs for each axle type according to the following formulae:

$$ESAL_{Single} = \sum_{x=0}^{51} (V_x * F_x)$$

$$ESAL_{Tandem} = \sum_{x=0}^{91} (V_x * F_x)$$

where *V* is the number of vehicles recorded, *F* is the ESAL factor, and *x* is the load range.

Single, steer, tandem, tridem, and quadrem ESALs were then summed to arrive at the total ESALs for each lane and day.

2.5.3 Mn/DOT Pavement Manual

The *Mn/DOT Pavement Manual*, section *4-4.0* was used as another basis for calculating ESALs in this study. Flexible and rigid factors were taken from the manual's *Table 4-4.3* and modified for application to the FHWA's vehicle classification system as recorded by the WIM. All factors used are those of the I-94 MnROAD column of the table.

Factors in the manual were converted from the manual's classification system to the FHWA vehicle classification system similarly to the process used for the seasonal adjustment factors in *Table 2-2*.

Factors for classes 14 and 15 were created for the purpose of not ignoring the volumes of these vehicles. This was done by multiplying each factor by the matching vehicle class volume distribution located in the *Veh_Class_Data* tab of the workbook (i.e. 0.0007 * 0.54 + … + 3.15*0.03 = 0.1209 for flexible factors).

Converted flexible and rigid factors are shown in *Table 2-4*.

Table 2-4: Modified Mn/DOT Pavement Manual ESAL Factors

	Flexible	**Rigid**
Class	**ESAL Factor**	**ESAL Factor**
1	0.0007	0.0007
2	0.0007	0.0007
3	0.0007	0.0007
4	0.5700	0.7400
5	0.2500	0.2400
6	0.6100	0.9000
7	0.6100	0.9000
8	0.5965	0.6055
9	0.9900	1.6400
10	0.6900	0.8300
11	3.1500	3.0600
12	3.1500	3.0600
13	3.1500	3.0600
14	0.1209	0.1801
15	0.1209	0.1801

This method calculated total ESALs for each lane-day according to the formulae:

$$ESAL = F_{DL} * \sum_{x=1}^{15} (V_x * F_x)$$

where V is the volume, F is the ESAL factor, F_{DL} is the design lane factor, and x is the FHWA vehicle classification (1-13). Classifications numbered 14 and 15 are unidentified and error vehicles, respectively. F_{DL} is equal to 1 for these calculations because all lane volumes are known.

2.5.4 Federal Highway Administration (FHWA)

Similar to the *Mn/DOT Pavement Manual*'s method, the FHWA ESAL estimate relies on factors built from vehicle loading data and therefore only requires known vehicle class volumes for application.

The WIM device records and stores vehicles into the FHWA classification scheme by default, but it also stores volumes of unidentified and error vehicles. These volumes are not excluded from calculation. The macro *N09_FHWA_ESAL_optional* uses class distributions listed in the tab *Veh_Class_Data* to split these volumes and add them back into the regular 13 classifications. The macro then calculates flexible and rigid ESAL values for each lane-day according to the following formula:

$$ESAL = \sum_{x=4}^{13} \left(\sum_{y=1}^{39} (V_x S_x D_{xy} L_y) + \sum_{y=1}^{39} (V_x T_x D_{xy} L_y) + \sum_{y=1}^{31} (V_x R_x D_{xy} L_y) + \sum_{y=1}^{31} (V_x Q_x D_{xy} L_y) \right)$$

where V is the volume, S is the number of single axles, T is the number of tandem axles, R is the number of tridem axles, Q is the number of quadrem axles, D is the axle load distribution, L is the load equivalent factor, x is the FHWA vehicle classification, and y is the mean axle load.

It should be noted that this method only calculates ESALs for commercial vehicle volumes (classes 4-13). Motorcycles, cars, and most pickup trucks are exempt from this method. Additionally, this method does not separately calculate steer axle ESALs, but instead combines them with single axles.

2.6 Final ESAL Values

Two methods of ESAL calculation were used to arrive at the final values presented in this report, the Representative Cell and Mn/DOT Pavement Manual methods. These two methods were chosen because of their close approximation to each other as seen in *Figure 3-1* and *Figure 3-2* of the Results section. The FHWA method’s values were consistently higher than either of the other methods for both flexible and rigid pavements; therefore it was not chosen for use in this report.

When available, the Representative Cell value was used as the official ESAL value. In the event of estimate days or after the date of 04/26/2006 (when the Representative Cell value began to fall to probably inaccurately low values), the Mn/DOT Pavement Manual value was chosen.

3.0 Results

This section contains the findings of this study of WIM data on the MnROAD mainline, presenting them in figures as well as tabular format.

3.1 Traffic Volume and ESAL Summary

Summaries for the traffic volumes and ESAL (flexible and rigid) totals for each year are found for the driving lane in *Table 3-1* and for the passing lane in *Table 3-2*.

Table 3-1: Traffic and ESAL summary for the driving lane on WB I-94 at the MnROAD site.

