Effects of Traffic Loads and Asphalt Thickness on PMED Software Predicted Distresses in New Flexible Pavements

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Paper prepared for the session PV - The Road Ahead: Analyzing Futuristic Vehicle Technologies and Changing Traffic Impact on Pavement Life
2026 Transportation Association of Canada (TAC) Conference & Exhibition, Winnipeg, Manitoba

Acknowledgements
The authors would like to acknowledge and thank the persons, listed herein, for their participation in design trials and/or discussion: John Crockett (Alberta Transportation and Economic Corridors), Diana Podborochynski (Saskatchewan Ministry of Highways), Marcus Wong (Manitoba Transportation and Infrastructure), Sam Esfandiarpour (EXP: Engineering), Shila Khanal (Applied Research Associates Inc.), Shivpal Yadav (Thurber Engineering), Shawn Lapain (AECOM), and Julie Roby and Olivier Sylvestre (Ministère des Transports et de la Mobilité durable).

Abstract

The imposed traffic loads and selected layer thicknesses of different materials impact performance of all pavement structures. The Pavement Mechanistic-Empirical Design (PMED) software is designed to predict pavement performance in terms of key surface distresses in different pavement types. The predicted distresses for flexible pavement include total rutting, rutting in asphalt concrete (AC) layer, thermal cracking (TC), bottom-up fatigue cracking (BUFC), top-down fatigue cracking (TDFC), and international roughness index (IRI). However, several past studies have noted some limitations and inconsistencies in predicted distresses for the variation of some key design inputs. In 2025, the Transportation Association of Canada (TAC) ME Pavement Design Subcommittee completed several design trials with four variations of both traffic loads and AC layer thickness (leading to eight design trials for each weather station). These allowed for quantifying and assessing trends of the predicted distresses for the variation of these two key design parameters. Each of these design simulations was also conducted for 11 weather stations to assess the influence of regional climatic variability across Canada.

These trials results and analyses indicated that the total rutting and AC layer rutting are highly sensitive to variation of traffic loads, and they decrease with increased AC thickness. Higher AC layer rutting was observed in some relatively colder climates as compared to warmer climatic areas, which is unexpected. As expected, thermal cracking performance improved with increased AC thickness, while the influence of traffic loads on thermal cracking was minimal. In general, both BUFC and TDFC were strongly influenced by the variation of traffic loads, with greater improvements associated with thicker AC layers. However, in some regions, increased AC layer thickness resulted in increased BUFC, which is unexpected. The predicted IRI is primarily governed by the variation of predicted other distresses in pavements. This paper presents the details of the study, results, analysis and findings.

Introduction

Highways and roads are designed and constructed for the movement of traffic including goods and services. The loads from heavy vehicles are key inputs to the design of pavement structures. The traffic pattern, volume and loads including growth on a highway section may also trigger the pavement reconstruction, rehabilitation, preservation and maintenance options or strategies. The required pavement structure in terms of thickness of various layer materials, for a given subgrade foundation and climatic condition, depends on the imposed traffic loads over a preselected design service life and the properties of pavement layer materials. An increased traffic loads will require an increase in pavement thickness to meet the design service life. Alternatively, an increased pavement layer thickness will increase pavement service and vice versa, where the AC layer thickness has the most pronounced impact.

Traditionally used pavement design methods, such as the AASHTO 1993 pavement design guide approach, were shown to provide logical variation of the required pavement structure for the variations of traffic loads and other design inputs. However, the adequacy and soundness of those design methods to the current traffic condition and volumes or loads and currently measured pavement distresses including the technologies used to collect these distress data are not yet thoroughly validated. The AASHTOWare PMED software, which is developed based on a mechanistic-empirical principle, has been designed to overcome the limitations of past design approaches. In this software, the calculated responses (stress, stain, etc.) of a selected pavement structure have been correlated with the observed performance in terms of IRI, rutting, cracking and faulting under various traffic loading and climatic conditions. However, although this

software has been under development and refinement for over a 20-year period, Canadian highway agencies are still facing challenges to adopt it because of several limitations and issues. These include inadequate or inconsistent impact of subgrade soils, granular aggregate layers, asphalt binder grade, climatic exposures, traffic loads and pavement rehabilitation treatments. This study aimed to further validate the influence of traffic loads and AC layer thickness variations of the PMED software predicted distresses in new flexible pavements. The findings from this study are expected to provide valuable insights into the sensitivity and trends of PMED software predicted distresses for the variation of these two key design inputs parameters. This will provide support to the ongoing efforts to better understand the models for pavement performance prediction, to improve confidence or make alternative decision and/or to consider additional efforts for model validation/calibration within Canadian context.

Background

The PMED software integrated mechanistic responses of pavement structures due to applied repeated loads and the resulting accumulated damage with empirically observed distresses in existing pavements to predict new and rehabilitated pavement performance. Traffic loading governs the magnitude and frequency of stresses and strains within the pavement structure, while AC layer thickness plays a key role in distributing these stresses and mitigating damage accumulation. Understanding the sensitivity and trends of PMED software predictions due to changes in these key design variables is essential for informed decision-making in pavement design and management. In the Canadian context, pavement performance is also influenced by a wide range of climatic conditions and material properties. Although general trends are well understood, such as increased distress with higher traffic and improved performance with thicker asphalt layers, the extent to which PMED captures these relationships, particularly under diverse Canadian climatic conditions requires a systematic investigation.

As one of the multi-year software evaluation design trials by the TAC ME Pavement Design Subcommittee since 2007, this study was conducted in 2025 to investigate the effects of traffic loads in terms of annual average daily truck traffic (AADTT) volumes and asphalt concrete (AC) layer thickness on PMED software predicted distresses in new flexible pavements. Using a comprehensive set of design trials that incorporate multiple traffic scenarios, structural configurations, and climatic regions across Canada, the study evaluates key performance indicators for flexible pavement structures. The analyses aimed to assess the quantity of predicted distresses, identify expected and unexpected trends in PMED predictions, assess their sensitivity to input variations, and provide insights that can inform future calibration, design practices, and decision-making processes within the Canadian pavement engineering community.

Literature Review

Since PMED design and analysis are based on the accumulation of damage as a function of climate and traffic loadings over time[1], numerous studies with various matrices of different climactic conditions and loading levels have been completed. These studies found that PMED software distress predictions are highly sensitive to traffic loads and asphalt thickness. Increased AC thickness generally reduces BUFC and AC rutting, and improves the IRI, while exhibiting complex effects on total rutting and top-down cracking[2,3,4,5]. By utilizing Environment and Climate Change Canada data, Maadani[6] reported that it is crucial to understand the impact of climate change on flexible pavements' long-term performance. Ahammed et al.[7] has completed multiple design trials to verify the predicted distresses/performance and

suitability of the PMED software for flexible pavement and increased traffic loads on an AC overlaid pavement result in increased IRI, thicker overlay decreases the total and AC rutting, increased traffic loads slightly increase the total and AC layer rutting and colder climatic areas exhibit higher AC rutting than warmer areas. However, the software predicted significant amount of rutting in the base and subgrade of overlaid pavements despite no such rutting in the existing pavements and a thicker AC layer produced higher TDFC than thinner AC layer.

To assess quantitatively the local sensitivity of PMED software predicted outputs, Schwartz et al.[8] adopted a normalized sensitivity index (NSI) as the percentage change of predicted distress relative to its design limit caused by a given percentage change in the design input. The results showed that TDFC and BUFC are hypertensive to AC thickness, very sensitive traffic volume and sensitive to ground water depth. Total rutting, AC layer rutting and IRI are very sensitive to AC thickness and sensitive to traffic volume.

Based on data from pavement projects of Florida Department of Transportation (FDOT), Goehi and Nyamuhokya[9] conducted a sensitivity analysis using the default global calibration factors in PMED software. The design inputs' sensitivity was evaluated using multivariate linear regression models and by grouping the input parameters in five ranges of mean plus standard deviations (std.). The analyses showed that the total rutting, BUFC, TDFC and IRI are sensitive (in 1-2 std. range), while AC layer rutting and TC are moderately sensitive (in <1 std. range) to the variation of AC layer thickness. The total rutting, IRI and TC were extra sensitive (in 2-3 std. range) and TDFC was sensitive, while AC layer rutting and BUFC were moderately sensitive to the variation of truck traffic volume (AADTT). All these distresses were moderately sensitive to variations in depth to water table.

Based on several design analysis, using both the AASHTO 1993 and AASHTO MEPDG approaches, Ahammed et al.[10] found that the difference between the design service life based on the AASHTO 1993 and the predicted service life based on the MEPDG predicted distresses increases as the traffic loads (truck volume) increases. This indicated that MEPDG require a substantially thicker structure for higher truck traffic volume. In addition, the difference between predicted distresses using local (Manitoba specific) axle load spectra (ALS) and the MEPDG default ALS were shown to be inconsistent. Another study by Ahammed et al.[11] using the MEPDG software found that increase of design traffic volumes from 250 to 500 and from 500 to 1,000 trucks per day lead to additional 20 mm and 65 mm AC thickness requirements, respectively to meet AC layer rutting limit of 12 mm. Such requirements did not match with Manitoba's local experience.

