Development of Traffic Inputs for Pavement ME Using Weigh-In-Motion Data in Alberta

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ABSTRACT

Traffic characterization to develop appropriate traffic inputs for pavement design using the Mechanistic Empirical Pavement Design procedure and its associated software, Pavement ME Design™ (PMED), is a crucial and challenging task. The purpose of this study was to develop vehicle class distributions (VCD), traffic growth factors (TGF), monthly adjustment factors (MAF), hourly distribution factors (HDF), and Axles per Truck, to be used as inputs for pavement design using PMED in Alberta. Weigh-In-Motion (WIM) data from eight different stations in Alberta, collected from 2007 to 2019, were analyzed to characterize traffic inputs. Traffic inputs were developed at two levels: Level 1 (site-specific) and Level 2 (provincial averages). It is important to note that this study does not address axle load spectra.

Simple statistical analyses like minimums, maximums, averages, and standard deviations both for individual stations and for all stations were completed to develop confidence in the Level 2 inputs. The effects of the developed Level 1 and Level 2 traffic inputs, and of the PMED default Level 3 traffic inputs, on the predicted performance of select highway segments were studied. A sensitivity analysis was conducted on the impact of the developed Level 1, Level 2, and PMED default Level 3 traffic inputs on the predicted performance of flexible pavements. The results indicate that asphalt rutting and total rutting is moderately sensitive to VCD, while pavement performance is only slightly sensitive to other traffic inputs like MAF, Axles per Truck, and TGF. The analysis also showed that using Level 2 inputs yields closer results to Level 1 in comparison to Level 3 default inputs. This study recommends the Level 1 (site-specific) inputs be used for pavement analysis and design. For projects where site-specific data are not available, Level 2 provincial average traffic inputs should be used, which provide more representative inputs than the default Level 3 traffic inputs.

OVERVIEW

Truck traffic data is one of the major inputs for pavement structural design and analysis. The Mechanistic-Empirical Pavement Design Guide (MEPDG) developed under NCHRP Project 1–37A [1], and its associated software, Pavement ME Design™ (PMED), requires detailed truck traffic inputs including:

- Initial two-way annual average daily truck traffic (AADTT) and percentage of trucks in the design direction and design lane,
- Operation speed,
- Axle and wheelbase configurations, and lateral wander,
- Axle load spectra (single, tandem, tridem and quad),
- Vehicle Class Distribution (VCD),
- Monthly Adjustment Factors (MAFs),
- Hourly Distribution Factors (HDFs),
- Traffic Growth Factors (TGF) and Function,
- Axles per Truck.

Traffic data can be input into PMED at three hierarchical levels. Level 1 is project site-specific and can be collected through WIM; Level 2 is region, state or provincial specific data if site-specific inputs are not available; and Level 3 is United States nationally-calibrated default data [2].

LITERATURE SEARCH AND SCOPE OF THE STUDY

Many agencies have completed studies to investigate traffic data inputs for use in PMED [3 to 10]. These studies noted diverse findings, with some reporting a significant difference in predicted distresses with the use of certain site-specific traffic data, and others reporting no significant differences in using site-specific versus default traffic data.

A previous study with limited Alberta WIM data (2009-2010) [3] showed that flexible pavement performance is sensitive to Truck Traffic Classification (TTC) and axle load distribution, and that rigid pavement performance is the most sensitive to axle load distribution. Another study in Virginia [4] demonstrated that the site-specific traffic data for the four traffic inputs (VCD, Axle Load Spectra, MAF and Axles per Truck) did not have a significant effect on PMED predicted distresses considering uncertainty of the pavement distress models. Romanoschi et al. [5] revealed through their study for New York State that site-specific and state-wide developed VCD has similar values as that used in PMED default for Rural-Principal and Arterial-Interstates, while the MAF and HDF varied significantly from PMED defaults. Another study by Swan et.al. [6] for Ontario showed that the number and type of trucks and axle load spectra predominantly influenced the predicted pavement performance, while other parameters such as HDF, and axle load spacing did not significantly influence the predicted pavement performance. In an effort to characterize traffic inputs for PMED in Michigan [7], it was recommended to use site-specific data wherever available due to the influence of local industry, land use, and truck configurations. In a study on estimating truck traffic inputs for California by Lu et.al [8], all the available WIM sites were divided based on geographical location and highway numbers and traffic inputs were developed for each site to use both in CalME and PMED. In an effort to develop traffic data input for the Arizona Department of Transportation, Darter et. al. [9] showed that VCD and axle load distribution significantly influenced the pavement design; however HDF, MAF, and axles per truck did not significantly affect the pavement design. Li et. al. [10] conducted a sensitivity analysis for axle load spectra in PMED for Washington State (WSDOT) that showed the typical WSDOT pavement designs are moderately sensitive to the axle load spectra and that WSDOT needed to calibrate PMED before use.

On the basis of the above findings, this study was conducted for Alberta to:

- Develop province-wide (Level 2) traffic data inputs for pavement design, using PMED; and
- Determine the influence of different input levels such as default inputs (Level 3), province-wide inputs (Level 2), and site-specific data (Level 1) on the predicted distresses using PMED software.

The scope of this study does not include axle load spectra, which will be developed and reviewed at a future date. The focus of this study was flexible pavements, which represents the vast majority of Alberta highway network. WIM data collected from 2007 through to 2019 were used in this study.

EXISTING WIM DATA IN ALBERTA

WIM systems were installed throughout the province of Alberta starting in the late 1990s. These systems can collect a variety of detailed traffic data inputs for use in pavement design. The traffic Monitoring Practice Guide for Canadian Provinces and Municipalities [11] describes Alberta's typical WIM data quality assurance practices. Various traffic data including the Federal Highway Administration (FHWA) vehicle classes [12] axle weight, type and spacing; are collected for each truck passing over the WIM stations. Figure 1 illustrates the FHWA vehicle classification chart.

Figure 1: FHWA Vehicle Classification [12]