Lane 1 (Driving Lane)							
Year	**Days**	**Mainline Full Days**	**Estimate Volume Days**	**Volume**	**Flexible ESAL**	**Rigid ESAL**	**Comment**
1994	170	148	11	1,753,227	239,369	372,568	Data Begin Date: 07/15/1994
1995	365	322	32	3,787,297	516,129	810,223	
1996	366	265	76	3,028,608	466,545	726,620	
1997	365	191	4	2,514,212	302,279	478,453	
1998	365	263	57	3,234,932	489,058	767,392	
1999	365	275	23	3,693,645	523,735	811,625	
2000	365	269	38	3,827,556	601,035	938,110	WIM #25 Start Date: 08/20/2000
2001	365	283	44	3,969,852	611,342	950,482	
2002	365	285	22	4,057,292	600,936	928,466	
2003	365	278	10	3,892,372	610,975	945,072	
2004	366	171	3	2,345,391	368,246	565,227	
2005	365	287	33	4,394,738	721,667	1,103,797	
2006	365	257	54	3,920,185	704,224	1,070,571	
2007	365	298	68	4,231,508	760,529	1,143,221	
2008	120	85	29	1,049,679	208,227	316,355	WIM #25 End Date: 04/29/2008
2009	331	272	162	3,876,022	758,814	1,148,638	WIM #37 Start Date: 07/14/2009
2010	365	220	55	2,931,302	555,810	836,126	
2011	152	122	93	1,543,694	331,340	501,703	Data End Date: 06/01/2011
TOTAL	**5,885**	**4,291**	**814**	**58,051,512**	**9,370,261**	**14,414,647**	

Column descriptions are as follows:

- Days: number of days that the WIM device was available to collect data
- Mainline Full Days: the number of days that had traffic on the mainline the full day (no traffic switches)

- Estimate Volume Days: days with unexplained missing data (not due to a traffic switch), requiring traffic volumes to be estimated
- Volume: total number of vehicles crossing the WIM (recorded and estimated)
- Flexible ESAL: calculated loading on bituminous cells (i.e. Cell #16)
- Rigid ESAL: calculated loading on concrete cells (i.e. Cell #12)

Table 3-2: Traffic and ESAL Summary for the passing lane on WB I-94 at the MnROAD site.

Lane 2 (Passing Lane)							
Year	**Days**	**Mainline Full Days**	**Estimate Volume Days**	**Volume**	**Flexible ESAL**	**Rigid ESAL**	**Comment**
1994	170	148	11	1,309,886	52,168	83,368	Data Begin Date: 07/15/1994
1995	365	322	32	2,993,198	125,062	200,220	
1996	366	265	76	2,578,778	114,777	182,035	
1997	365	191	4	2,050,604	74,632	119,462	
1998	365	263	57	3,000,969	121,809	193,344	
1999	365	275	23	3,316,057	143,219	226,410	
2000	365	269	38	3,456,256	160,154	252,374	WIM #25 Start Date: 08/20/2000
2001	365	283	44	3,722,393	169,741	265,730	
2002	365	285	22	3,817,098	145,600	227,961	
2003	365	278	10	3,846,751	145,966	230,202	
2004	366	171	3	2,222,964	82,321	130,174	
2005	365	287	33	4,293,101	191,984	301,345	
2006	365	257	54	3,751,782	176,725	270,596	
2007	365	298	68	4,259,696	188,670	285,870	
2008	120	85	29	990,723	45,830	69,840	WIM #25 End Date: 04/29/2008
2009	331	272	162	3,934,240	192,782	285,699	WIM #37 Start Date: 07/14/2009
2010	365	220	55	2,952,924	134,733	205,122	
2011	152	122	93	1,492,165	81,255	123,626	Data End Date: 06/01/2011
TOTAL	**5,885**	**4,291**	**814**	**53,989,585**	**2,347,430**	**3,653,377**	

3.2 Vehicle Classification Summary

A breakdown of passenger vehicle and truck traffic by lane was also performed for WIM data on westbound I-94 at the MnROAD site. It is seen in *Table 3-3* that trucks (commercial vehicles) make up 13.2% of all traffic at this location over the last 18 years, or 15.3 million vehicles. 77.2% of these trucks travel in the right (driving) lane.

Table 3-3: Breakdown of MnROAD Traffic by Vehicle Type from 7/15/94 – 6/1/2011*

	TOTAL	Passenger	Trucks
Volume	116,089,655	100,816,522	15,273,133
% of Total Volume	100.00%	86.84%	13.16%
% in Lane 1	51.67%	47.58%	77.24%
% in Lane 2	48.33%	52.42%	22.76%

* - all non-error vehicles passing over the WIM device; includes vehicles on estimate days and traffic switches for WIM #37.

Vehicle types are further broken down into their respective FHWA classifications in *Table 3-4*.

Table 3-4: Breakdown of MnROAD Traffic by FHWA Vehicle Class from 7/15/94 – 6/1/2011*

FHWA Class	Total Volume	% of Total Volume	% in Lane 1	% in Lane 2
1	636,266	0.55%	50.02%	49.98%
2	74,961,796	64.57%	46.52%	53.48%
3	25,218,460	21.72%	50.66%	49.34%
4	515,297	0.44%	79.09%	20.91%
5	2,145,485	1.85%	67.16%	32.84%
6	628,698	0.54%	78.30%	21.70%
7	110,684	0.10%	79.32%	20.68%
8	628,982	0.54%	79.53%	20.47%
9	10,316,399	8.89%	78.60%	21.40%
10	491,317	0.42%	73.39%	26.61%
11	307,919	0.27%	94.12%	5.88%
12	93,200	0.08%	84.46%	15.54%
13	35,152	0.03%	85.33%	14.67%
TOTAL	116,089,655	100.00%	51.67%	48.33%

* - all non-error vehicles passing over the WIM device; includes vehicles on estimate days and traffic switches for WIM #37

Table 3-3 and *Table 3-4* do not include Class 14 and Class 15 vehicles, which are unidentified and error vehicles, respectively. These vehicles comprise 1.53% of the total volume; therefore, the tables are representative of 98.5% of the total vehicle volume. These tables include estimated volumes for days listed as Estimate Days. The raw data containing all vehicles and no estimate volumes is found in *Appendix B, Table B-2*.