Scope, Objective, and Significance

The review of available literature indicates that traffic loading and AC thickness are among the most influential design inputs affecting the predicted distresses and performance trends in mechanistic–empirical pavement design tools. Several published studies and sensitivity investigations have reported that PMED software predicted rutting, fatigue cracking, and IRI are generally sensitive to traffic volume and asphalt layer thickness, although the response of individual distress components (e.g., total rutting versus layer rutting, and TDFC) may vary depending on climatic exposure and the overall design input set. Recent TAC papers have also documented that, while PMED may provide reasonable trends for some design inputs, unexpected and inconsistent trends may occur for others and can vary among climatic areas, which requires careful review before broad implementation.

In this study, design trials were completed to investigate the effects of varying traffic loads and AC thickness on PMED software predicted distresses in new flexible pavements under Canadian climatic conditions. The design trials included four AADTT levels and four total AC thicknesses. Varying climatic exposure was represented using inputs from 11 Canadian weather stations. All other key design inputs, including granular layer thickness and properties, subgrade type and properties, initial IRI, design life, and reliability settings, were held constant to isolate the effects of AADTT and AC thickness. The results from these trials allowed for assessing the sensitivity and trends of PMED software predicted distresses due to variations in traffic loads and AC thickness under Canadian climatic exposures.

The objective of this paper is to present the details of the trial input data, results, analysis, and findings. The presented information may help agencies and other interested individuals in assessing the suitability of PMED software outputs for new flexible pavement designs and in interpreting predicted distress trends when AADTT and AC thickness are varied under Canadian conditions.

Software Version and General Inputs

All participants utilized the PMED software version 3.0 using the global calibration coefficients in all design trials. The general input parameters for the design trials are summarized in Table 1, which remained unchanged in all design runs. The varying design inputs for different trial runs included varying truck traffic volumes and AC layer thickness, and varying climatic data from across Canada.

Selected Weather Stations and Summary of Climate Data

MERRA-2 climate data from 11 weather stations across Canada with varying climatic input parameters were selected for the design trials presented in this study. Table 2 presents the list of weather stations and the summary of the key climatic parameters. It should be noted here that some of the climatic parameters (such as minimum air temperature, frost depths and annual number of wet days) in the MERRA-2 climate database seem to be unreasonable as they do not match actual ground observations.

Trial Matrix and Varied Design Inputs

The design trials were structured to evaluate the sensitivity and trends of PMED predicted distresses in new flexible pavements due to changes in traffic loads (AADTT) and asphalt concrete (AC) thickness, leading to two different assessments for each climate station:

1. Sensitivity to traffic loads: AADTT was varied over four levels (two-way AADTT = 1,250; 2,500; 5,000; and 7,500) while maintaining a constant total AC thickness of 150 mm (40 mm thick SP12.5 AC surface layer and 110 mm thick SP19.0 AC base layer).
2. Sensitivity to AC layer thickness: Traffic load was held constant at two-way AADTT of 7,500, and the total AC thickness was increased from 150 mm to 180, 210, and 240 mm by increasing the SP19.0 base thickness from 110 mm to 140, 170, and 200 mm, respectively. The SP12.5 surface thickness remained constant at 40 mm in all cases.

Table 1. General inputs for design trials

Inputs		Value Used
Climate Data		MERRA-2 from 11 weather stations across Canada
Truck Traffic		AADTT was varied over four levels; Cumulative annual growth rate = 2%
Vehicle Class Distribution and Axle Load Spectra		Manitoba Level 1
Traffic Speed		100 km/h
Design Life		20 years
Initial IRI		0.9 m/km
Design Reliability		50% and 90 % for all distress types
HMA Properties		Manitoba SP12.5 mix: Asphalt binder = 4.8%; density = 2,276 kg/m^3; VMA = 17.2%; AV = 6.9%; particles finer than 9.50 mm = 80.6%, 4.75 mm = 52.6% and 0.075 mm = 2.8% Manitoba SP19.0 mix: Asphalt binder = 4.5%; density = 2,294 kg/m^3; VMA = 16.6%; AV = 7.0%; particles finer than 19.0 mm = 95.3%, 9.50 mm = 67.9%, 4.75 mm = 51.8% and 0.075 mm = 3.0% Asphalt binder grade: PG 58-34 in both mixes Software default Poisons ratio, reference temperature, thermal conductivity and heat capacity for both mixes
Pavement Structures	Asphalt Concrete	Surface layer = 40 mm thick Manitoba SP12.5 Base layer = Manitoba SP 19.0: Varied over four levels
	Granular Base	GBC- I = 150 mm; Annual representative Mr =225 MPa
	Granular Subbase	CR-M50 = 300 mm; Annual representative Mr = 200 MPa
Subgrade Type and Properties		Soil Type: High Plastic Clay (AASHTO A-7-6); Resilient Modulus = 35 MPa (software default minimum).

IRI = International Roughness Index; SP = SuperPave; VMA = Voids in Mineral Aggregates; AV = Air Voids; PG = Performance Grade.

Table 2. List of weather stations and summary of key climatic parameters over the design life

Weather Station	Annual Air Temp. (°C)			Mean Annual			
	Min.	Max.	Mean	Precipitation (mm)	Number of Wet Days	FI (°C-days) (FD, m)	# of F-T Cycles
Victoria, BC	-15.4	29.4	10.9	1502	332	11 (0.5)	7.2
Fort McMurray, AB	-47.1	36.9	0.2	630	337	2081 (4.4)	66.5
Swift Current, SK	-42.1	37.9	4.9	451	274	999 (2.0)	108.6
Winnipeg, MB	-45.9	38.3	3.5	605	302	1754 (3.2)	67.6
The Pas, MB	-48.1	37.9	0.5	590	329	2357 (7.5)	58.9
Wheatley, ON	-21.7	31.6	9.6	1092	304	301 (2.0)	52.0
Waldhof, ON	-48.9	33.6	1.3	858	335	2131 (4.1)	56.8
Rouyn, QC	-45.7	31.1	2.0	1226	350	1794 (2.7)	67.3
Montreal, QC	-41.5	36.7	6.2	1379	326	1100 (2.2)	70.8
Fredericton, NB	-36.2	31.8	5.0	1389	345	1028 (1.6)	81.2
Halifax, NS	-20.1	27.1	7.3	1647	340	315 (1.1)	70.0

FI = Freezing Index, FD = Frost Depth; F-T = Freeze-Thaw

Results, Analysis and Discussion

In this study, project locations were selected in proximity to 11 weather stations. As per the design trial matrix, both AADTT and AC thickness were varied for each of these locations, and the resulting pavement distresses were predicted. The predicted distresses are summarized in Table A1 and Table A2 (Appendix) for different combinations of AADTT and AC layer thickness predicted at 90% and 50% reliability. A detailed analysis and discussion are presented in the following sections, supported by graphical trends of the predicted distresses.

Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted IRI

Figure 1a illustrates the variation in predicted IRI with respect to changes of AADTT, while Figure 1b presents the variation of IRI with respect to changes in AC layer thickness. The results indicate that IRI increases with increased AADTT, except for Winnipeg. The atypical trend for the Winnipeg location, where IRI initially increases with increased AADTT and subsequently decreases at higher traffic levels could be due to inconsistency in predicted other distresses among climatic exposures. As a composite performance indicator reflecting the cumulative effect of multiple distress types, IRI generally follows trends similar to those observed for traffic loads. Figure 1b shows that IRI generally decreases with increasing AC layer thickness, indicating improved ride quality with greater structural capacity. However, the rate of reduction is relatively small compared to the influence of AADTT. In addition, IRI is shown to increase with increased AC thickness for few stations, e.g., there an increase of IRI for increase in AC thickness from 110 mm to 140 mm at Fredericton and Rouyn.

Figure 1a. Effect of AADTT on predicted IRI

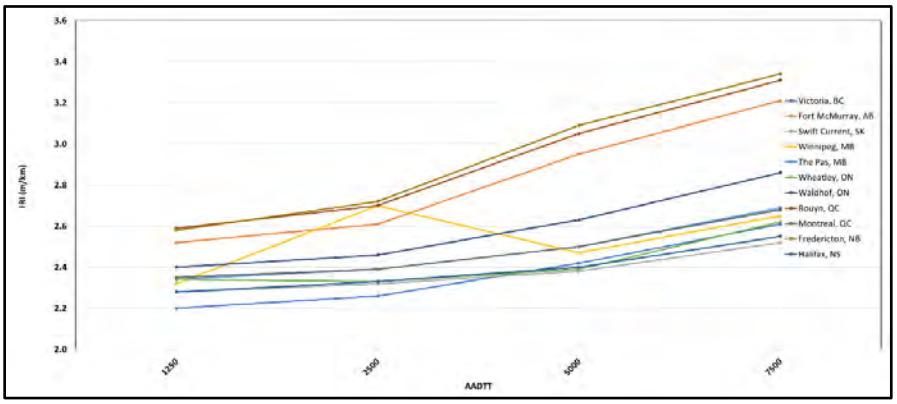
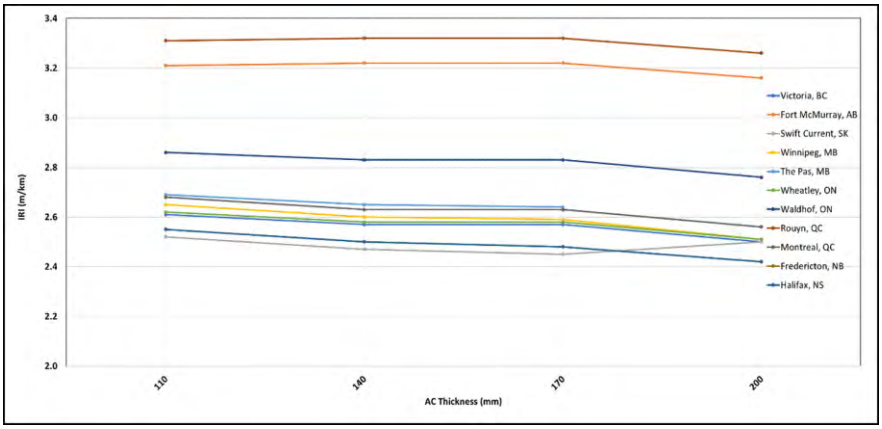