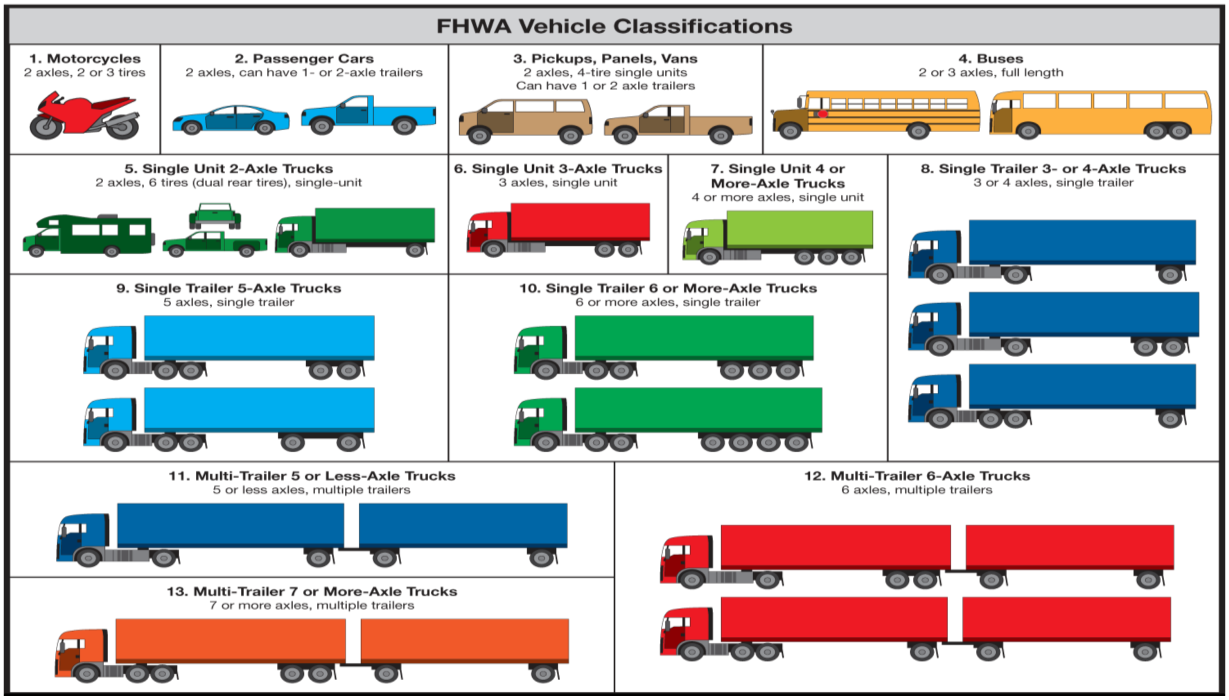


Table 1: WIM Stations with Available Data Periods in Alberta

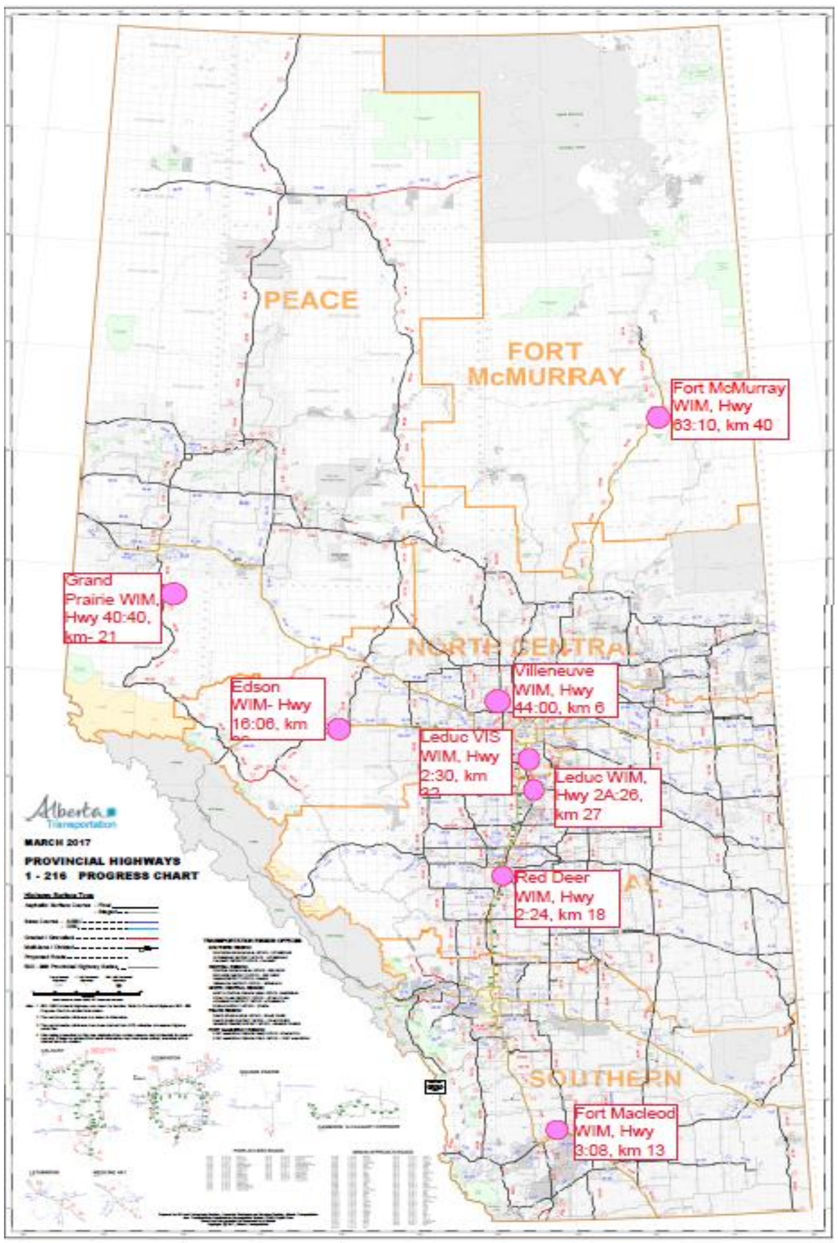
Station No.	Location of WIM	Highway	Control Section	km	Lane*	Available data period
1	Leduc VIS	2	30	32	NDL	Jan. 2007 – Dec. 2019
	Leduc VIS	2	30	32	NPL	Jan. 2007 – Dec. 2019
	Leduc VIS	2	30	32	SDL	Jan. 2007 – Dec. 2019
	Leduc VIS	2	30	32	SPL	Jan. 2007 – Dec. 2019
2	Leduc	2A	26	27	NDL	Jan. 2007 – Dec. 2019
	Leduc	2A	26	27	SDL	Jan. 2007 – Dec. 2019
3	Red Deer	2	24	18	NDL	Jan. 2007 – Dec. 2019
	Red Deer	2	24	18	NPL	Jan. 2007 – Dec. 2019
	Red Deer	2	24	18	SDL	Jan. 2007 – Dec. 2019
	Red Deer	2	24	18	SPL	Jan. 2007 – Dec. 2019
4	Edson	16	6	39	EDL	Jan. 2007 – Dec. 2019
	Edson	16	6	39	EPL	Jan. 2007 – Dec. 2019
	Edson	16	6	39	WDL	Jan. 2007 – Dec. 2019
	Edson	16	6	39	WPL	Jan. 2007 – Dec. 2019
5	Fort Macleod	3	8	13	EDL	Jan. 2007 – Dec. 2019
	Fort Macleod	3	8	13	EPL	Jan. 2007 – Dec. 2019
	Fort Macleod	3	8	13	WDL	Jan. 2007 – Dec. 2019
	Fort Macleod	3	8	13	WPL	Jan. 2007 – Dec. 2019
6	Villeneuve	44	0	6	NDL	Jan. 2007 – May 2016
	Villeneuve	44	0	6	SDL	Jan. 2007 – May 2016
7	Grand Prairie	40	40	21	NDL	June 2016 – Dec. 2019
	Grand Prairie	40	40	21	SDL	June 2016 – Dec. 2019
8	Ft Mc Murray	63	10	40	NDL	June 2015-Dec. 2019
	Ft Mc Murray	63	10	40	NPL	June 2015-Dec. 2019
	Ft Mc Murray	63	10	40	SPL	Jan. 2018-Dec. 2019
	Ft Mc Murray	63	10	40	SDL	Jan. 2018-Dec. 2019

*NDL-Northbound Drive Lane, NPL-Northbound Pass Lane, SDL-Southbound Drive Lane, SPL-Southbound Pass Lane, EDL-Eastbound Drive Lane, EPL-Eastbound pass lane, WDL- Westbound Drive Lane, WPL-Westbound pass lane

WIM data used in this study are VCD, MAF, HDF, and Axle per Truck. Data collected from eight WIM stations across Alberta for the period of 2007-2019 were analysed in this study. However, not all the stations had a complete 13 years of data. Table 1 shows location, lane directions and period of data collection for each WIM station.

Figure 2 presents the locations of different WIM stations in the province of Alberta. WIM data in Villeneuve were collected from January 2007 to May 2016 and then that WIM station was moved from Villeneuve to Grande Prairie.

Figure 2: Locations of Various Weigh-In-Motion Stations in Alberta

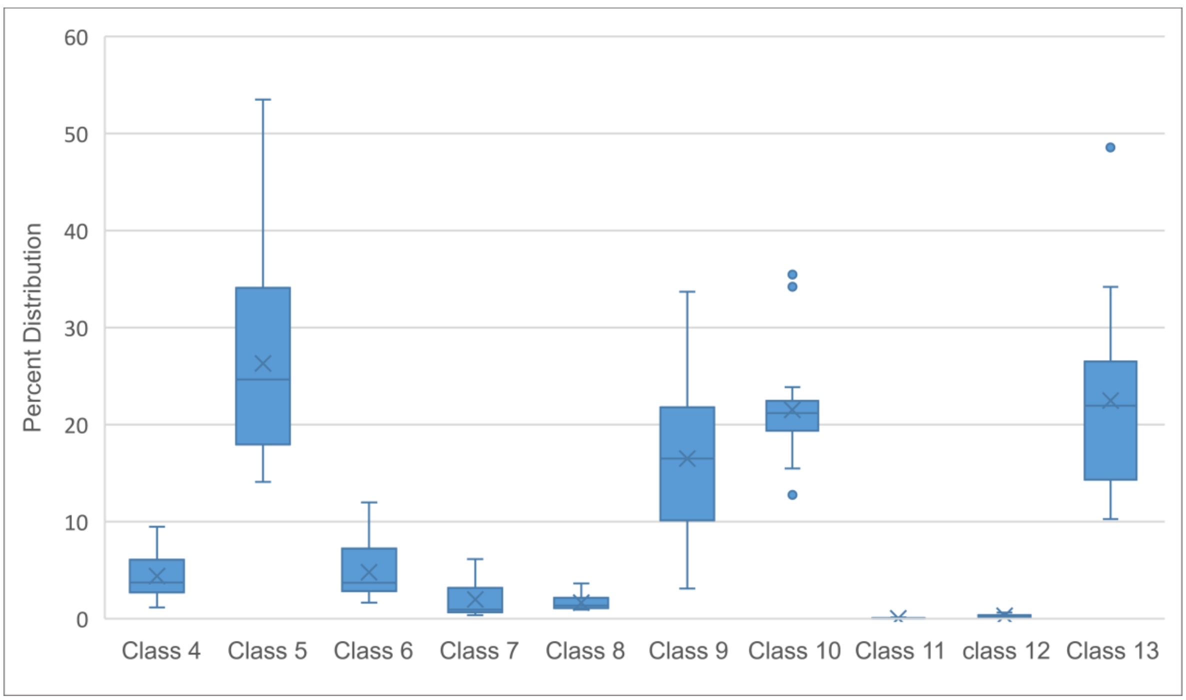


EVALUATION OF WIM DATA

Truck traffic data such as vehicle class, MAF, HDF, and Axles per Truck collected at each WIM station were reviewed to examine their inherent variability through Box-and-whisker plots as shown in Figures 3 to 6. Box-and-whisker plots graphically illustrates the range of data. The lower, middle, and upper edge line of each box show the 25th, 50th, and 75th percentiles of the data. The bottom and upper lines extending beyond the box (i.e. the whiskers) are 1.5 times the Inter Quartile Range (IQR, the difference between 75th and 25th percentile). Data points above or below the whiskers are typically considered outliers and need further verification.