3.3 Comparison of ESAL Calculation Methods

The differences between the four ESAL calculation methods used in this study are represented in *Figure 3-1* for flexible pavements and *Figure 3-2* for rigid pavements. In these charts, the Representative Cell method is labeled as Cell 12/ Cell 16.

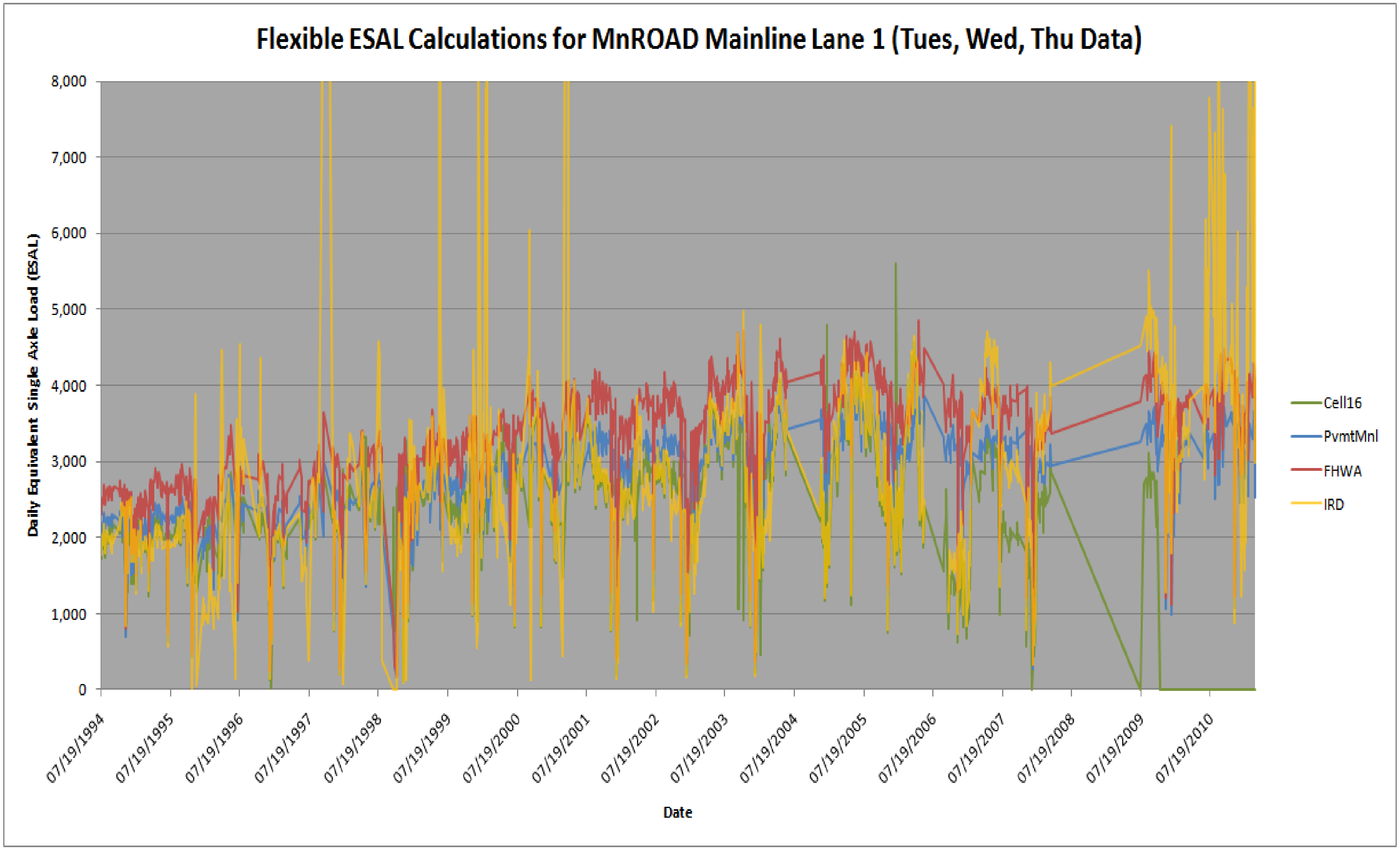

Figure 3-1: Flexible ESAL Calculations for MnROAD Mainline Lane 1. This figure shows daily ESAL values calculated by several different methods. It should be noted that the IRD value is not specified as flexible or rigid at any point, though it seems to match the flexible values better than rigid values until July 2009 when WIM #37 began operation.