Figure 1b. Effect AC thickness on predicted IRI



Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted Total Rutting

Figure 2a illustrates the variation in total rut depth with respect to the variation of AADTT, while Figure 2b presents the variation rutting with respect to the variation of AC layer thickness. The results indicate that increasing AADTT leads to an increase in total rutting, while, as shown in Figure 2b, increasing AC layer thickness results in a reduction in rut depth. These trends are consistent across all provinces and climatic conditions considered in this study.

The results also suggest an interaction between traffic loads, and structural capacity, where the benefit of increased AC layer thickness becomes more pronounced at higher AADTT levels. Overall, the total rutting performance diminishes progressively with increasing traffic loads, while thicker AC layers improve rutting performance. However, the magnitude of improvement varies across locations, reflecting the influence of regional climatic conditions.

Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted AC Layer Rutting

Figures 3a and 3b present the trends in AC layer rutting with respect to changes in traffic loads and layer thickness, respectively. The trends in AC layer rutting due to changes in AADTT and AC layer thickness are consistent with those observed for the total rutting. AC rutting increases with increasing AADTT, reflecting the cumulative effect of traffic loads. In contrast, increasing AC layer thickness leads to a reduction in AC

rutting, indicating improved structural resistance to permanent deformation. This trend is consistent across all provinces and climatic conditions considered in this study.

Figure 2a. Effect of AADTT on predicted total rutting

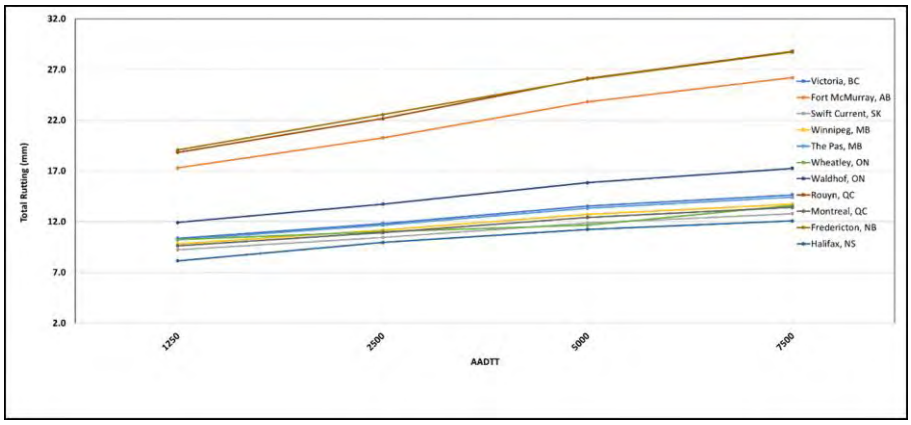


Figure 2b. Effect of AC thickness on predicted total rutting

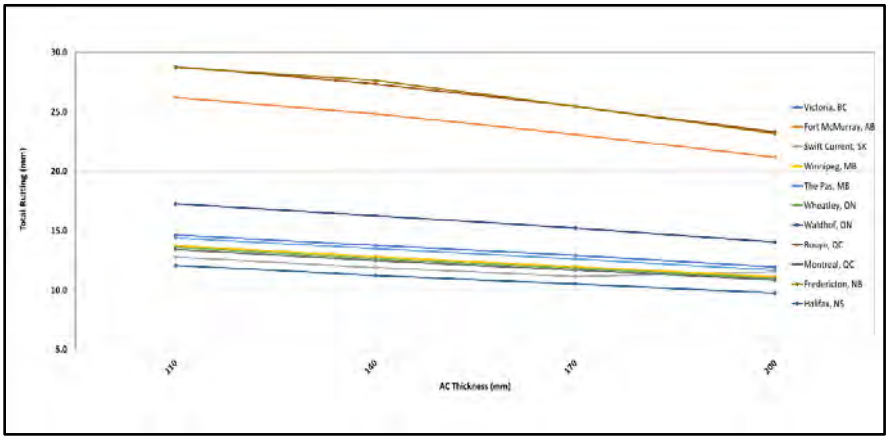


Figure 3a. Effect of AADTT on predicted AC layer rutting

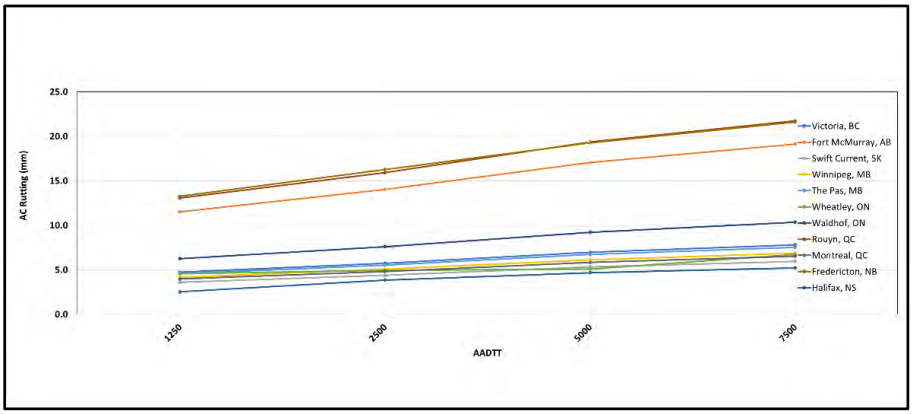
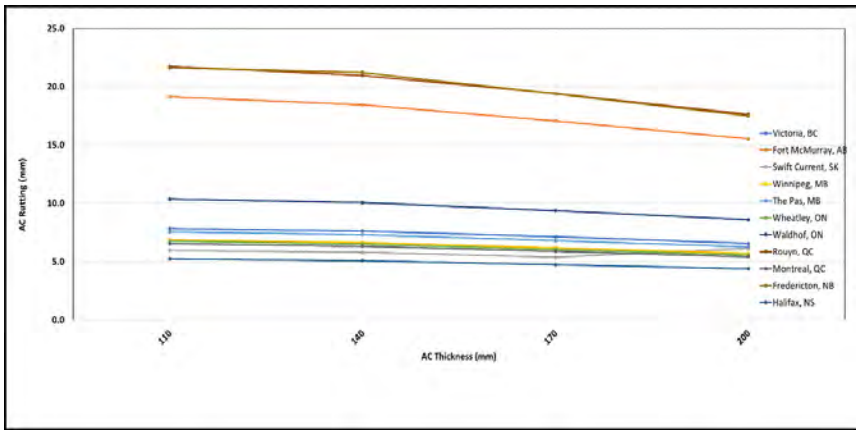


Figure 3b. Effect AC thickness on predicted AC layer rutting



Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted BUFC

Figures 4a and 4b present the changes of BUFC due to variations in traffic loads and AC layer thickness, respectively. The results, as shown in Figure 4a, indicate that BUFC is influenced by both input parameters; however, it is considerably more sensitive to traffic loads (AADTT) than to AC layer thickness. A significant increase in BUFC is observed with increasing AADTT, emphasizing the dominant role of repeated traffic loads on fatigue damage accumulation. This effect is most pronounced in Fredericton , Rouyn , and Fort McMurray , where the highest BUFC levels are predicted under higher traffic conditions.

With respect to AC layer thickness variation, as shown in Figure 4b, contrasting trends are observed across regions. In Fredericton, Rouyn, and Fort McMurray, BUFC increases with increasing thickness. In contrast, for most other locations, BUFC initially decreases with increasing AC thickness, reflecting improved structural capacity. However, beyond a certain thickness threshold, BUFC begins to increase, indicating a non-linear response. This unexpected behaviour warrants further investigation.