Figure 3 shows the per cent distribution of vehicle classes across all WIM stations, for all years and lanes. Figure 3 reveals that most of the data lie between 25th and 75th percentile for each vehicle class. However, Class 5, 9, and 13 have higher variations. Class 10 and 13 also have some outliers. As presented later, since these Classes represent over 90% of the truck traffic in Alberta, and recognizing the unique industry-related truck traffic in Alberta (e.g. 9 or 10-axle logging trucks, specialty oilfield servicing trucks, all-terrain cranes, etc.), these variations and outliers in VCD were deemed acceptable.

Figure 3: Box-and-whisker plot for Vehicle Class in all years and all WIMs



Figures 4 to 6 show the Axles per Truck distribution for Single, Tandem and Tridem axles across the different vehicle classes. These figures indicate that Classes 9, 12, and 13 have some outliers in the data but data for all other vehicle classes and axles are scattered around the median and generally lie inside the IQR. Box plots for MAF, HDF and other data have not been included here due to significantly lower variability as well as for brevity. Based on the relatively few outliers and generally tight grouping of the data, with more than 75% of the data randomly scattered around the median, the WIM data was deemed of suitable quality to be considered for use in development truck traffic inputs for PMED for Alberta.

Figure 4: Box-and-whisker plot for Single Axle per Vehicle Class

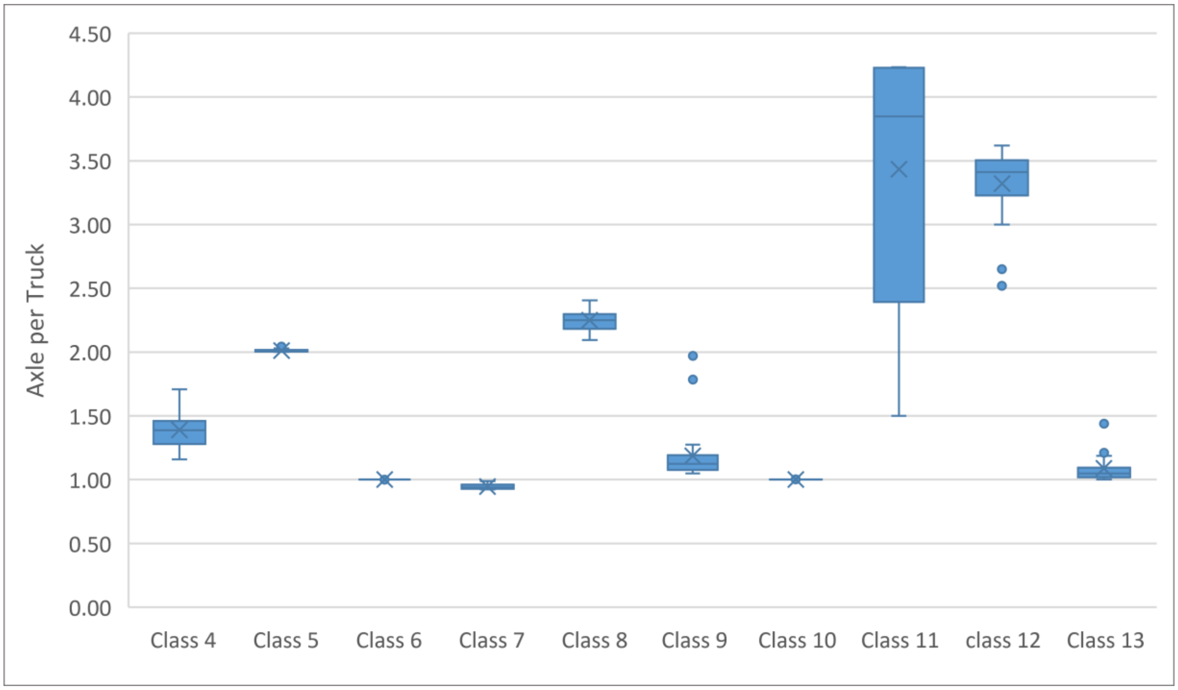


Figure 5: Box-and-whisker plot for Tandem Axle per Vehicle Class

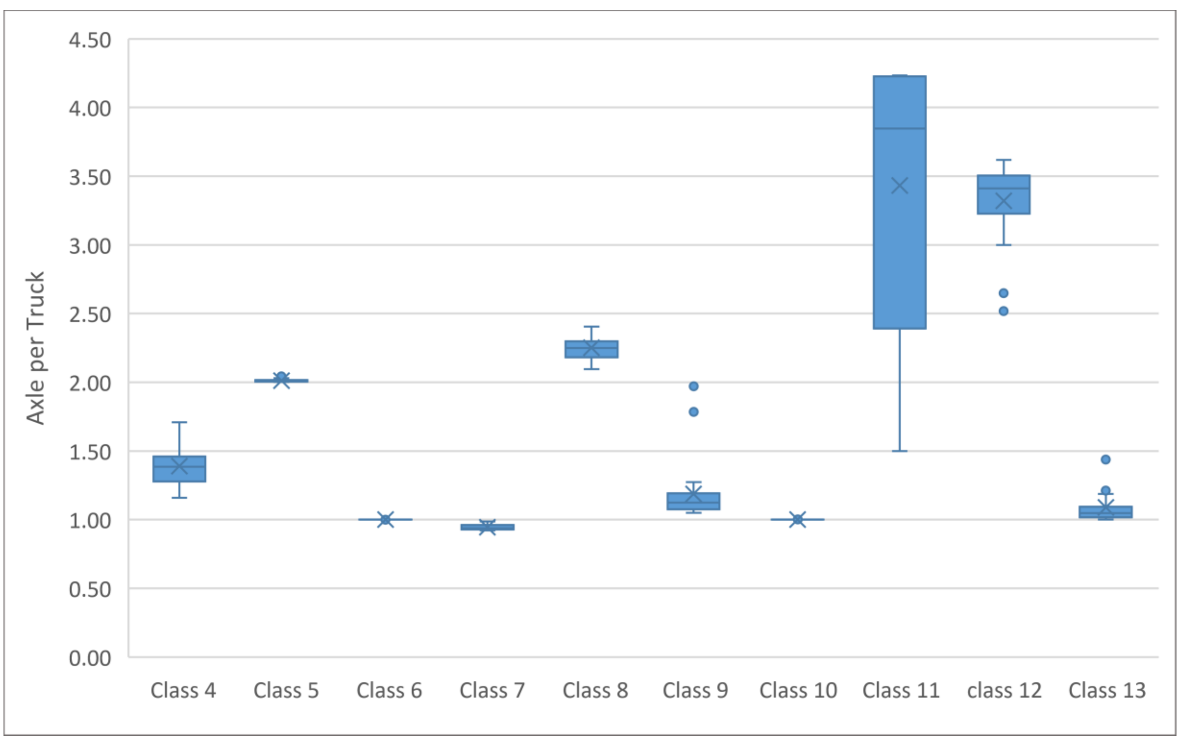
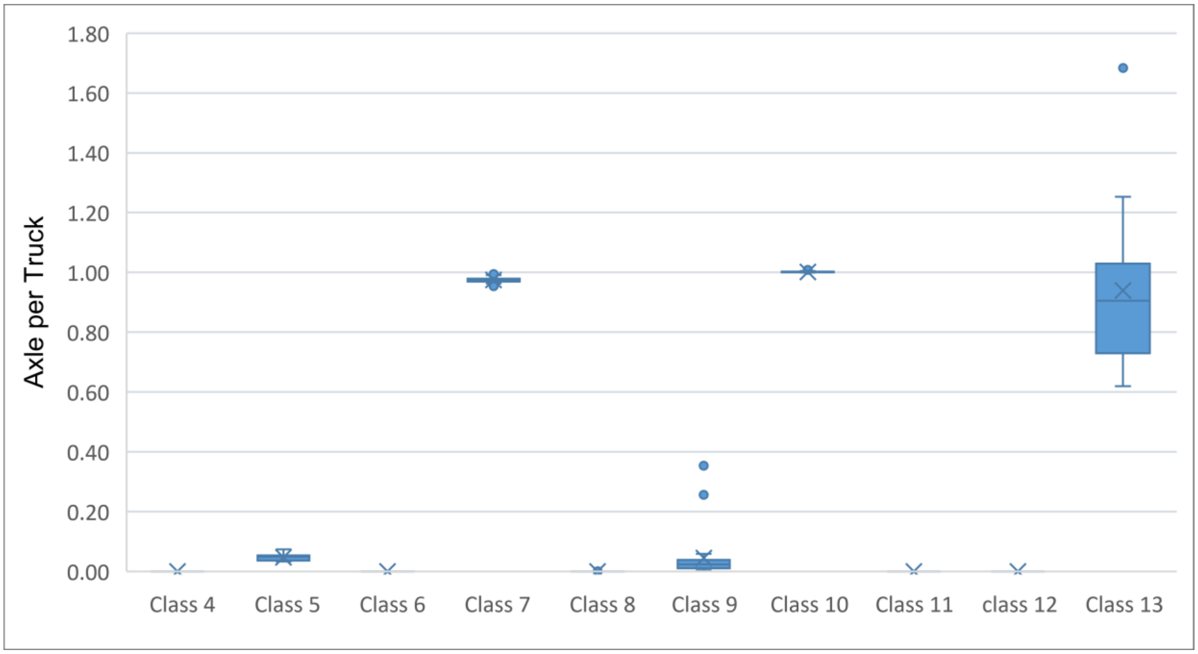


Figure 6: Box-and-whisker plot for Tridem Axle per Vehicle Class



DEVELOPMENT OF ALBERTA LEVEL 2 TRAFFIC INPUTS FOR PMED

Given that the WIM data were deemed acceptable for use, the data was then used to develop Level 2 traffic inputs for PMED. Simple statistical analyses like minimums, maximums, averages, and standard deviations both for individual WIM stations and for the data across all stations, as well as sensitivity analysis, were conducted to develop confidence in the Level 2 inputs. Given the quantity of data reviewed, only select details and analyses are presented in this section.