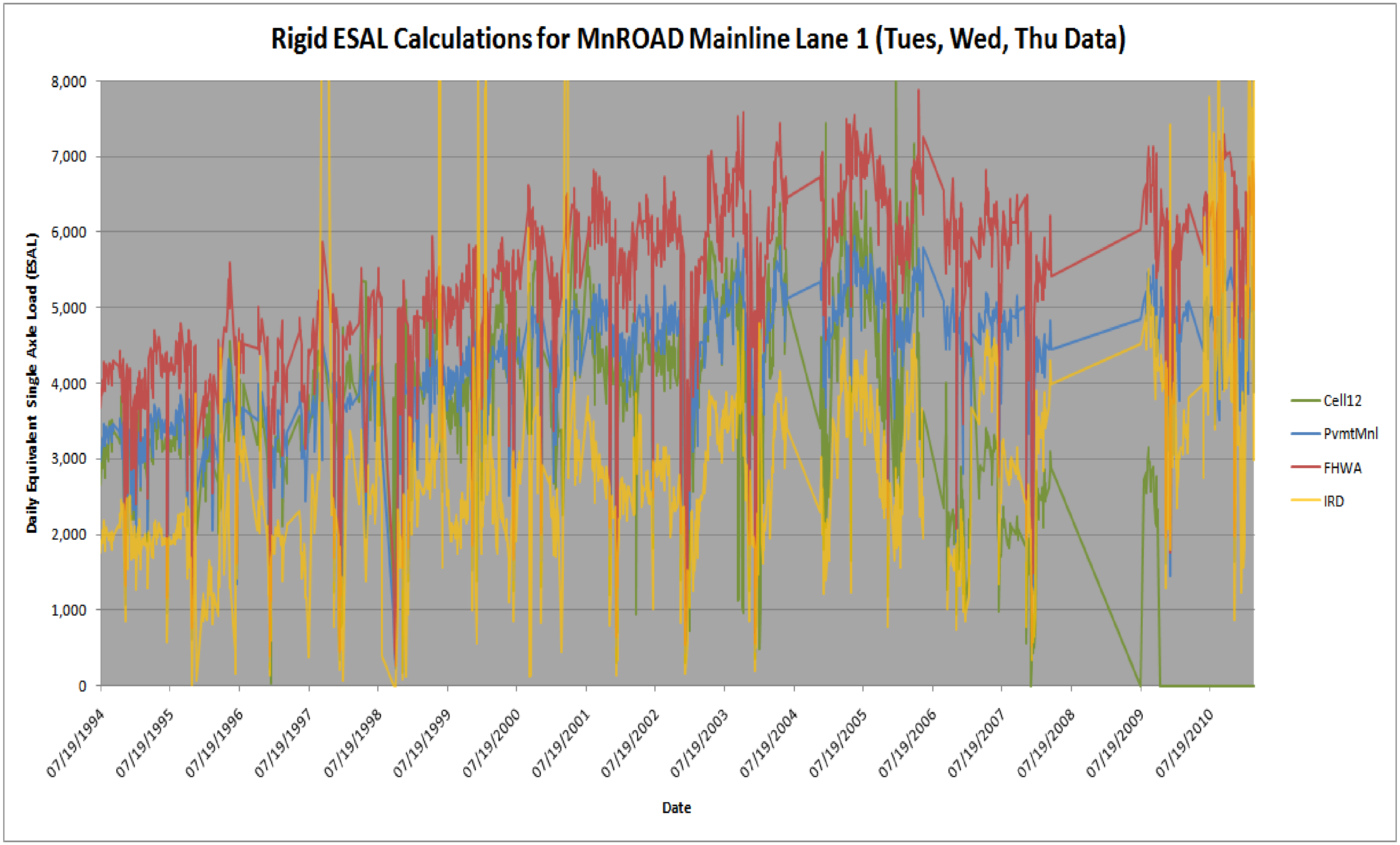

Figure 3-2: Rigid ESAL Calculations for MnROAD Mainline Lane 1. This figure shows daily ESAL values calculated by several different methods. It should be noted that the IRD value is not specified as flexible or rigid at any point, though it seems to match the flexible values better than rigid values until July 2009 when WIM #37 began operation.

It was chosen to compare these methods on Tuesdays, Wednesdays, and Thursdays because these days typically have the highest commercial vehicle volumes.

It should be noted that the IRD ESAL measurement is not signified as a rigid or flexible value. However, it is seen in *Figure 3-1* and *Figure 3-2* that this value as measured by the WIM more closely matches the values of a flexible pavement, especially previous to the installation of WIM #37 in July 2009. The IRD value varies greatly in comparison to the Representative Cell method which also relies on weight data, and may be the result of instrument error. It is possible that vehicle loadings were much higher or lower on certain days than what would be assumed by factors, but probably not to the levels shown in the charts.

3.4 Heavy Commercial Vehicle Summary

Heavy commercial (HC) vehicles encompass all vehicles in FHWA classes 4 – 13. *Table 3-5* displays a history of these vehicles' percentage of total volume in each lane as well as total for the route. This table was compiled using vehicle class AADT as shown in *Figure B-1* of *Appendix B.* In 2010, HC vehicles made up 12.9% of all vehicles on the MnROAD mainline, split by 20.4% of vehicles in the driving lane and 5.52% of vehicles in the passing lane. From July 1994 to June 2011, HC vehicles were 13.2% of all traffic (*Table 3-3*) on the mainline.

Table 3-5: Heavy Commercial Vehicles as a Percentage of Total Lane Volume

Year	Total HC %	Lane 1 HC %	Lane 2 HC %
2010	12.88%	20.40%	5.52%
2009	13.09%	20.24%	6.22%
2008	12.33%	19.37%	4.98%
2007	11.78%	18.55%	5.11%
2006	12.07%	18.55%	5.26%
2005	13.19%	20.06%	6.20%
2004	13.58%	20.57%	6.26%
2003	13.18%	20.00%	6.27%
2002	12.92%	19.42%	6.09%
2001	13.08%	19.70%	6.18%
2000	12.61%	18.65%	5.98%
1999	12.41%	18.12%	5.98%
1998	11.30%	16.63%	5.53%
1997	11.65%	16.77%	5.47%
1996	12.28%	17.73%	5.81%
1995	11.66%	16.05%	5.96%
1994	11.56%	16.05%	5.59%

4.0 Conclusion

Since July 1994, the MnROAD mainline has seen a total traffic volume of over 112 million vehicles, split by 58.1 million vehicles in the driving lane and 54.0 million vehicles in the passing lane. In the same period, the driving lane experienced 9.37 million flexible ESALs, or 14.4 million rigid ESALs. The passing lane experienced flexible and rigid ESAL values of 2.35 million and 3.65 million, respectively.