Figure 4a. Effect of AADTT on predicted BUFC

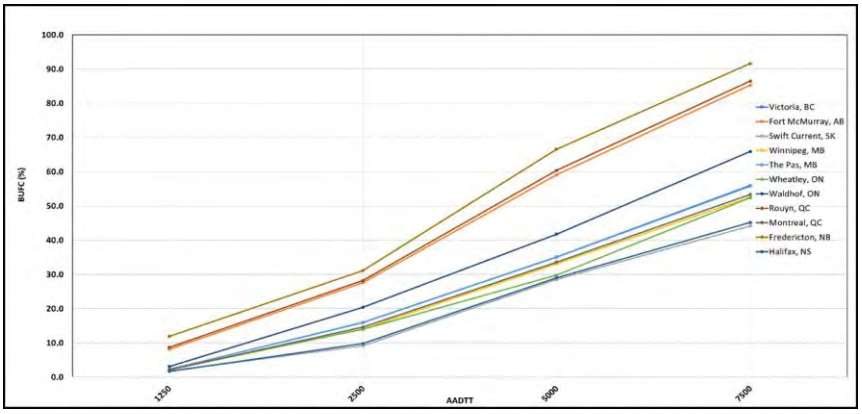
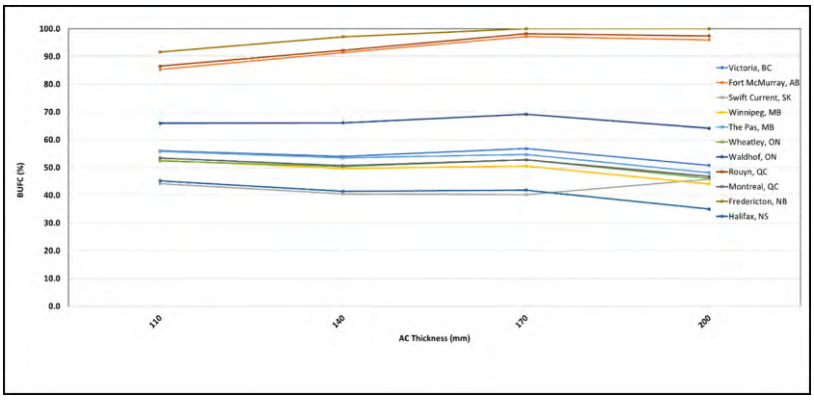


Figure 4b. Effect of AC thickness on predicted BUFC



Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted TDFC

Figures 5a and 5b illustrate the trends of TDFC with respect to varying AADTT levels and AC layer thicknesses, respectively.

Figure 5a. Effect of AADTT on predicted TDFC

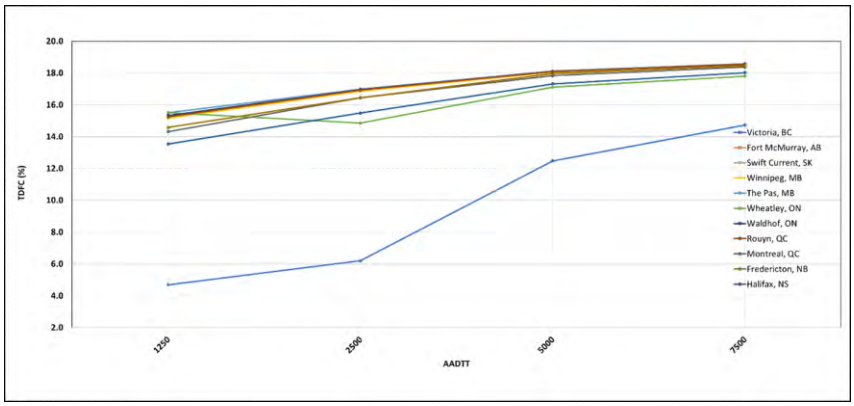


Figure 5b. Effect AC thickness on predicted TDFC

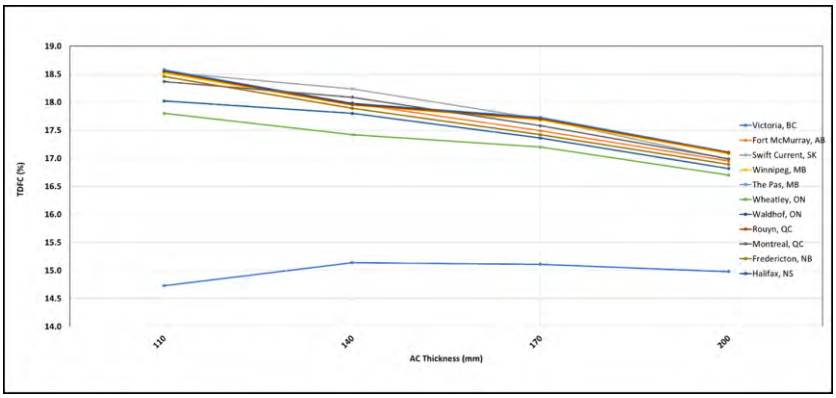


Figure 5a shows that TDFC generally increases with increasing AADTT, indicating a strong influence of traffic loads on crack initiation and propagation. This trend is consistently observed across most provinces, with the exception of Wheatley, ON, where a deviation from the general pattern is noted. Figure 5b indicates that TDFC decreases with increasing AC layer thickness, demonstrating the beneficial effect of increased structural capacity in mitigating top-down fatigue cracking. However, in Halifax, the predicted TDFC values remain comparatively lower, with increase of TDFC for increase in AC layer thickness from 110 mm to 140 mm, than those observed in other provinces.

Impacts of Varying Truck Traffic (AADTT) and AC Thickness on Predicted Thermal Cracking

Figures 6a and 6b present the variation in thermal cracking with respect to the variation of AADTT and AC layer thickness, respectively. The results, as shown in Figure 6a, indicate that thermal cracking is largely insensitive to changes in traffic loads, with AADTT having a negligible influence on the predicted response. In contrast, as shown in Figure 6b, increasing AC layer thickness generally leads to a slight improvement in thermal cracking performance, even under higher traffic conditions, indicating that thermal cracking is primarily governed by climatic and material-related factors rather than traffic loads. However, with increasing AC thickness, improved thermal cracking performance is observed in Manitoba , Waldhof (ON), and Montreal , while no significant improvement is observed in several other provinces. Notably, Saskatchewan exhibits an opposite trend, where thermal cracking increases with greater AC layer thickness. This anomalous behaviour warrants further investigation.

Figure 6a. Effect of AADTT on predicted thermal cracking

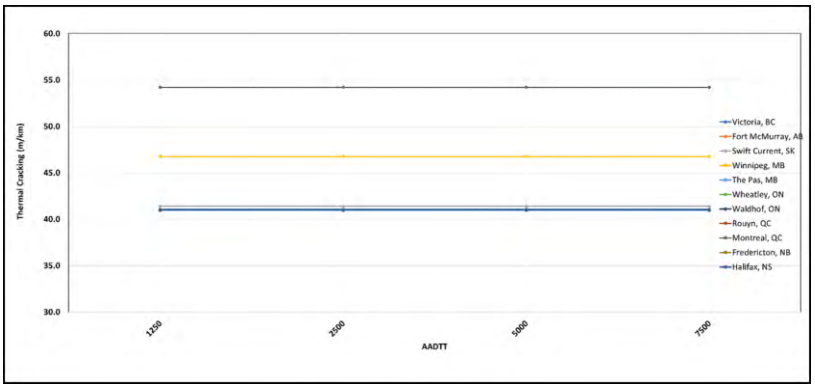
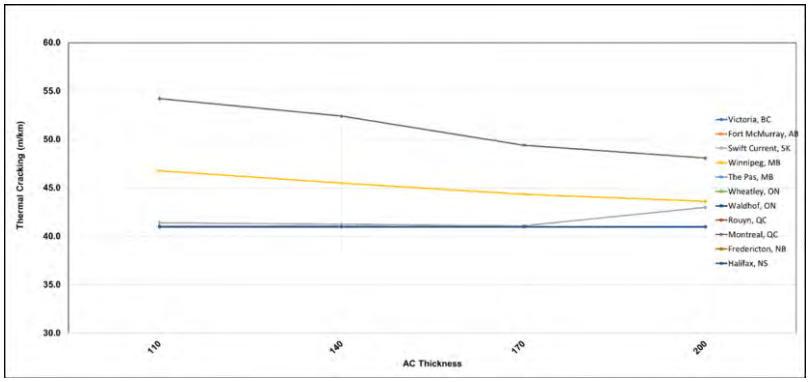


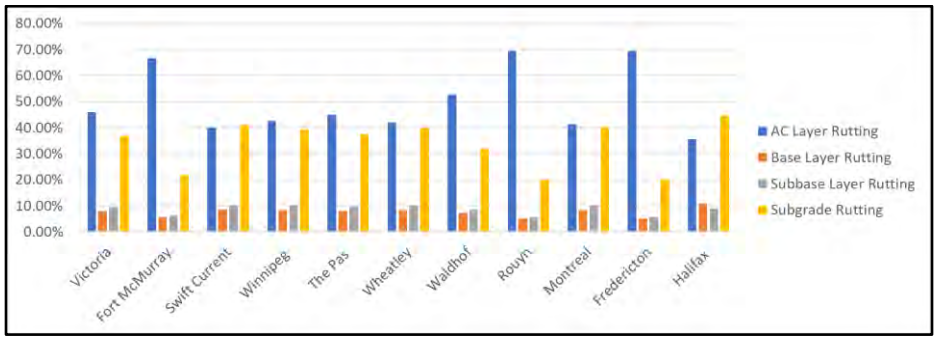
Figure 6b. Effect of AC thickness on predicted thermal cracking



Distribution of Predicted Rutting among Pavement layers

To further examine the relative contribution of individual pavement layers to total rutting, the distribution of predicted rutting at 50% reliability level was used. The results indicate that the majority of rutting originates from the AC layer, contributing approximately 50% of the total rutting on average. This is followed by the subgrade, which accounts for about 33% of total rutting. The base and subbase layers had significantly less impact, with average contributions of approximately 7.5% and 8.5%, respectively. These findings highlight the dominant role of the AC layer and subgrade in overall rutting performance. Figure 7 presents the distribution of rutting among different layers.