AADTT, percentage of trucks in the design direction, design lanes, and vehicle operation speed

AADTT for each highway segment can be calculated by multiplying the annual average daily traffic (AADT) volume by the percentage of Single Unit Trucks and Tractor Trailer Units that are available in Alberta traffic volume and class reports [13]. The percentage of trucks in the design direction, number of design lanes, and vehicle operation speed (that is typically little over the posted speed limit) are project specific parameters and are available for each project site at the design phase. This data should be considered as Level 1 input for Alberta.

Axle and wheelbase configurations and lateral wander

Axle and wheelbase configurations used in the PMED software have been taken from trucking industry standards [2]. Lateral wander used in the software assumes a standard wander for all trucks unless it is measured. Since there inputs have not been measured for Alberta, default Level 3 PMED values should be used.

Axle load spectra

Axle load spectra represents the normalized axle weights for each axle type (single, tandem, tridem and quad axles) for each vehicle class. All WIM stations in Alberta have recorded axle weights for each axle. However, this study did not evaluate the axle load spectra data as this is viewed as a separate but equally large undertaking, and presently the conversion of US customary axle load bins to SI bins is under review. Axle load spectra inputs for Alberta is planned as a future work.

VCD

VCD for FHWA Class 4 to Class 13 were obtained from each WIM station in different lanes and directions. Level 2 traffic inputs were developed by averaging all years' data at each station and then subsequently averaging all stations' data. Table 2 shows the VCD average of all years' data across all lanes, the effect of separating out the passing from driving lanes, and the default Level 3 PMED distribution. While aggregating the data across all years and lanes is simplistic and perhaps not entirely accurate, for Level 2 inputs it was deemed adequate since the difference in VCD was not overly significant. The VCD from all WIM stations shows that Alberta highways carry mostly Class 5, 9, 10, and 13 trucks.

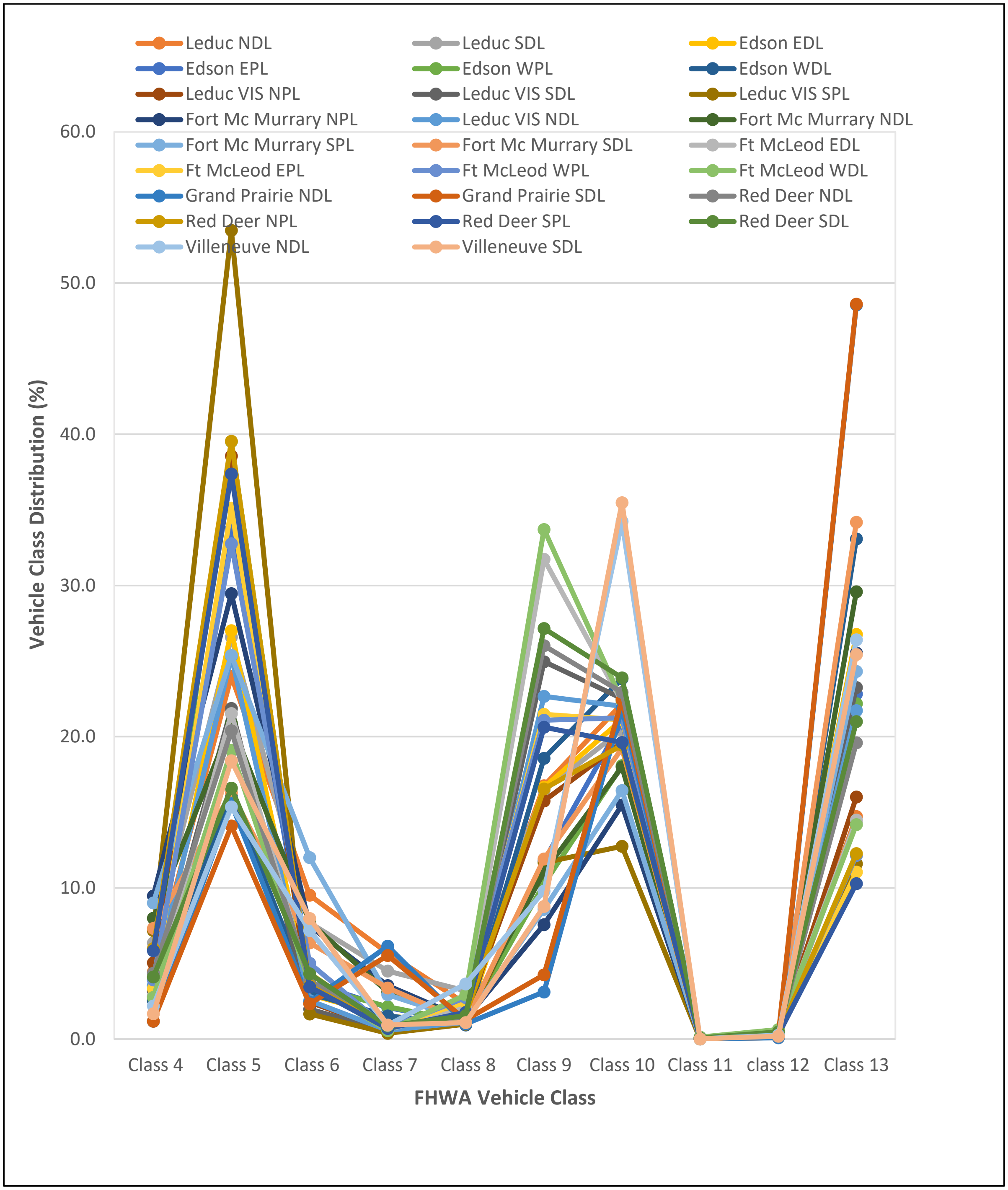
Table 2: Comparison between Alberta WIM derived (Level 2 inputs) and PMED Default VCD

Vehicle class	WIM Average VCD (%) across all lanes	WIM Average VCD (%) without passing lanes	PMED Default VCD (%)
Class 4	4.4	3.6	0.8
Class 5	26.3	20	33.6
Class 6	4.8	4.8	6.2
Class 7	2	2.3	0.1
Class 8	1.7	1.7	7.9
Class 9	16.5	17.7	26
Class 10	21.5	23.4	10.5
Class 11	0	0.1	1.4
Class 12	0.3	0.4	3.2
Class 13	22.5	26	10.3
Total	100	100	100

Comparing the VCD to historical traffic data from 'Alberta traffic volume and class reports' [13] indicates that the data is reasonable. Class 5 and 6 represent single unit trucks and a total percentage of just over 30 aligns with the truck data in [13]. Class 5, 9, 10, and 13 trucks contribute about 90% of the total truck volume and align with the typical truck types observed on Alberta highways. Classes 7, 8, and 11 are not frequently observed on Alberta highways. Class 13 represents seven or more axle multi-trailers and captures nearly all the multi-trailers in the province. The significantly higher Class 13 percentage in Alberta compared to Level 3 PMED defaults aligns with the higher multi-trailer usage in Canada versus the US. The Fort McMurray north as well as south WIM stations carry a significant number of buses (Class 4) at an average of 8.5% of total truck volume. Other than Fort McMurray, Leduc and Red Deer also show higher (average 5%) Class 4 vehicles. This higher Class 4 traffic is consistent with the intercity bus transportation along those highway corridors.

Figure 7 shows the VCD for the WIM stations in Alberta. It can be observed that Class 5 has a larger data spread that corresponds to the data previously presented in the box plots. It is noted that generally from 2007 to 2009 the recorded Class 5 vehicle volume was lower at most of the WIM stations, and it has been increasing since, which is contributing to the larger variation in data. Class 9 and Class 13 volume decreased over time at the corresponding WIM stations. At some stations (Fort McMurray and Grande Prairie) the average of Class 13 is significantly higher, reflecting the heavy haul and industry in the area.

Figure 7: Vehicle Class Distribution from WIM stations



Traffic Growth Rate Derivation

The average of each VCD for each year was used to calculate the traffic growth rate and function type. PMED allows linear or compound growth function types. The initial and final years' data were used to calculate the compound growth rate. All years' data were plotted for each class to observe the trend and calculate the linear growth rate. Based on a detailed analysis of the available data, neither the linear nor compound growth type fit in all situations. Since PMED does not have other growth functions (e.g. exponential, logarithmic, polynomial, etc.), judgement was applied to decide the growth type and rate. For most of the classes except 11 and 13, a compound growth rate was more applicable. The average growth rate along with recommended growth rate from all WIM stations for each truck class are provided in Table 3.