During the period of 1994 - 2010, the average daily volume of traffic, flexible ESALs, and rigid ESALs experienced by the driving lane was 13,500 vehicles, 2,160 ESALs, and 3,330 ESALs, respectively. In the same 17 year period for the passing lane, the average daily volume of traffic, flexible ESALs, and rigid ESALs experienced was 12,400 vehicles, 540 ESALs, and 840 ESALs, respectively. This period averaged 245 full days of mainline traffic with 42 estimate days per year.

Annual average values for the period 1994 – 2010 for the driving lane were 3.31 million vehicles, 529,000 flexible ESALs, and 816,000 rigid ESALs. For the passing lane, annual averages were 3.04 million vehicles, 132,000 flexible ESALs, and 206,000 rigid ESALs.

Heavy commercial vehicle traffic represented 13.2% of the volume on the mainline from 1994 - 2011. 18.8% of all vehicles in the driving lane were heavy commercial vehicles, while only 5.79% of all vehicles in the passing lane were heavy commercial vehicles. 77.2% of all heavy commercial vehicles were recorded as traveling in the driving lane. By contrast, 47.6% of passenger vehicles traveled in the driving lane. Together, this showed that 51.7% of all vehicles were in the driving lane at the location of the WIM device.

5.0 References

Wei, Chu. *Determination of Seasonal Adjustment Factors for Vehicle Class Counts*. Tech. Minnesota Department of Transportation, Feb. 2011. Web. May 2011. <http://www.dot.state.mn.us/traffic/data/reports/Seasonal Adjustment Factors.pdf>.

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Appendix A: Database Table and View Descriptions

This appendix section contains descriptions of SQL database tables and views involving WIM data. These descriptions were written as requested alongside of the main project performed in this report.

Table A-1: MnROAD Traffic Database Tables

Table Name	Description
WIM_MNS25_ALL_DAYS	This table contains a summary of data for every day in each lane. This includes vehicle classification, speed, gross vehicle weights for Class 9 vehicles (5-axle semi trucks w/ trailers) as well as ESALs as calculated by the WIM's IRD software.
WIM_MNS25_ALL_HOURS	This table contains an hourly summary of data for every day and lane. This includes vehicle classification as well as average speed and distribution.
WIM_MNS25_CAR_STATS_HOURLY	This table contains hourly summaries of passenger vehicles (Class 1 – Class 3) for each lane. Vehicle lengths, speeds, gross weights, and ESALs are included.
WIM_MNS25_FATAL_ERROR_HOURLY	This table contains an hourly listing of 15 error types occurring for each day and lane.
WIM_MNS25_CAR_STATS_DAILY	This table contains daily summaries of passenger vehicles (Class 1 – Class 3) for each lane. Vehicle lengths, speeds, gross weights, and ESALs are included.
WIM_MNS25_FATAL_ERROR_DAILY	This table contains a daily listing of 15 error types occurring in each lane.
LVR-ESALS	This table contains information related to the loading on the Low Volume Road (LVR). Number of loads and ESALs are given for 80K loads on the inside loop and for 102k loads on the outside loop.

Table A-2: MnROAD Traffic Database Views

Table Name	**Description**
WIM_MNS25_STEER_AX_ESALS	This view shows a record of each truck or unidentified/error vehicle (Class 4-15) containing steer axles to pass over the WIM. Vehicle class number, axle code and quantity, axle group weight in kips, and the exact time of the vehicle passing over the WIM are included.
WIM_MNS25_SINGLE_AX_ESALS	This view shows a record of each truck or unidentified/error vehicle (Class 4-15) containing single axles to pass over the WIM. Vehicle class number, axle code and quantity, axle group weight in kips, and the exact time of the vehicle passing over the WIM are included.
WIM_MNS25_TANDEM_AX_ESALS	This view shows a record of each truck or unidentified/error vehicle (Class 4-15) containing tandem axles to pass over the WIM. Vehicle class number, axle code and quantity, axle group weight in kips, and the exact time of the vehicle passing over the WIM are included.
WIM_MNS25_TRIDEM_AX_ESALS	This view shows a record of each truck or unidentified/error vehicle (Class 4-15) containing tridem axles to pass over the WIM. Vehicle class number, axle code and quantity, axle group weight in kips, and the exact time of the vehicle passing over the WIM are included.
WIM_MNS25_QUAD_AX_ESALS	This view shows a record of each truck or unidentified/error vehicle (Class 4-15) containing quadrem axles to pass over the WIM. Vehicle class number, axle code and quantity, axle group weight in kips, and the exact time of the vehicle passing over the WIM are included.
WIM_MNS25_TOTAL_ESALS	This view shows a summary of total ESALs for each axle type (single, steer, tandem, tridem, quadrem) for each lane and day. ESALs are calculated for Cell 50.

Appendix B: Miscellaneous Tables & Other Data

This appendix section contains data used in the study. Though not necessary for presentation of findings, it is available here for those interested in related data.