Figure 7. Distribution of rutting among different layers



Sensitivity Analysis of Predicted Distresses

In the preceding sections, the predicted pavement distresses were evaluated with respect to variations in AADTT and AC layer thickness. Given that the distress types differ in units and physical interpretation, direct comparison of their absolute changes is not appropriate. Accordingly, the percentage change in each distress corresponding to percentage changes in AADTT and AC layer thickness was used to assess and rank their relative sensitivities. In this study, sensitivity refers to the magnitude of change in each predicted distress resulting from a controlled change in either AADTT or AC layer thickness from the reference design, which is Trial #1. The observed sensitivity represents the change in overall outcome from the PMED software's mechanistic-empirical response and distress prediction framework for each change in the selected inputs, rather than the effect of any particular model in the PMED software.

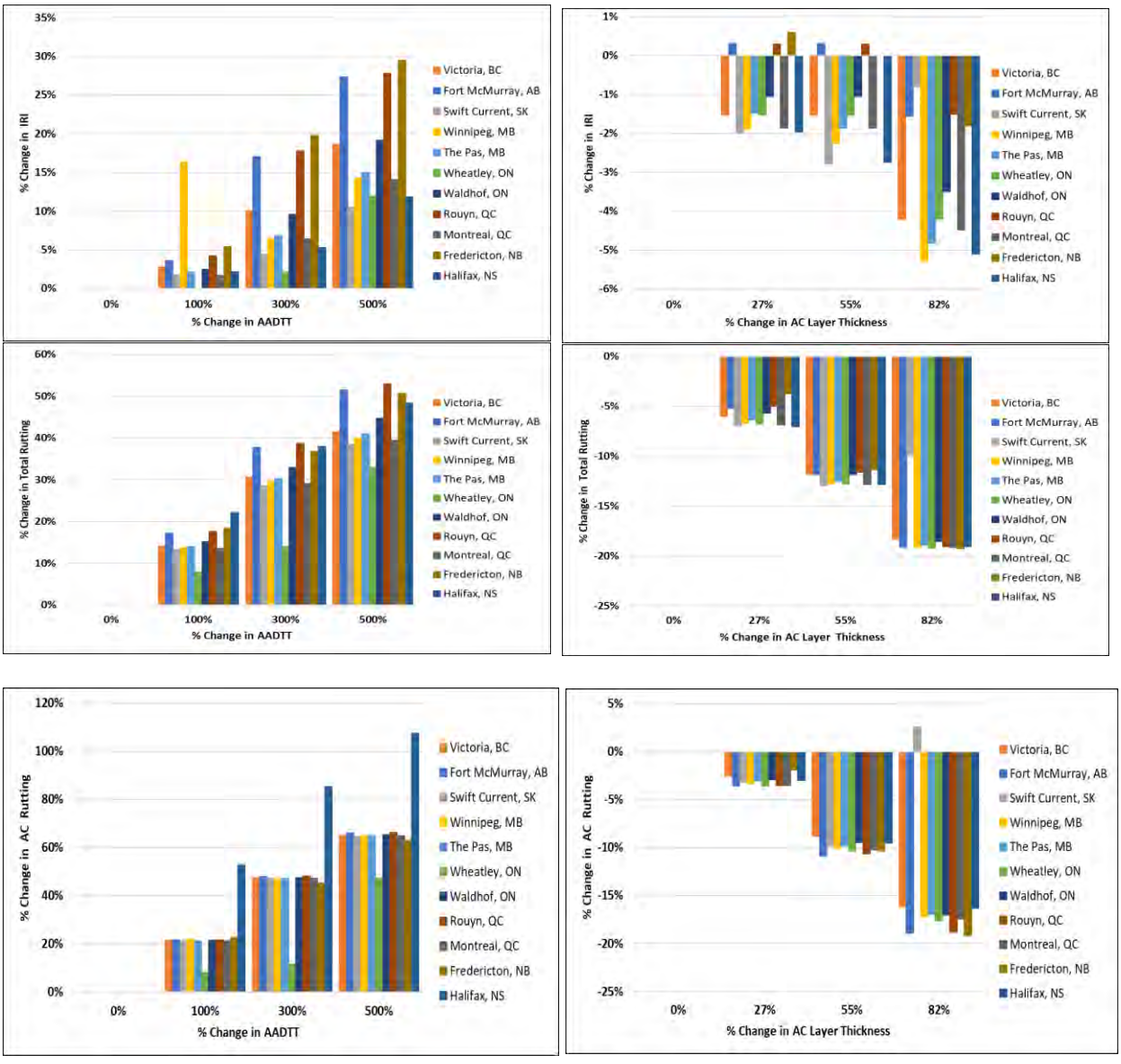
Since only AADTT and AC layer thickness were varied independently while all other input parameters were held constant, the analysis captures only the effects of these two variables. Interaction effects among input variables were not considered. Figure 8 illustrates the percentage change in predicted distresses resulting from variations in AADTT and AC layer thickness. For IRI, the smallest response to AADTT variation is observed in BC, whereas the largest response occurs in Fredericton. With respect to AC layer thickness, BC exhibits the least improvement, while Fredericton shows the greatest improvement. Overall, the highest percentage change in IRI is observed in Halifax.

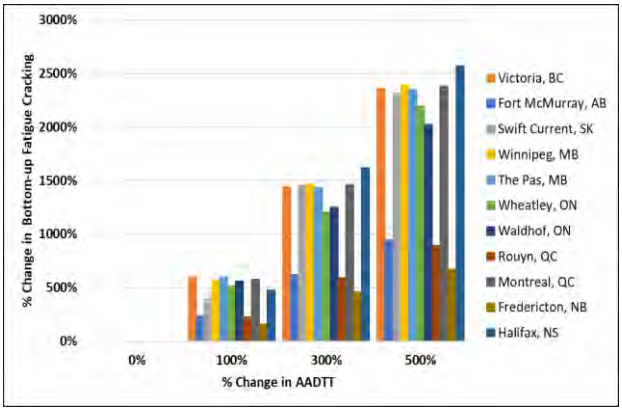
For total rutting, Rouyn exhibits the highest increase due to AADTT increase, while BC shows the lowest response. In terms of AC layer thickness, Rouyn, Fredericton, and Fort McMurray demonstrate the greatest variation in rutting response. For AC layer rutting, Rouyn, Fredericton , and Fort McMurray show

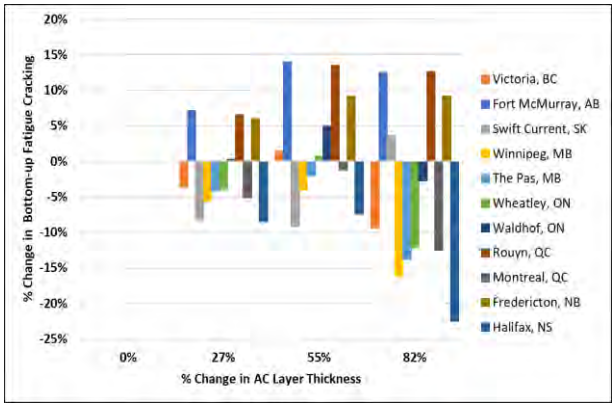
the highest increases with increasing AADTT. These same locations also exhibit the most pronounced reductions in AC layer rutting with increasing AC layer thickness.

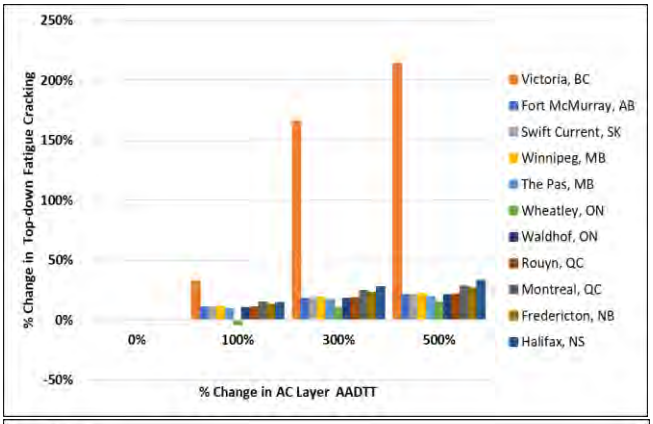
For BUFC, Fredericton, Rouyn, and Fort McMurray exhibit the highest increases in response to AADTT increase. Halifax shows the largest overall percentage change. With respect to AC layer thickness, Halifax demonstrates the greatest reduction in BUFC, whereas Fredericton shows an opposite trend, with BUFC increasing as AC layer thickness increases.