Table 3: Summary of WIM Derived and Recommended Growth Rate and Function for PavementME

Vehicle Class	WIM derived Growth Rate (%)	WIM derived Growth Function	Recommended Growth Rate (%)	Recommended Growth Function
Class 4	2	Compound	3	Compound
Class 5	3	Compound	3	Compound
Class 6	1	Compound	3	Compound
Class 7	5	Compound	3	Compound
Class 8	2	Compound	3	Compound
Class 9	1	Compound	3	Compound
Class 10	1	Compound	3	Compound
Class 11	0	Linear	3	Compound
Class 12	3	Linear	3	Compound
Class 13	1	Compound	3	Compound

Alberta Transportation's pavement design manual [14] recommends a three per cent compound growth rate is applicable for all highways in Alberta, recognizing that Alberta has traffic data going back to 1962. WIM sites have recorded data only for 13 years. While traffic growth can be very localized, and recognizing the boom and bust Alberta economy, judgement and experience suggest a three per cent compound growth rate at Level 2 for all FHWA traffic classes. By comparison, the Level 3 default PMED TGF is three percent using a linear function.

MAF

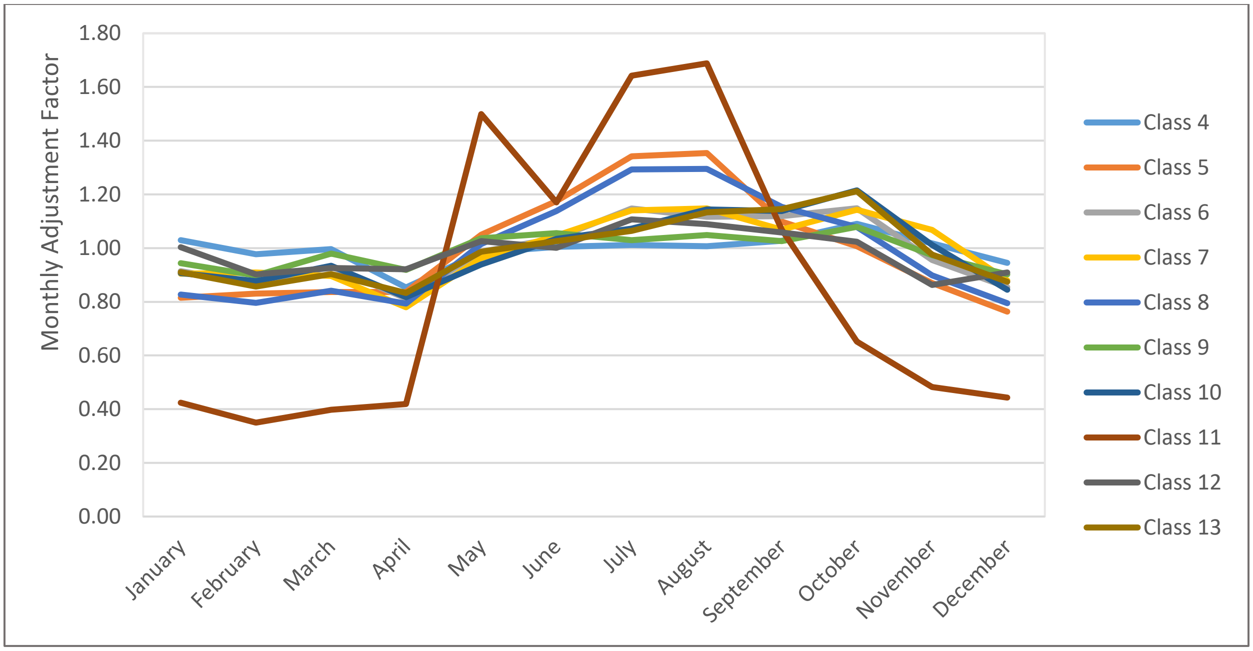
MAF characterizes the distribution of each truck class for each month. MAF data were collected from all WIM stations. Variation was evident in the MAF from year to year, between different lanes, as well as between directions at all stations. The average MAF for each month for all stations and all years for each traffic class was calculated and is provided in Table 4.

Table 4: Alberta WIM Derived Average Monthly Adjustment Factors (Level 2 inputs)

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.03	0.81	0.91	0.90	0.83	0.94	0.91	0.42	1.00	0.91
February	0.98	0.83	0.87	0.91	0.80	0.90	0.88	0.35	0.90	0.86
March	1.00	0.84	0.93	0.90	0.84	0.98	0.93	0.40	0.93	0.90
April	0.85	0.84	0.81	0.78	0.79	0.92	0.82	0.42	0.92	0.83
May	0.98	1.05	0.99	0.96	1.02	1.04	0.94	1.50	1.03	0.99
June	1.00	1.18	1.04	1.05	1.14	1.06	1.03	1.17	1.00	1.03
July	1.01	1.34	1.15	1.14	1.29	1.03	1.07	1.64	1.11	1.06
August	1.01	1.35	1.12	1.15	1.30	1.05	1.14	1.69	1.09	1.13
September	1.03	1.10	1.12	1.07	1.15	1.03	1.14	1.07	1.06	1.14
October	1.09	1.01	1.15	1.14	1.08	1.08	1.22	0.65	1.02	1.21
November	1.02	0.87	0.96	1.07	0.90	0.97	1.01	0.48	0.86	0.98
December	0.94	0.76	0.85	0.88	0.80	0.90	0.84	0.44	0.91	0.88

The average Alberta WIM MAF values appear reasonable and show the same trends across classes as shown in Figure 8. For Class 11, unusually high and low MAF were recorded at the Leduc and Edson WIM stations in both directions and lanes. Class 11 are the least frequent (0 % - 0.1%) vehicle class on Alberta highways. Given this, it is not expected that the Class 11 variability would have any impact on predicted pavement performance. Class 5 and 8 show expected higher MAF in the summer months. It should be noted that the default Level 3 PMED values for MAF are 1.0 for all months and truck classes.

Figure 8: Distribution of Monthly Adjustment Factors for Different Classes of Traffic



HDF

HDF characterizes the percentage of trucks using a road for each hour of the day [2]. HDF for Level 2 were developed by averaging the available HDF over the years of data collected for each WIM station. A detailed analysis showed that hourly distribution data was consistent across the years. Differences observed between the Level 2 and Level 3 default HDF are shown in Figure 9. At all WIM stations, the HDF percentage is consistently higher than the Level 3 PMED default between 8:00 AM and 6:00 PM. On the other hand, during the evening, overnight, and early morning hours, the WIM derived HDF values are lower. However, since HDF is only necessary for rigid pavement design [2], these differences are not significant but simply provide a sense of the difference between the truck traffic characteristics in Alberta versus the Level 3 defaults.

Axles per Truck

The Axles per Truck represents the number of axle types (single, tandem, tridem, quad) per vehicle class. The data available for the eight WIM stations were examined. Figure 10 to Figure 12 show the typical Axles per Truck at Level 1 for each axle type at different WIM stations. Figure 13 to 15 show the comparison between the Level 3 PMED defaults and the WIM derived data. The average number of axle groups per vehicle were developed province-wide as Level 2 inputs and are provided in Table 5.