Table B-1: Average Volumes by Weekday and FHWA Classification for Year 2010

AVERAGES FOR YR 2010, TRAFFIC ALL DAY, ESTIMATE DAYS = NO								
Vehicle Class	**SUN**	**MON**	**TUE**	**WED**	**THU**	**FRI**	**SAT**	**AVG DAY**
C1	123	167	151	154	159	136	156	149
C2	16,199	14,969	15,093	15,718	16,934	20,879	17,745	16,820
C3	5,848	5,779	5,886	6,268	6,821	8,540	6,641	6,556
C4	32	39	47	53	86	83	37	54
C5	202	567	589	598	635	634	261	500
C6	44	161	172	172	174	159	64	136
C7	10	25	39	33	31	32	14	26
C8	87	190	197	209	214	194	88	169
C9	1,064	2,571	2,920	3,071	2,943	2,606	1,240	2,353
C10	31	159	183	187	189	152	46	136
C11	10	46	81	85	78	73	34	59
C12	11	24	36	41	40	37	24	31
C13	11	18	32	29	38	30	17	25
C14	235	309	355	356	387	444	311	344
C15	0	0	0	0	0	0	0	0
Count of DAY_OF_WEEK	43	43	45	45	45	46	45	N/A

Table B-2: Breakdown of MnROAD Traffic by FHWA Vehicle Class (Raw Recorded Data)

FHWA Class	Total Volume	Pct. of Volume	% in Lane 1	% in Lane 2
1	523,475	0.54%	46.92%	53.08%
2	61,860,133	64.09%	46.65%	53.35%
3	20,486,897	21.23%	50.88%	49.12%
4	437,246	0.45%	79.38%	20.62%
5	1,703,385	1.76%	67.48%	32.52%
6	504,693	0.52%	78.59%	21.41%
7	89,598	0.09%	79.33%	20.67%
8	500,373	0.52%	79.72%	20.28%
9	8,179,613	8.47%	78.36%	21.64%
10	387,336	0.40%	73.22%	26.78%
11	246,140	0.26%	94.37%	5.63%
12	71,561	0.07%	84.61%	15.39%
13	26,241	0.03%	86.27%	13.73%
14	1,323,432	1.37%	65.02%	34.98%
15	182,189	0.19%	53.05%	46.95%
Total	96,522,312	100.00%	51.65%	48.35%

LANE 1

Class \ Year	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994
1	244	132	1	14	4	60	35	99	100	126	31	27	27	18	6	11	8
2	7,098	7,419	7,244	7,966	7,901	8,200	7,413	7,619	7,551	7,117	7,654	7,594	6,921	7,334	6,506	7,280	7,387
3	3,088	3,433	2,958	3,449	3,533	3,263	2,932	2,880	3,155	2,961	2,662	2,060	1,765	1,766	1,876	1,905	2,003
4	34	50	20	26	22	119	151	135	137	132	136	99	63	69	75	74	91
5	337	415	286	360	309	412	363	393	349	327	250	218	156	168	170	175	215
6	96	92	93	110	119	116	86	106	99	98	97	167	92	75	68	71	68
7	21	15	15	16	17	29	21	30	22	23	17	15	12	11	11	10	9
8	127	156	88	131	104	107	92	97	92	88	108	90	72	80	88	77	86
9	1,856	1,898	1,781	1,767	1,839	1,914	1,815	1,727	1,758	1,682	1,629	1,429	1,233	1,321	1,285	1,245	1,219
10	100	77	75	96	97	98	71	81	65	74	55	50	51	53	52	46	45
11	53	58	70	70	73	72	67	60	61	59	63	58	45	47	48	50	54
12	26	23	21	21	24	19	16	14	16	15	14	11	10	10	8	7	7
13	23	5	2	4	3	5	6	7	4	5	4	4	6	3	2	4	2
14	293	229	12	25	39	151	234	192	306	587	316	160	236	148	155	199	174
15				141	164	139	14				0	0	0	0	0	0	0
SUM	13,397	14,000	12,665	14,197	14,246	14,704	13,316	13,440	13,716	13,295	13,036	11,982	10,687	11,104	10,351	11,152	11,369

LANE 2

Class \ Year	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994
1	15	60	2	3	28	48	91	256	205	106	197	39	21	14	13	14	19
2	9,278	9,493	8,564	9,998	8,990	9,740	8,627	8,789	8,715	8,543	8,399	8,245	7,689	7,724	6,497	6,370	6,407
3	3,365	3,869	2,957	3,513	3,663	3,491	2,963	3,218	3,045	2,812	2,292	1,595	1,408	840	1,570	1,552	1,520
4	16	18	7	8	11	30	35	34	32	30	30	19	15	10	22	24	23
5	152	298	121	166	125	237	194	215	201	183	122	83	53	35	55	53	51
6	37	34	27	31	34	30	22	25	24	23	29	31	21	26	16	16	15
7	4	4	5	4	4	7	5	6	5	6	8	5	4	5	3	3	3
8	33	52	18	30	25	29	23	24	22	25	43	22	16	12	15	14	14
9	459	445	388	441	455	498	469	476	456	450	435	442	397	384	364	373	344
10	28	28	25	36	36	37	25	30	26	30	19	21	22	20	18	16	16
11	5	5	6	5	5	4	4	4	3	4	3	2	3	3	4	3	3
12	4	4	4	5	7	4	3	3	4	3	2	3	2	1	1	1	1
13	1	2	2	2	3	2	1	2	2	2	1	0	1	1	1	1	1
14	55	52	23	12	106	122	142	159	168	273	210	263	49	40	68	74	70
15				189	242	109	13				0	0	0	0	0	0	0
SUM	13,448	14,318	12,143	14,271	13,727	14,367	12,613	13,240	12,907	12,486	11,789	10,768	9,699	9,115	8,474	8,483	8,486

	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994
Both Lanes	26,844	28,319	24,808	28,468	27,973	29,071	25,929	26,680	26,623	25,780	24,824	22,751	20,386	20,219	18,825	19,635	19,856
#Days Data	200	116	56	230	203	254	168	268	263	239	231	252	206	187	189	290	137

Figure B-1: MnROAD (WB I-94) AADT as recorded by the WIM; Estimate days and traffic switches excluded.