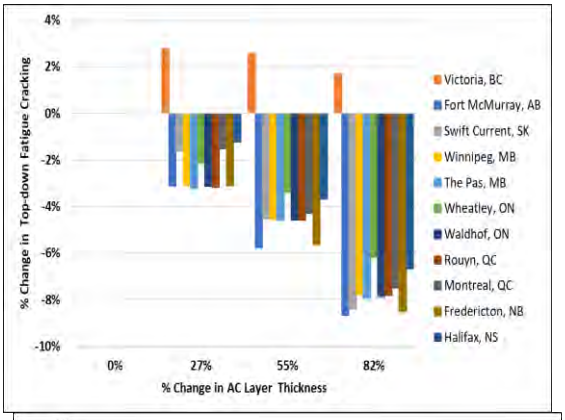
Figure 8. % Change in output distresses due to change in AADTT and AC thickness

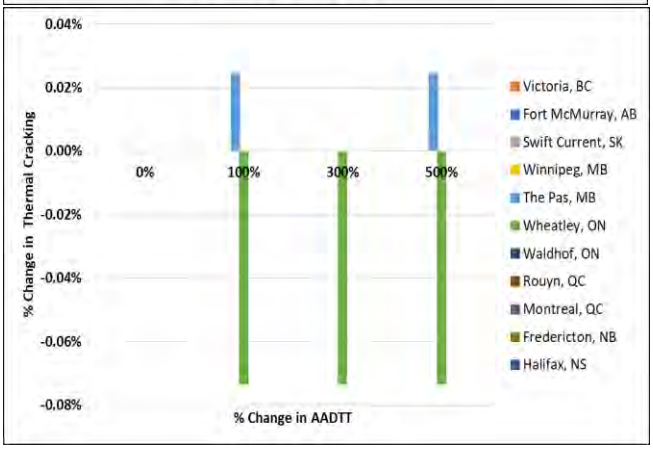


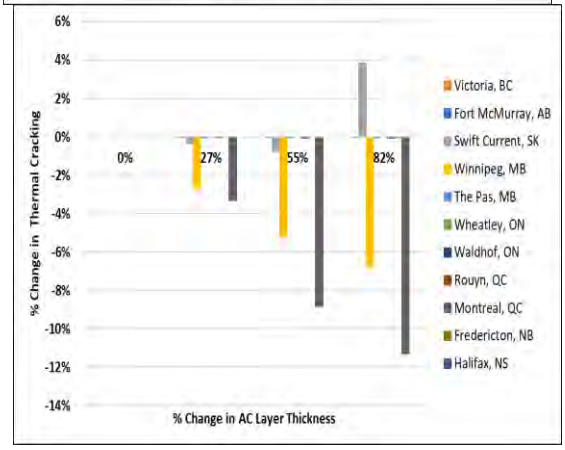












For TDFC, the highest absolute values associated with increased AADTT are observed in The Pas. BC exhibits the highest percentage change in response to AADTT, while other locations show relatively consistent behaviour. In contrast, Fort McMurray and Fredericton display the most significant sensitivity of TDFC to changes in AC layer thickness. BC also exhibits a non-monotonic trend, where TDFC initially increases and then decreases with increasing AC thickness.

For thermal cracking, variations in AADTT have a negligible effect, with distress levels remaining nearly unchanged across all locations. However, Montreal and Winnipeg exhibit the highest sensitivity to AC layer thickness. Conversely, Swift Current shows an increase in thermal cracking with increasing AC thickness, which warrants further investigation.

After analyzing the percentage changes in distresses across provinces, the ranges of these variations due to changes in AADTT and AC layer thickness were summarized. The ranges associated with AADTT are presented in Table 3, while Table 4 lists the ranges of distress changes resulting from variations in AC layer thickness. Based on these ranges, the relative sensitivities of the output distresses were ranked, with Rank 1 indicating the highest sensitivity and Rank 6 the lowest, as shown in Table 5.

The results indicate that, with respect to AADTT, bottom-up fatigue cracking is the most sensitive distress, followed by top-down fatigue cracking, AC rutting, and IRI, while thermal cracking exhibits the lowest sensitivity. In contrast, with respect to AC layer thickness, total rutting is the most sensitive distress, followed by AC rutting and bottom-up fatigue cracking, whereas thermal cracking shows negligible sensitivity.

Table 3. Summary of percent change ranges in distresses due to change in AADTT

AADTT	AADTT Changed by %	Change in Predicted Output Distress Across 11 Project Locations											
		IRI		Total Rutting		AC Rutting		Bottom-Up Fatigue Cracking (BUFC)		Top Down Fatigue Cracking (TDFC)		Thermal Cracking	
		IRI (m/km)	% Change	Total Rutting (mm)	% Change	AC Rutting (mm)	% Change	BUFC (%)	% Change	TDFC (%)	% Change	Thermal Cracking (m/km)	% Change
1250	0%	2.20 to 2.59	0%	8.14 to 19.06	0%	2.52 to 13.27	0%	1.69 to 11.92	0%	4.69 to 15.51		40.97 to 54.20	0%
2500	100%	2.26 to 2.72	1.7% to 16.38%	9.94 to 22.55	7.83 to 22.01%	3.85 to 16.27	8.10% to 52.78%	9.15 to 31.15	161.33 % to 600.44%	6.2 to 16.98	0% to 32.2%	40.97 to 54.20	0%
5000	300%	2.38 to 3.09	2.14% to 19.77%	11.23 to 26.12	13.99 to 38.71%	4.67 to 19.28	11.60% to 85.33%	28.52 to 66.61	458.81% to 1617.64%	12.47 to 18.12	10.32% to 165.88%	40.97 to 54.20	0%
7500	500%	2.52 to 3.31	10.53% to 29.46%	12.07 to 28.79	32.88 to 52.89%	5.23 to 21.73	47.48% to 107.45%	44.19 to 91.61	668.54% to 2571.36%	14.73 to 18.56	14.76% to 214.07%	40.97 to 54.20	0%

Table 4. Summary of percent change ranges in distresses due to change in AC layer thickness

AC Thickness		Change in Output Distress Across 11 Project Locations											
		IRI		Total Rutting		AC Rutting		Bottom-Up Fatigue Cracking		Top Down Fatigue Cracking		Thermal Cracking	
(SP19.0) (mm)	Changed by %	Predicted Value (m/km)	% Change	Predicted Value (mm)	% Change	Predicted Value (mm)	% Change	Predicted Value (%)	% Change	Predicted Value (%)	% Change	Predicted Value	% Change
110	0%	2.52 to 3.34	-1.96 % to 0.6%	12.07 to 28.79	0%	5.23 to 21.73	0%	44.19 to 91.61	0%	14.73 to 18.56	0%	40.97 to 54.20	0%
140	27%	2.47 to 3.36	-2.78 % to 0.31 %	11.22 to 27.64	-7.05 % to -3.73 %	5.08 to 21.21	- 3.61 % to - 1.91 %	40.55 to 97.11	-8.46 % to 7.15 %	15.14 to 18.24	- 3.23 % to 2.78 %	40.97 to 52.40	-3.32 % to 0%
170	55%	2.45 to 3.34	-1.96 % to 0.6%	10.52 to 25.46	-12.91 % to 11.32 %	4.74 to 19.41	-8.83 % to 10.87 %	40.17 to 100	-9.10 % to 13.95 %	15.11 to 17.71	-5.77 % to 2.58 %	40.97 to 49.41	-5.16 % to 0%

200	82%	2.42 to 3.28	-5.28 % to -0.79 %	9.771 to 23.30	-19.30 % to -9.86 %	4.38 to 17.64	-19.15 % to 2.52 %	35.02 to 100	-22.50 % to 12.52 %	14.98 to 17.10	-8.67 % to 1.70 %	40.97 to 48.07	-11.31 % to 0%

Table 5. Ranking of sensitive distresses as per change in predicted distresses

Variables	**Ranking of Sensitive Distresses as per Change in Output Distresses**
AADTT	1. Bottom-up Fatigue Cracking, 2. Top Down Fatigue Cracking, 3. AC Rutting , 4. Total Rutting, 5. IRI, 6. Thermal Cracking
AC Layer Thickness	1. Total Rutting, 2. AC Rutting, 3. Bottom-Up Fatigue Cracking, 4. Top-Down Fatigue Cracking, 5. IRI, 6. Thermal Cracking
Note: Rank 1 indicates the highest sensitivity, while Rank 6 indicates the lowest sensitivity.	

To further evaluate the statistical significance of the observed relationships, linear regression analyses were conducted for all distress types, with AADTT and AC layer thickness considered as independent variables. The ANOVA results for the developed distress sensitivity models are presented in Table A3 (Appendix). The findings indicate that all models are statistically significant, except those corresponding to AC rutting and thermal cracking. This suggests that additional explanatory variables may be required to adequately capture the behaviour of these two distress types.

The significance of individual regression coefficients was evaluated using t-tests. The estimated regression coefficients for AADTT and AC layer thickness are summarized in Table A4 (Appendix). The results show that AADTT is a statistically significant predictor for all distress types except thermal cracking. In contrast, AC layer thickness is statistically significant only for top-down fatigue cracking, while its effect is not significant for the remaining distress models at the 5% level. These findings indicate that additional variables may be necessary to better capture the influence of AC layer thickness.

Given that the AC rutting and thermal cracking models were initially not statistically significant, and that AC layer thickness showed limited significance in other models, the regression analysis was extended to include climate variables. Specifically, minimum air temperature, maximum air temperature, precipitation, and the number of freeze–thaw cycles were incorporated alongside AADTT and AC layer thickness.