Figure 9: Comparison between Level 2 and Level 3 Hourly Distribution Factor

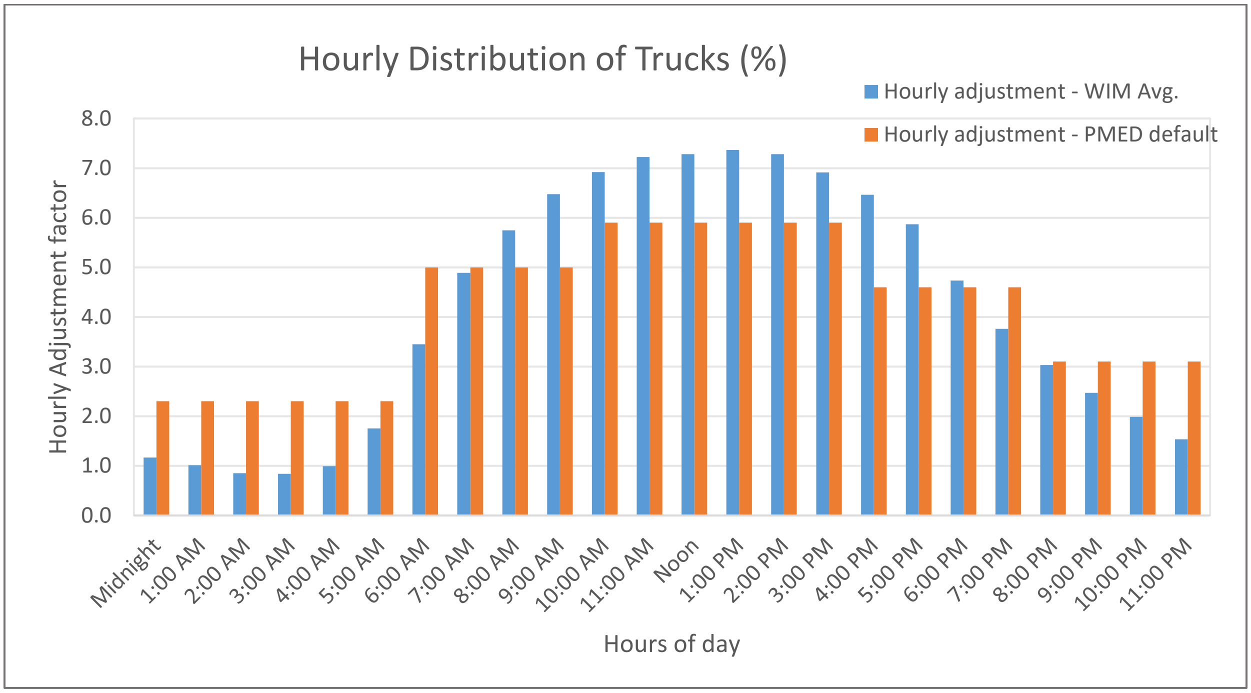


Figure 10: Single Axles per Truck for Different WIM Stations

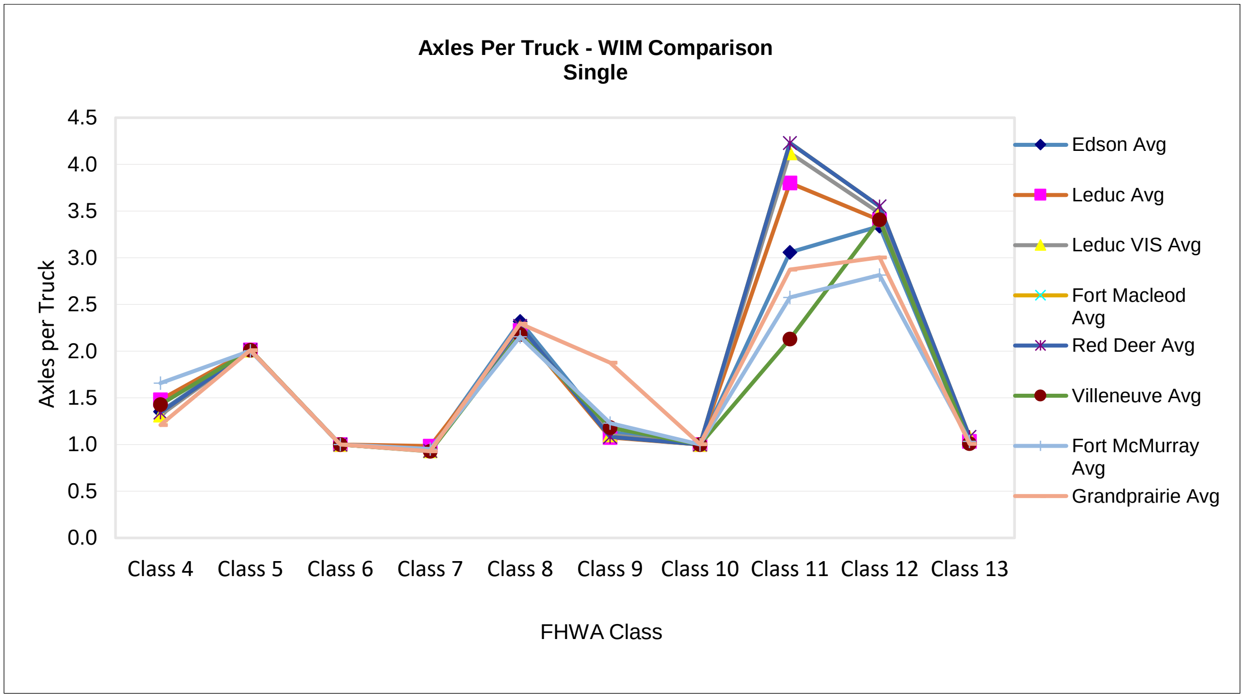


Figure 11: Tandem Axles per Truck at Different WIM Stations

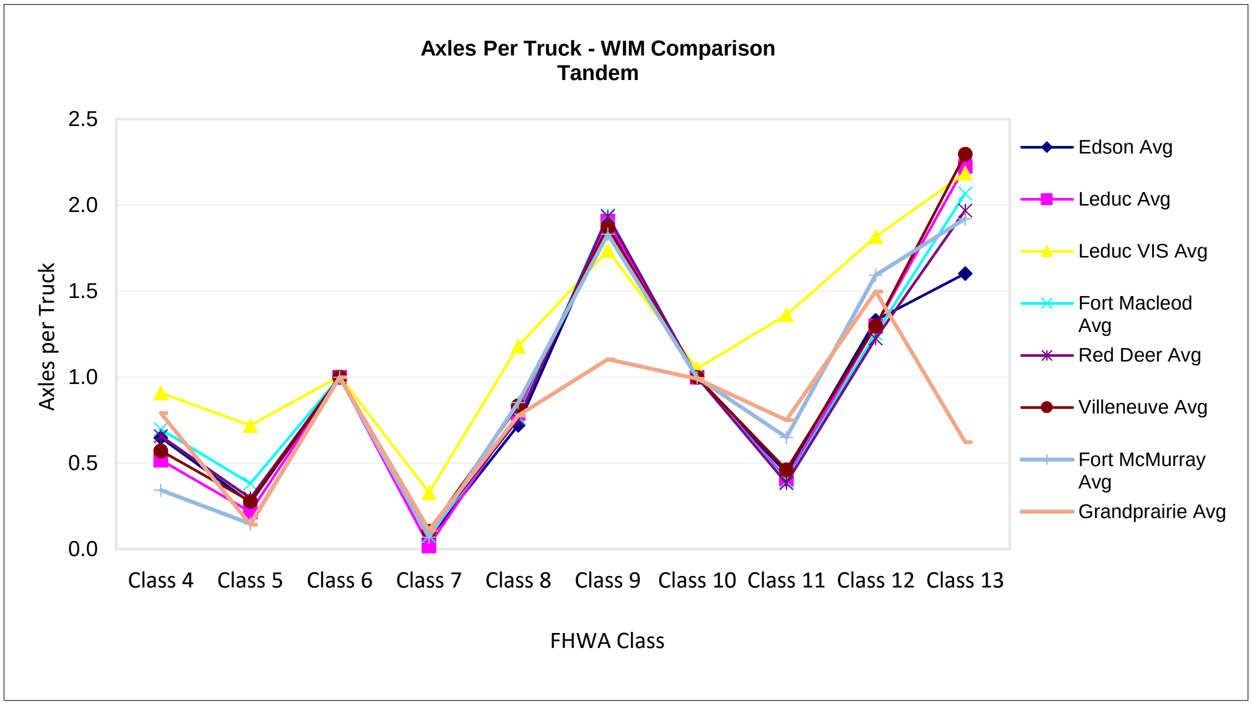


Figure 12: Tridem Axles per Truck at Different WIM Stations

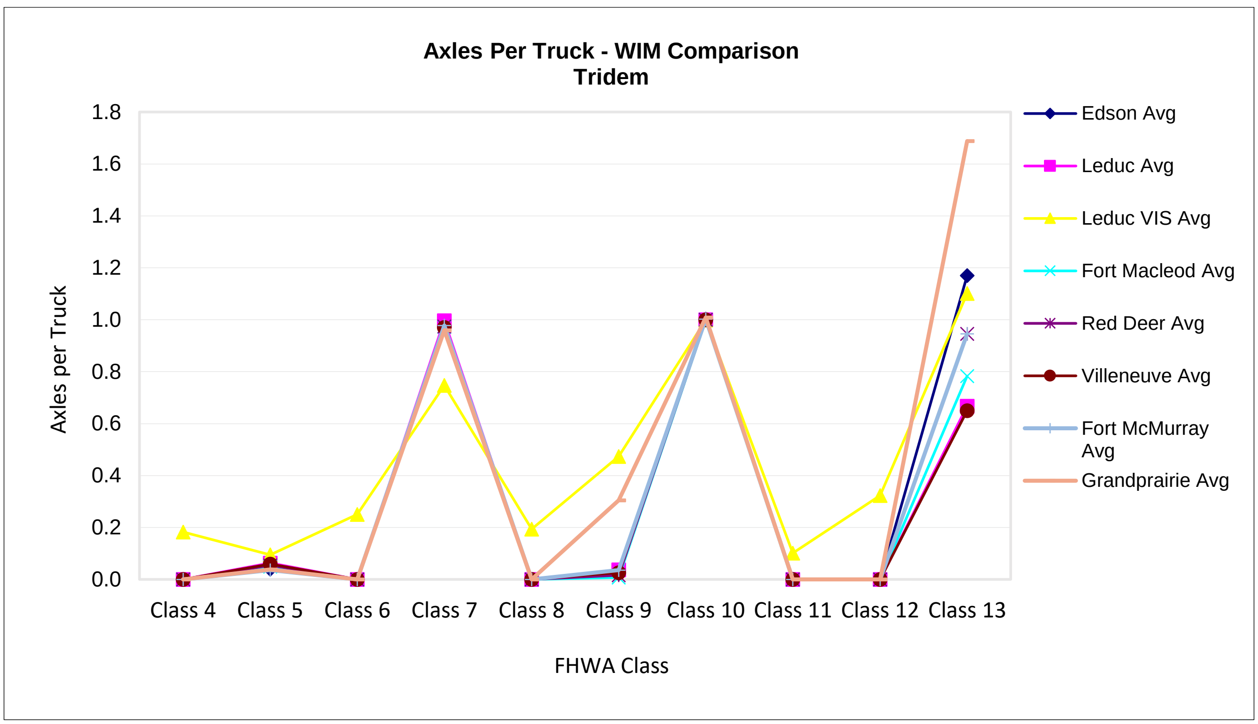


Figure 13: PavementME Defaults and WIM Derived Axle/truck factors Distributions for Single Axle