B.1 Estimated Volumes Using Vehicle Class AADTs (Figure B-1)

Estimated volumes for estimate days are generally accurate but in some cases are higher or lower than they should be. This is because the macros written for the estimation process do not take into account what the time of year WIM data is recorded, if only a partial year. For example, if the available WIM data was recorded only for the months of January – April (as in 2008), then approximate vehicle class AADTs formulated for that year will be lower than normal, therefore leading to lower vehicle volume estimates. Likewise, if the AADTs are heavily based on summer data, volumes will be higher than normal. This is because vehicle volumes are typically higher in the summer and lower in the winter. This could be accounted for if tests were done to check for monthly distributions of available data and then applying seasonal adjustment factors, but this was not done in this study due to time constraints. This is not expected to significantly affect the end numbers of this study.

Appendix C: Excel Workbook Summary

This section describes the function and contents of the various spreadsheet tabs and VBA macro codes existing within the Microsoft Excel workbook *WIM_Mainline_Summary.xlsm*. This workbook is found in the following directory:

\\AD\MRL\SECTIONS\RESEARCH\MnROAD\Data - Collection\Traffic\Mainline\Data.

C.1 Workbook Tab Descriptions

The Excel workbook contains 20 different pages of data, all of which were used to arrive at final values for the traffic volume and ESAL summary done in this report. Some tabs show summaries and final values, while others serve to show charts for the comparison of data, function as pivot tables for analysis, supply factor tables for calculations, or merely hold tabular values exported from the database.

C.1.1 General_Summary

This page of the workbook displays a summary of traffic volume and ESALs incurred for each lane and year. A summary can also be obtained for a custom date range via the use of a macros on the page. These summaries are performed on data located in the *Final_Table* tab.

It should be noted that any macro operation or custom data filtering in the *Final_Table* or *Main_Table* tab will be quite slow because of the complex formulae located in the cells. If running macros or data filtering is desired, this page should be deleted in a separate file save before doing so.

C.1.2 Final_Table

This tab of the workbook should be regarded as the final tabular values for this study, and is the table to be exported should the ESAL and newly estimated traffic volumes be placed into a database. This page is dependent on values located in the *Main_Table* tab.

C.1.3 Main_Table

The *Main_Table* tab is for all purposes the “main” table used in macro calculations and data analysis during this study. Data columns in this tab are viewed as important data fields for analysis and creation of a traffic and ESAL summary, taken from the *Export Worksheet* tab.

C.1.4 RigidTest

The *RigidTest* tab contains ESAL estimates from three different methods as well as the IRD_ESAL reading. These values are displayed in a chart, which can be found in this report in *Figure 3-2*. It should be noted that the values on this page are not “live” values – they have been copied and pasted into the page and therefore are static.

C.1.5 FlexTest

The *FlexTest* tab contains ESAL estimates from three different methods as well as the IRD_ESAL reading. These values are displayed in a chart, which can be found in this report in *Figure 3-1*. It should be noted that the values on this page are not “live” values – they have been copied and pasted into the page and therefore are static.

C.1.6 Veh_Class_Data

This tab of the workbook serves to summarize the data located in the *Main_Table* tab. Vehicle class information displayed includes total volume, percentage of total volume, and lane distribution. The top half of this page gives this information for current data, while the lower half of the page displays the information prior to volume estimation for estimate days.

C.1.7 Pivot_Table_AADT

This tab containing a pivot table was constructed from data located in the *Main_Table* tab in order to create the page *WIM_Class_AADT*.

C.1.8 WIM_Class_AADT

Located in this tab are the data obtained from pivot tables used in the tab *Pivot_Table_AADT*. These values are used in the estimation of volumes for estimate days.

C.1.9 Season_Adj_Factors

The *Season_Adj_Factors* tab contains TDA's seasonal adjustment factors as explained in section *2.3.1* of this report.

C.1.10 Estimate_Days

This tab contains a listing of all days considered to be estimate days, as described in section *2.2.2* of this report.

C.1.11 Traffic Switches

This tab contains a listing of all days where traffic switches occurred, as described in section *2.2.1* of this report.

C.1.12 MnDOT_ESAL_Factors

This tab contains the ESAL factors used by the *Mn/DOT Pavement Manual's* estimation method, as described in section *2.5.3* of this report.

C.1.13 FHWA Tables

This tab contains tables of factors for axle distribution, load distribution, and load equivalencies used by the FHWA's estimation method, as described in section *2.5.4* of this report.

C.1.14 Admin_ESAL_Factors

The *Admin_ESAL_Factors* tab contains factors from the *WIM.WIM_ADMIN_ESAL_FACTORS* database table. It is used for ESAL calculation via the Representative Cell method as described in section *2.5.2*. Only the most recent factors for each cell are represented here; the older values were removed.

C.1.15 Export Worksheet

This tab of the workbook contains data from the *ALL_DAYS*-type tables from the SQL database. All three WIM datasets are represented. All data fields are available, but currently visible columns are those deemed to be important for this study. A gray-shaded column labeled *Date* is the only column not from the database, which was added for quicker sorting and filtering of the data as well as for use in macros.