With the inclusion of climate variables, all models became statistically significant, including the thermal cracking model, as shown in Table A5 (Appendix). The improved performance of the thermal cracking

model is consistent with expected pavement behaviour, as thermal distress is strongly influenced by environmental conditions.

The significance of individual predictors in the extended models was further evaluated using t-statistics) which is shown in Table 6. For the IRI model, AADTT, maximum air temperature, minimum air temperature, and freeze–thaw cycles were significant. For total rutting, AC layer thickness, maximum air temperature, and minimum air temperature were significant. In the AC rutting model, AADTT, maximum air temperature, and minimum air temperature were identified as significant predictors. Similarly, for BUFC, AADTT, maximum air temperature, and minimum air temperature were significant. For TDFC, AADTT, AC layer thickness, minimum air temperature, and freeze–thaw cycles were significant. Finally, for thermal cracking, maximum air temperature and precipitation were found to be significant variables, although further investigation is recommended to better understand their effects because the effects of some climatic variables do not follow logical trends e.g., significantly increasing effect of colder temperature on rutting or vice versa and significantly increasing effect of warmer temperature on thermal cracking, as shown in Table 6.

Table 6. Distress prediction models from AADT, AC thickness and climatic variables

Input Variables	**Coefficient Value**	**t_{obs}**	**Significance for $t_{critical}$ (0.025, 70) = 1.99**	**Coefficient Value**	**t_{obs}**	**Significance for $t_{critical}$ (0.025, 70) = 1.99**
	IRI Prediction			**Total Rutting Prediction**		
AADTT	0.000	5.746	Yes	0.001	3.390	Yes
AC Layer Thickness	-0.001	-0.911	No	-0.039	-2.130	Yes
Min Air Temp	-0.023	-7.088	Yes	-0.447	-6.577	Yes
Max Air Temp	-0.047	-3.522	Yes	-1.106	-3.987	Yes
Precipitation	0.000	1.197	No	0.001	0.629	No
Freeze-Thaw Cycles	0.000	0.042	Yes	0.000	0.017	No
	AC Layer Rutting Prediction			**BUFC Prediction**		
AADTT	0.001	2.749	Yes	0.009	11.429	Yes
AC Layer Thickness	-0.023	-1.256	No	-0.012	-0.205	No
Min Air Temp	-0.439	-6.584	Yes	-1.304	-5.923	Yes
Max Air Temp	-1.091	-4.005	Yes	-2.787	-3.101	Yes
Precipitation	0.001	0.612	No	0.006	0.783	No
Freeze-Thaw Cycles	0.000	0.008	No	-0.067	-0.823	No
	TDFC Prediction			**TC Prediction**		
AADTT	0.001	8.175	Yes	0.000	-0.076	No
AC Layer Thickness	-0.018	-3.187	Yes	-0.008	-1.169	No
Min Air Temp	-0.074	-3.595	Yes	0.022	0.835	No
Max Air Temp	-0.104	-1.237	No	1.553	14.269	Yes
Precipitation	0.000	-0.373	No	0.012	13.859	Yes
Freeze-Thaw Cycles	0.039	5.209	Yes	0.004	0.369	No

Summary and Conclusions

This study evaluated the effects of traffic loading (AADTT) and asphalt concrete (AC) layer thickness on PMED-predicted distresses in new flexible pavements across diverse Canadian climatic conditions. The results indicate that traffic loading is the primary driver of pavement deterioration, with consistent increases observed in rutting, fatigue cracking (BUFC and TDFC), and IRI as AADTT increases. Rutting responses showed strong sensitivity to traffic, while fatigue cracking exhibited the highest overall sensitivity among all distress types. In contrast, thermal cracking was largely insensitive to traffic loading and governed primarily by environmental factors. Increasing AC layer thickness generally improved pavement performance by reducing rutting and, to a lesser extent, fatigue cracking, although non-monotonic trends in BUFC were observed in some regions. Sensitivity analysis confirmed that fatigue cracking is most responsive to traffic, while rutting is most influenced by AC thickness. Regression analysis further showed that AADTT is a statistically significant predictor for most distress types, whereas AC thickness has limited statistical significance unless combined with climate variables. The inclusion of climatic factors significantly improved model performance, particularly for thermal cracking, highlighting the importance of environmental inputs. Despite generally consistent trends, some anomalies—such as higher rutting in colder regions and inconsistent fatigue and thermal cracking responses—suggest limitations in PMED predictions under certain Canadian conditions.

Traffic loading (AADTT) is the dominant factor influencing pavement deterioration, particularly for fatigue-related distresses.

- Total rutting and AC layer rutting increase consistently with traffic and decrease with increasing AC layer thickness.
- Fatigue cracking (BUFC and TDFC) is highly sensitive to traffic; however, BUFC shows non-monotonic behavior with increasing AC thickness in some regions.
- Thermal cracking is largely insensitive to traffic loading and is primarily controlled by climatic conditions.
- Increasing AC layer thickness improves rutting performance and generally reduces TDFC, but its influence on other distresses is limited.
- IRI is moderately affected by both traffic and thickness, reflecting its dependence on multiple distress mechanisms.
- Rutting distribution analysis indicates that the AC layer and subgrade contribute most to total rutting.
- Inclusion of climate variables significantly improves model predictions, particularly for thermal cracking.
- Observed inconsistencies in distress trends highlight the need for further calibration and refinement of PMED models for Canadian conditions.

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APPENDIX

Table A1. Summary of predicted distresses for varying AADTT and AC layer thickness: BC, AB, SK, MB-Winnipeg, MB-The Pas and ON-Wheatly

Project Location	Traffic	AC Layer	Predicted Distresses							
	AADTT (2-Way)	SP19.0 Thickness (mm)	Terminal IRI (m/km)	Total Rutting (mm)	Bottom-up Fatigue Cracking (%)	Thermal Cracking (m/km)	Top-down Fatigue Cracking (%)	AC Layer Rutting (mm)	AC Layer Rutting (mm)	Total Rutting (mm)
			90% Reliability						50% Reliability	
Victoria, BC	1250	110.0	2.20	10.35	2.28	40.97	4.69	4.73	3.21	8.09
	2500	110.0	2.26	11.81	15.97	40.97	6.20	5.74	3.96	9.31
	5000	110.0	2.42	13.52	35.14	40.97	12.47	6.97	4.87	10.72
	7500	110.0	2.61	14.64	56.00	40.97	14.73	7.81	5.49	11.65
	7500	140.0	2.57	13.76	53.97	40.97	15.14	7.61	5.34	10.88
	7500	170.0	2.57	12.91	56.80	40.97	15.11	7.12	4.98	10.16
	7500	200.0	2.50	11.96	50.75	40.97	14.98	6.55	4.55	9.35
Fort McMurray, AB	1250	110.0	2.52	17.29	8.18	40.98	15.33	11.53	8.31	13.63
	2500	110.0	2.61	20.26	27.61	40.98	16.98	14.02	10.23	16.05
	5000	110.0	2.95	23.81	59.10	40.98	18.12	17.06	12.59	18.94
	7500	110.0	3.21	26.19	85.31	40.98	18.56	19.14	14.21	20.88
	7500	140.0	3.22	24.83	91.41	40.97	17.98	18.45	13.67	19.70
	7500	170.0	3.22	23.09	97.21	40.97	17.49	17.06	12.58	18.26
	7500	200.0	3.16	21.17	95.99	40.97	16.95	15.52	11.39	16.68
Swift Current, SK	1250	110.0	2.28	9.23	1.83	41.38	15.22	3.62	2.41	7.18
	2500	110.0	2.32	10.45	9.15	41.38	16.89	4.39	2.96	8.21
	5000	110.0	2.38	11.86	28.52	41.38	18.07	5.33	3.65	9.38
	7500	110.0	2.52	12.78	44.19	41.38	18.54	5.96	4.12	10.15
	7500	140.0	2.47	11.89	40.55	41.23	18.24	5.77	3.97	9.38
	7500	170.0	2.45	11.13	40.17	41.08	17.70	5.37	3.68	8.72
	7500	200.0	2.50	11.52	45.78	42.97	16.98	6.11	4.23	9.00
Winnipeg, MB	1250	110.0	2.32	9.81	2.11	46.75	15.16	4.17	2.80	7.66
	2500	110.0	2.70	11.15	14.09	46.75	16.86	5.08	3.45	8.78
	5000	110.0	2.47	12.71	33.10	46.75	18.05	6.13	4.24	10.07
	7500	110.0	2.65	13.73	52.60	46.75	18.52	6.87	4.79	10.92
	7500	140.0	2.60	12.81	49.65	45.49	17.95	6.64	4.62	10.12
	7500	170.0	2.59	11.98	50.52	44.34	17.68	6.18	4.28	9.41
	7500	200.0	2.51	11.10	44.06	43.60	17.08	5.69	3.91	8.67
The Pas, MB	1250	110.0	2.34	10.22	2.28	41.00	15.51	4.57	3.09	8.00
	2500	110.0	2.39	11.65	15.88	41.01	16.99	5.54	3.81	9.19