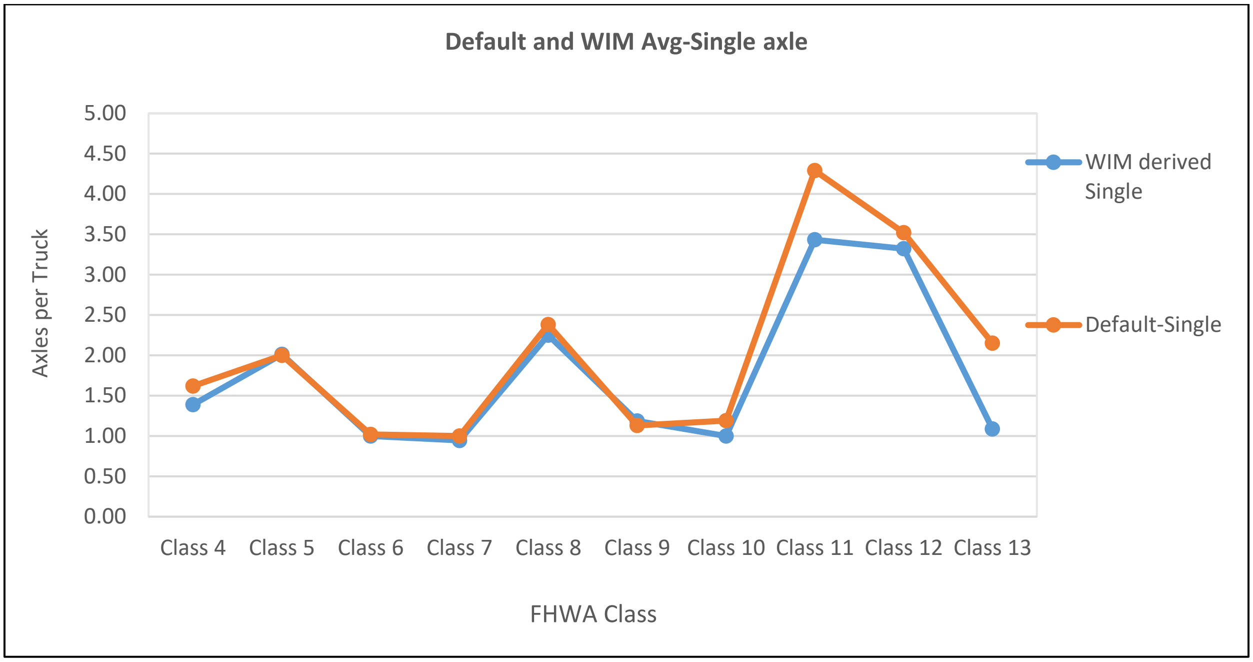


Figure 14: PavementME Defaults and WIM Derived Axle/truck factors Distributions for Tandem Axle

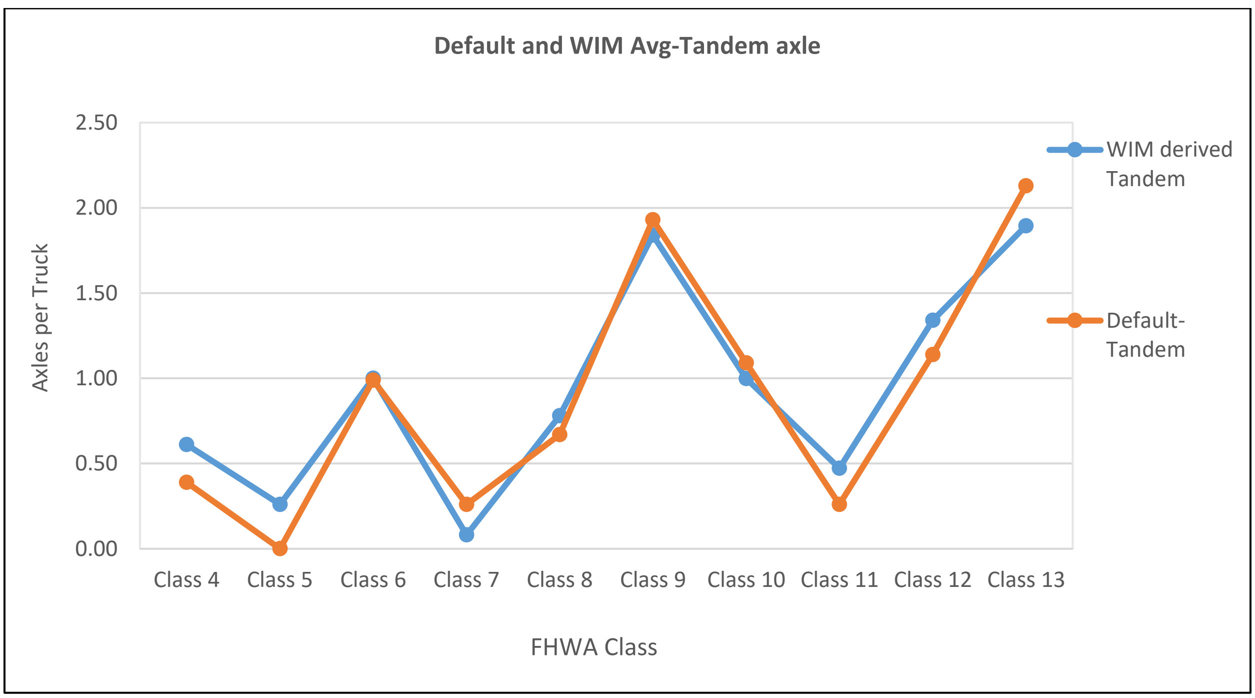


Figure 15: PavementME Defaults and WIM Derived Axle/truck factors distributions for Tridem Axle

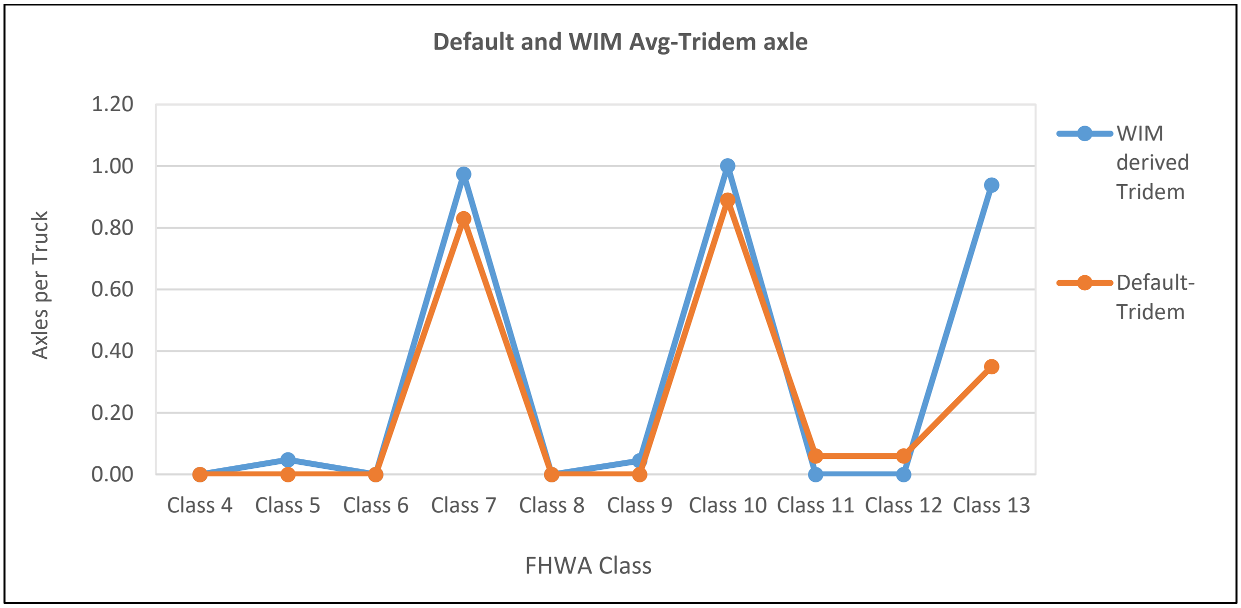


Table 5: Average Axles per Truck for Alberta (Level 2 inputs)

Month	Single	Tandem	Tridem	Quad
Class 4	1.39	0.61	0.00	0.00
Class 5	2.01	0.26	0.05	0.00
Class 6	1.00	1.00	0.00	0.00
Class 7	0.95	0.08	0.97	0.00
Class 8	2.25	0.78	0.00	0.00
Class 9	1.19	1.84	0.04	0.00
Class 10	1.00	1.00	1.00	0.00
Class 11	3.43	0.47	0.00	0.00
Class 12	3.32	1.34	0.00	0.00
Class 13	1.09	1.90	0.94	0.00

A detailed analysis showed that there were year-to-year variations in the Axles per Truck. Site-specific, and hence the averages of, Axles per Truck information is comparable to the Level 3 default PMED values, with the exception of the tridem for Class 13 vehicles, reflective of the significant use of multi-trailers in Alberta as well as the catch-all nature of this vehicle class (i.e. any truck with greater than 7 axles is placed in Class 13).