C.1.16 Single_Ax_Bins

The *Single_Ax_Bins* tab of the workbook contains data exported from the *SINGLE_AX_BINS*-type tables from the SQL database. This sheet has one added column labeled *Date*, which was added for quicker sorting and filtering of the data, as well as for use in macros.

C.1.17 Steer_Ax_Bins

The *Steer_Ax_Bins* tab of the workbook contains data exported from the *STEER_AX_BINS*-type tables from the SQL database. This sheet has one added column labeled *Date*, which was added for quicker sorting and filtering of the data, as well as for use in macros.

C.1.18 Tandem_Ax_Bins

The *Tandem_Ax_Bins* tab of the workbook contains data exported from the *TANDEM_AX_BINS*-type tables from the SQL database. This sheet has one added column labeled *Date*, which was added for quicker sorting and filtering of the data, as well as for use in macros.

C.1.19 Tridem_Ax_Bins

The *Tridem_Ax_Bins* tab of the workbook contains data exported from the *TRIDEM_AX_BINS*-type tables from the SQL database. This sheet has one added column labeled *Date*, which was added for quicker sorting and filtering of the data, as well as for use in macros.

C.1.20 Quadrem_Ax_Bins

The *Quadrem_Ax_Bins* tab of the workbook contains data exported from the *QUAD_AX_BINS*-type tables from the SQL database. This sheet has one added column labeled *Date,* which was added for quicker sorting and filtering of the data, as well as for use in macros.

C.2 VBA Macro Descriptions

Detailed in this section are macro descriptions as taken from the Excel workbook MnROAD_Mainline_Traffic_Summary.xlsx. In the event of analyzing new data, the macros should be run in the order presented here.

C.2.1 N01_Fix_Traffic_Switches_Axle_Bins

This macro uses the dates of traffic switches (when traffic was off the mainline) and goes into the axle bin data (single, steer, tandem, tridem, quadrem) and removes any existing axle bin data for these dates. This is necessary because "replacement days" have been added to the database, sometimes putting weight data into dates where there actually was no traffic on the mainline.

C.2.2 N02_Rep_and_Switch_Days

This macro searches other sheets in the workbook for replacement days and traffic switch days, and signifies these dates in the “main_table” sheet.

C.2.3 N03_Single_Axle_ESALs

This macro calculates ESALs based on axle-type and load data. Axle types include single, steer, tandem, tridem, and quadrem. Volume and loading for vehicles falling into these categories is contained in the *axle type*_AX_BINS sheets in this workbook. This data is then applied to the ADMIN_ ESAL_FACTORS table to determine the ESAL values for each axle type. Steer axle ESALs use single axle factors for calculation, and quadrem axle ESALs use tridem axle factors.

C.2.4 N04_Steer_Axle_ESALs

This macro calculates ESALs based on axle-type and load data. Axle types include single, steer, tandem, tridem, and quadrem. Volume and loading for vehicles falling into these categories is contained in the *axle type*_AX_BINS sheets in this workbook. This data is then applied to the ADMIN_ ESAL_FACTORS table to determine the ESAL values for each axle type. Steer axle ESALs use single axle factors for calculation, and quadrem axle ESALs use tridem axle factors.

C.2.5 N05_Tandem_Axle_ESALs

This macro calculates ESALs based on axle-type and load data. Axle types include single, steer, tandem, tridem, and quadrem. Volume and loading for vehicles falling into these categories is contained in the *axle type*_AX_BINS sheets in this workbook. This data is then applied to the ADMIN_ ESAL_FACTORS table to determine the ESAL values for each axle type. Steer axle ESALs use single axle factors for calculation, and quadrem axle ESALs use tridem axle factors.

C.2.6 N06_Tridem_Axle_ESALs

This macro calculates ESALs based on axle-type and load data. Axle types include single, steer, tandem, tridem, and quadrem. Volume and loading for vehicles falling into these categories is contained in the *axle type*_AX_BINS sheets in this workbook. This data is then applied to the ADMIN_ ESAL_FACTORS table to determine the ESAL values for each axle type. Steer axle ESALs use single axle factors for calculation, and quadrem axle ESALs use tridem axle factors.

C.2.7 N07_Quadrem_Axle_ESALs

This macro calculates ESALs based on axle-type and load data. Axle types include single, steer, tandem, tridem, and quadrem. Volume and loading for vehicles falling into these categories is contained in the *axle type*_AX_BINS sheets in this workbook. This data is then applied to the ADMIN_ ESAL_FACTORS table to determine the ESAL values for each axle type. Steer axle ESALs use single axle factors for calculation, and quadrem axle ESALs use tridem axle factors.

C.2.8 N08_Volume_Estimate

This macro estimates the volume of traffic on the MnROAD mainline for any given day based on the following values: year, month, day of week, lane, and FHWA class (1-13). These volumes can then be used to calculate ESALs in methods requiring vehicle class information. This is important information to know in times when the WIM was not recording vehicle class information.

C.2.9 N09_FHWA_ESAL_optional

This macro uses volume data to estimate ESALs under the FHWA system. The numbers are not used in the production of the final table, but may be used for comparison. For that reason, the use of this macro is optional.

C.2.10 P01_Summarize_Data_Button

This macro counts the number of days, mainline full days, volume estimate days, displays the date entered by the user, and calculates the volume, flex ESAL, and rigid ESAL for the date range entered by the user. This macro is implemented via a button on the "general summary" page, and eliminates the requirement for filtering the data for a desired range.

C.2.11 P02_Reset_Fields_Button

This macro clears the fields in the specific date range area of the general summary tab of this workbook. This should be done in between updates.