Project Location	Traffic	AC Layer	Predicted Distresses							
	AADTT (2-Way)	SP19.0 Thickness (mm)	Terminal IRI (m/km)	Total Rutting (mm)	Bottom-up Fatigue Cracking (%)	Thermal Cracking (m/km)	Top-down Fatigue Cracking (%)	AC Layer Rutting (mm)	AC Layer Rutting (mm)	Total Rutting (mm)
			90% Reliability						50% Reliability	
	5000	110.0	2.50	13.32	35.03	41.00	18.12	6.73	4.68	10.57
	7500	110.0	2.69	14.41	55.80	41.01	18.58	7.54	5.29	11.48
	7500	140.0	2.65	13.49	53.47	40.99	17.98	7.31	5.12	10.67
	7500	170.0	2.64	12.61	54.67	40.98	17.73	6.80	4.74	9.92
	7500	200.0	2.56	11.68	48.13	40.98	17.11	6.26	4.33	9.13
Wheatley, ON	1250	110.0	2.34	10.22	2.28	41.00	15.51	4.57	3.09	7.99
	2500	110.0	2.33	11.02	13.98	40.97	14.85	4.94	3.37	8.67
	5000	110.0	2.39	11.65	29.80	40.97	17.11	5.10	3.48	9.22
	7500	110.0	2.62	13.58	52.40	40.97	17.80	6.74	4.69	10.80
	7500	140.0	2.58	12.66	50.36	40.97	17.42	6.50	4.51	10.00
	7500	170.0	2.58	11.84	52.75	40.97	17.20	6.04	4.17	9.30
	7500	200.0	2.51	10.97	46.10	40.97	16.70	5.55	3.82	8.57

Table A2. Summary of predicted distresses for varying AADTT and AC layer thickness: ON-Waldhof, QC-Rouyn, QC-Montreal, NB and NS

Project Location	Traffic	AC Layer	Predicted Distresses							
	AADTT (2-Way)	SP19.0 Thickness (mm)	Terminal IRI (m/km)	Total Rutting (mm)	Bottom-up Fatigue Cracking (%)	Thermal Cracking (m/km)	Top-down Fatigue Cracking (%)	AC Layer Rutting (mm)	AC Layer Rutting (mm)	Total Rutting (mm)
			90% Reliability						50% Reliability	
Waldhof, ON	1250	110.0	2.40	11.92	3.10	41.02	15.33	6.26	4.34	9.36
	2500	110.0	2.46	13.72	20.40	41.02	16.95	7.60	5.33	10.84
	5000	110.0	2.63	15.84	41.78	41.02	18.09	9.23	6.56	12.58
	7500	110.0	2.86	17.25	65.91	41.02	18.56	10.35	7.41	13.74
	7500	140.0	2.83	16.27	66.10	41.01	17.98	10.05	7.19	12.88
	7500	170.0	2.83	15.21	69.17	40.99	17.71	9.37	6.66	11.99
	7500	200.0	2.76	14.05	64.11	40.99	17.10	8.59	6.08	11.02
Rouyn, QC	1250	110.0	2.59	18.83	8.71	40.98	15.25	13.08	9.50	14.85
	2500	110.0	2.70	22.15	28.20	40.98	16.93	15.91	11.69	17.55
	5000	110.0	3.05	26.12	60.41	40.98	18.09	19.37	14.38	20.78
	7500	110.0	3.31	28.79	86.51	40.98	18.55	21.73	16.24	22.96
	7500	140.0	3.32	27.35	92.21	40.98	17.96	20.96	15.63	21.71
	7500	170.0	3.32	25.45	98.21	40.98	17.70	19.41	14.41	20.14
	7500	200.0	3.26	23.30	97.40	40.97	17.10	17.64	13.04	18.37

Project Location	Traffic	AC Layer	Predicted Distresses							
	AADTT (2-Way)	SP19.0 Thickness (mm)	Terminal IRI (m/km)	Total Rutting (mm)	Bottom-up Fatigue Cracking (%)	Thermal Cracking (m/km)	Top-down Fatigue Cracking (%)	AC Layer Rutting (mm)	AC Layer Rutting (mm)	Total Rutting (mm)
			90% Reliability						50% Reliability	
Montreal, QC	1250	110.0	2.35	9.62	2.15	54.20	14.32	3.97	2.66	7.51
	2500	110.0	2.39	10.92	14.60	54.20	16.44	4.81	3.27	8.60
	5000	110.0	2.50	12.42	33.61	54.20	17.83	5.84	4.02	9.85
	7500	110.0	2.68	13.41	53.40	54.20	18.37	6.54	4.54	10.67
	7500	140.0	2.63	12.49	50.66	52.40	18.09	6.31	4.37	9.86
	7500	170.0	2.63	11.69	52.75	49.41	17.58	5.87	4.04	9.18
	7500	200.0	2.56	10.84	46.75	48.07	16.99	5.40	3.70	8.46
Fredericton, NB	1250	110.0	2.58	19.06	11.92	40.97	14.58	13.27	9.65	15.03
	2500	110.0	2.72	22.55	31.15	40.97	16.45	16.27	11.97	17.87
	5000	110.0	3.09	26.06	66.61	40.97	17.96	19.28	14.32	20.74
	7500	110.0	3.34	28.71	91.61	40.97	18.46	21.62	16.15	22.90
	7500	140.0	3.36	27.64	97.11	40.97	17.89	21.21	15.83	21.94
	7500	170.0	3.34	25.46	100.00	40.97	17.42	19.38	14.39	20.16
	7500	200.0	3.28	23.17	100.00	40.97	16.89	17.48	12.91	18.28
Halifax, NS	1250	110.0	2.28	8.14	1.69	40.97	13.54	2.52	1.62	6.28
	2500	110.0	2.33	9.94	9.80	40.97	15.48	3.85	2.58	7.79
	5000	110.0	2.40	11.23	29.06	40.97	17.32	4.67	3.17	8.88
	7500	110.0	2.55	12.07	45.19	40.97	18.02	5.23	3.58	9.58
	7500	140.0	2.50	11.22	41.37	40.97	17.80	5.08	3.47	8.84
	7500	170.0	2.48	10.52	41.86	40.97	17.36	4.74	3.22	8.24
	7500	200.0	2.42	9.77	35.02	40.97	16.82	4.38	2.96	7.60

Table A3. ANOVA of distress sensitivity models with AADTT and AC layer thickness variables

Regression Model	df	SS	MS	F	Significance for Fcritical for (0.05, 2, 74) = 3.13 (Yes/No)
IRI					
Regression	2	1.952434	0.976217	12.7493	Yes
Residual	74	5.666197	0.07657		
Total	76	7.618631			
Total Rutting					
Regression	2	220.2375	110.1187	3.581007924	yes
Residual	74	2275.557	30.75076		
Total	76	2495.794			
AC Rutting					

Regression Model	df	SS	MS	F	Significance for Fcritical for (0.05, 2, 74) = 3.13 (Yes/No)
Regression	2	144.0806	72.04028	2.427601633	No
Residual	74	2195.987	29.67549		
Total	76	2340.067			
Bottom-up Fatigue Cracking					
Regression	2	40245.35	20122.68	69.57892139	Yes
Residual	74	21401.28	289.2065		
Total	76	61646.64			
Top-down Fatigue Cracking					
Regression	2	125.039	62.51951	17.36694412	Yes
Residual	74	266.3936	3.599914		
Total	76	391.4326			
Thermal Cracking					
Regression	2	6.835881	3.417941	0.26865345	No
Residual	74	941.4642	12.72249		
Total	76	948.3001			

Table A4. Estimate of AADTT and AC thickness for distress regression models

Distress Sensitivity Regression Model with AADTT and AC layer Thickness	Input Variables					
	AADTT			AC Thickness		
	Coefficient Value	t_{obs}	Significance for t_critical (0.025, 74) = 1.99	Coefficient Value	t_{obs}	Significance for t_critical (0.025, 74) = 1.99
IRI	0.00007	4.41521	Yes	-0.00082	-0.70002	No
Total Rutting	0.00085	2.67473	yes	-0.03940	-1.68028	No
AC Rutting	0.00068	2.16809	yes	-0.02282	-0.99074	No
Bottom-up Fatigue Cracking	0.00929	9.52305	yes	-0.01227	-0.17070	No
Top-down Fatigue Cracking	0.00062	5.69663	yes	-0.01782	-2.22165	Yes
Thermal Cracking	-0.00001	-0.03699	No	-0.00848	-0.56241	No

Table A5. ANOVA of distress sensitivity models with AADTT, AC layer thickness and climate variables

	df	**SS**	**MS**	**F**	**Significance for F critical (0.05, 6, 70) =2.24**
IRI					
Regression	6	4.454	0.742	16.423	Yes
Residual	70	3.164	0.045		
Total					
Total Rutting					
Regression	6	1155.843	192.640	10.064	Yes
Residual	70	1339.951	19.142		
Total					
AC Rutting					
Regression	6	1048.007	174.668	9.463	Yes
Residual	70	1292.060	18.458		
Total					
Bottom-up Fatigue Cracking					
Regression	6	47593.910	7932.318	39.513	Yes
Residual	70	14052.726	200.753		
Total					
Top-down Fatigue Cracking					
Regression	6	268.932	44.822	25.612	
Residual	70	122.501	1.750		
Total	76	391.433			
Thermal Cracking					
Regression	6	742.183	123.697	42.009	Yes
Residual	70	206.117	2.945		
Total	76	948.300			