EFFECTS OF THE DEVELOPED LEVEL 2 TRAFFIC INPUTS ON PAVEMENT PERFORMANCE

To determine the effects of the newly developed Level 2 traffic inputs on pavement performance, the following analyses were carried out using the un-calibrated PMED version 2.6:

- Impacts of Level 2 versus default Level 3 values for VCD, TGF, MAF and Axles per Truck; and

- Investigation of effects of hierarchical traffic inputs (Level 1, Level 2 and Level 3) on the predicted pavement distresses.

Level 2 Versus Default Level 3 Analysis

To investigate the pavement performance impacts of using the Level 2 traffic inputs versus the default Level 3 PMED values, select highway rehabilitation overlay designs, as presented in Table 6, were run through PMED. Rehabilitation overlay designs with 20 years of design life were used since that represents the majority of the pavement design work in Alberta. The overlay design was first run using only default Level 3 inputs. Then the design was re-run using the Level 2 value for the select parameter (i.e. VCD, TGF, MAF, and Axles per Truck) and keeping all other values at default Level 3. A total of 20 designs (5 x 4) were run.

Table 6: Flexible Pavement Design Inputs for Sensitivity Analysis

Hwy	Control Section	Km Limits	AADTT	ACP (mm)	GBC (mm)	Climate
60	02	31.44 -31.84	4,448	310	500	Station ID - 159659
37	02	37.00 - 41.06	777	320	150	Station ID - 159659
33	08	27.44 - 28.84	285	250	250	Station ID - 160234
899	06	19.20 - 27.13	49	170	300	Station ID - 157936
2A	18	11.78 - 17.52	416	350	225	Station ID - 158507

Recognizing that the scenarios presented in Table 6 are all rehabilitation designs and have a relatively thick asphalt layer, a new construction design for highway 37:02 was also run to assess the impact of the Level 2 inputs on predicted performance. For the sake of brevity, those results are not presented, but the impacts on predicted pavement performance aligned with those for the rehabilitation designs. VCD was the only parameter that had any measurable impact (~20%, 2 mm increase in total rutting) while the other parameter had none to negligible impact.

The analyses showed that the VCD, TGF, MAF, and Axles per Truck influence pavement distresses in terms of IRI, asphalt concrete (AC) rutting and total rutting. The effects on other pavement distresses, such as fatigue cracking (top down, bottom up, and total), thermal cracking and transverse cracking (thermal + reflective), were negligible. Table 7 shows the effects of the Level 2 developed traffic inputs and their impacts on pavement distresses.

Table 7: Increase in Predicted Pavement Distress from using Level 2 traffic inputs versus Level 3 defaults

Affected Distress	Vehicle Class Distribution (VCD)	Monthly Adjustment Factor (MAF)	Axles Per Truck	Traffic Growth Rate (TGF)
AC rutting (mm)	**8% - 15%**	0.5% - 1.0%	2.5% - 7.0%	0.8% - 1.6%
Total rutting (mm)	**10% - 21%**	0.5%- 3.5%	0.5% - 3.5%	0.6% - 0.8%
IRI (m/km)	1.5% - 4%	0% - 1%	0.5% - 3.8%	0% - 3%

While MAF, Axles per Truck, and TGF increase pavement distress, this increase is generally considered insignificant. For typical flexible pavement designs in Alberta, pavement distress predictions using PMED is moderately sensitive to the VCD. For the same total truck volume, the changes in the VCD indicate some influence on the predicted AC rutting and total rutting.

Effects of Hierarchical Traffic Inputs (Level 1, Level 2, and Level 3) on the Predicted Pavement Distresses

To investigate the effects of hierarchical traffic input levels on pavement performance, PMED runs were conducted for all eight WIM stations. The first run used all default Level 3 inputs. The second run used the developed Level 2 inputs for VCD, TGF, MAF, and Axles per Truck, and changed them all at once. The third run changed those four inputs to Level 1 based on site-specific WIM data. Twenty-four runs were completed – three hierarchical levels at each of the eight WIM stations. For each run, a rehabilitation overlay designs with 20 years of design life and climatic station were considered corresponding to that WIM station.

Similar to the previous one-at-a-time sensitivity analysis observations, AC rutting, total rutting, and IRI were slightly affected by the different hierarchical input levels, as presented in Table 8. Distresses increased when going from Level 3 to Level 2, and when going from Level 2 to Level 1. The maximum increase in estimated total rutting between Level 3 and Level 1 was about 3.1 mm at the end of the 20-year design life.

Table 8: Difference in Pavement Distress using Different Input Levels

Affected Distress	Difference in predicted distress using Level 2 and 3 inputs		Difference in predicted distress using Level 1 and 3 inputs	
	Distress value	Per cent change	Distress value	Per cent change
AC rutting (mm)	0.12 - 0.33	10%-13%	0.07 – 0.55	5%-22%
Total rutting (mm)	0.68 – 1.67	10%-17%	0.81 – 3.08	11%-30%
IRI (m/km)	0.00 - 0.08	0.5%-3 %	0.02 - 0.08	1%-7%

Negligible differences were noted for fatigue and thermal cracking, except at two WIM stations where the fatigue cracking predictions changed. As provided in Table 9, there was a noticeable difference in AC total fatigue cracking (bottom up + reflective (% lane area)) at the Fort McMurray (Hwy 63:10) and Grande Prairie (Hwy 40:40) stations. The increase in predicted distress in Grande Prairie was about 12% of the lane area. At the other six WIM stations this fatigue cracking difference was near zero. This difference may in part be due to the difference in Class 13 truck percentage between input levels at both of these stations, as presented in Table 10; the more global-type sensitivity analysis by changing the four inputs at once; and the site specific pavement design.

Table 9: Difference in AC total fatigue cracking: Bottom up + Reflective (% lane area)

WIM Station	Difference in fatigue cracking (% lane area) using Level 2 and 3 inputs	Difference in fatigue cracking (% lane area) using Level 1 and 3 inputs
Hwy 63:10, Ft. McMurray	5.11	6.83
Hwy 40:40, Grande Prairie	4.43	12.05

Table 10: Class 13 Distribution in Different Input Levels

WIM Station	Level 3	Level 2	Level 1
Hwy 63:10 Fort Mc Murray	10.30%	22.47%	29.60%
Hwy 40:40, Grande Prairie	10.30%	22.47%	48.60%

As shown from the impacts of hierarchical traffic input level analysis, site-specific Level 1 traffic data does not appear to significantly impact pavement distress predictions, with the exception of fatigue cracking. This sensitivity, which was not observed in the one-at-a-time VCD analysis, warrants further investigation and indicates the importance of understanding local truck traffic and using site-specific inputs where available.

CONCLUSIONS AND RECOMMENDATIONS

PMED enables comprehensive truck traffic categorization and classification. The Level 2 inputs for VCD, Axles per Truck, monthly, and hourly distribution factors were determined from traffic data collected at different WIM stations in Alberta. The following conclusions and recommendations are drawn from this work:

- VCD from all WIM sites indicates that Alberta highways carry primarily Class 5, 9, 10, and 13 trucks. These four classes add up to approximately 90% of the truck traffic. VCD data trends from different WIM stations over the data collection years seem to be reasonably consistent.
- Traffic growth rate analysis indicates that most of the traffic classes have a compound growth function. The average growth rate from the WIM data analysis ranged between zero and 5 per cent for different traffic classes. Although possibly conservative, a three per cent compound growth rate for all truck types is recommended based on traffic experience in Alberta.
- MAF varies modestly from WIM site to site and month-to-month. However, the province-wide average MAF was reasonably close to PMED default value. In the absence of site specific data, Level 2 MAF provided in Table 4 are recommended.
- Axles per Truck vary year-to-year and station-to-station, although the average Axles per Truck factors of all Alberta sites appear comparable with the PMED defaults.
- For typical Alberta pavements, out of the four traffic inputs developed (VCD, MAF, Axles per Truck and TGF), VCD has the most influence on predicted pavement distresses, with rutting generally being the only distress seeing some measurable impact. Other inputs appear to insignificantly influence the un-calibrated PMED distress predictions.
- Site-specific Level 1 traffic data does not appear to significantly impact pavement distress predictions, with the exception of fatigue cracking. However, this warrants further investigation.
- This study indicates that using Level 2 inputs generates generally comparable pavement distresses to Level 1 traffic inputs. It recommends to use Level 1 (site-specific) inputs wherever available. For projects where site-specific data are not available, Level 2 provincial average traffic inputs should be used, which will provide more representative inputs than the default Level 3 PMED traffic inputs.
- The above conclusions and recommendations should be revisited upon development of axle load spectra inputs for Alberta.
- To ensure the reliability of the PMED distress predictions, it is recommended to calibrate the PMED flexible pavement distress models for Alberta environment.

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