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TRANSPORT CANADA

Estimation of the Relationships of Road Deterioration to Traffic and Weather in Canada

FINAL REPORT

BPR Reference: **M61-04-07 (60ET)**

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APPENDICES

1. INTRODUCTION

In the Canadian context, climatic factors are a major cause of pavement deterioration. It is well known that temperature, frost and thaw action as well as moisture are factors that can cause certain types of pavement deterioration. These factors can also intensify pavement deterioration caused by heavy vehicles. The proportion of damage that can be attributed to climatic factors relative to those caused by heavy vehicles is however not known.

The Canadian context is unique with a surface of more than 10 million square kilometres but with a population one-tenth that of the United States. In that context, the road system plays a vital role in economic and social environment (TAC, 1997). The total length of Canada road and street system is about 840,000 km: 63 % is earth and gravel and 37 % is paved roads (TAC, 1997). The deterioration of these roads is mainly caused by heavy loads and by climatic factors. Several North-American studies have provided some insight on the relative proportion of damage caused by these two main contributing factors. This proportion is however not well documented for the Canadian context.

As stated in the terms of reference, the main objective of this project is: « **to provide estimates on the nature of the contribution of traffic and climate to wear of pavements ».** The project involves a detailed review of existing information available in the literature. It also involves a review of existing design practices in Canada and of available data to support the assessment of pavement deterioration and validation and calibration of performance models. The project also involves running a limited number of performance simulations in order to assess preliminary estimates of rates of wear to be attributed to traffic and climate.

2. BACKGROUND

2.1 Pavement damage caused by truck and climate

Cold region pavements are subjected to intense solicitation by traffic as well as climatic and environmental factors. In addition to normal wear caused by heavy trucks, the three main factors contributing to pavement deterioration in cold climate are: Thermal contraction and fracture in bound layers, volume change caused by frost heave and bearing capacity loss during spring thaw. These factors are likely to reduce both the functional and the structural levels of service of pavements. They are considered to be important causes of pavement deterioration in cold climates. The effect of seasonal variation on pavement performance is generally considered to be more important in seasonal frost areas where, in the presence of water and frost susceptible soils, pavements are likely to heave during winter and then loose part of their bearing capacity during spring thaw. For many authors [White and Coree, 1990; Berg, 1988; OCDE, 1988 Janoo and Berg, 1990], the latter problem is the prominent seasonal phenomena leading to pavement deterioration. As a matter of fact, White and Coree [1990] have reported that 60% of the failures during the AASHTO road test occurred during spring. By focusing on the bearing capacity loss during spring thaw in their design procedures, many road administrations support this opinion. Depending on the severity of the climatic conditions, this approach is certainly valid especially if the main concern is the structural integrity of the pavement.

Figure 2-1 shows the relationship between spring thaw and fatigue cracking propagation for the highway A-10, in Fleurimont (Quebec). It is clear that most of the fatigue cracking occur during the spring thaw, even if load restrictions are applied during this period.

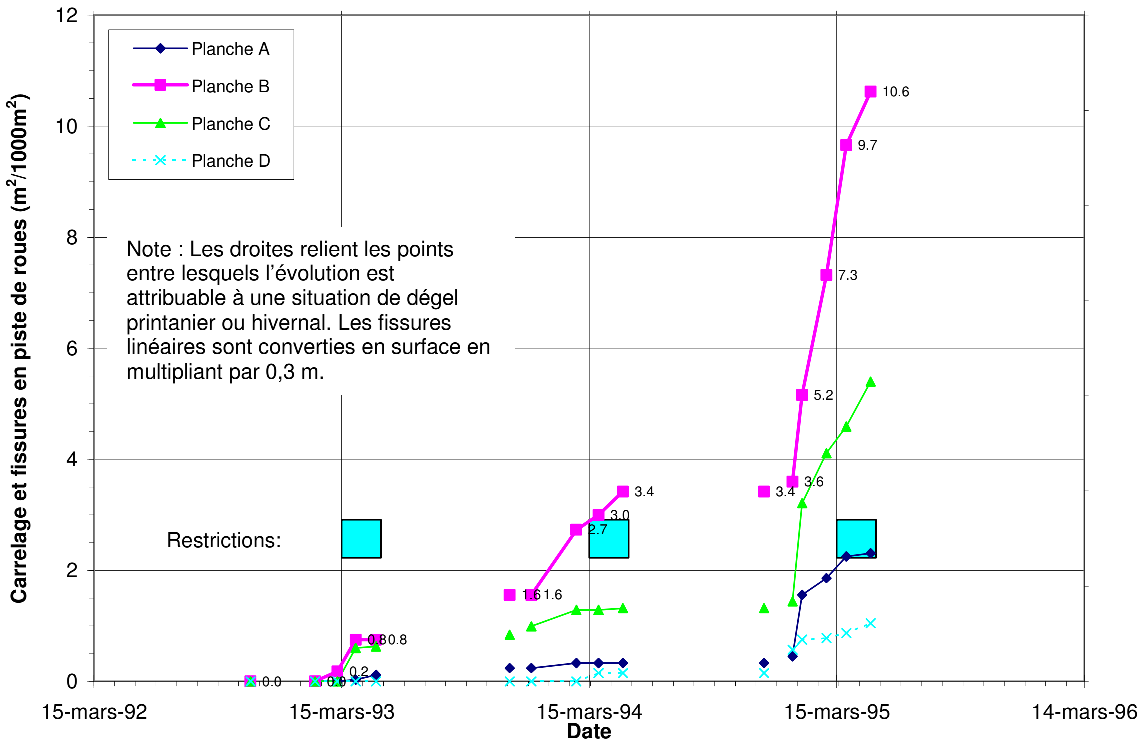

Figure 2-1: Spring thaw and fatigue cracking (A-10, Fleurimont,; source : MTQ)

It is however believed that distresses induced and progressing during winter might also have an important contribution to the overall pavement deterioration of the pavement. Unlike the spring thaw related distresses which are controlled by the combined action of traffic and climate, winter distresses are primarily associated with climatic factors.

Heavy loads cause structural distresses affecting the pavement courses including the subgrade soil. The most typical forms of structural distresses are fatigue cracking in bound courses and permanent deformation of bituminous courses, unbound layers and subgrades (OECD, 1988). Excessive structural distresses usually occur at the end of pavement life, for properly designed pavements, or earlier for pavements where the number of load applications or the level of stress exceeds the assumptions made by the designer.

Climatic factors can also be the cause of specific pavement distresses. Bound materials are sensitive to temperature variations. As temperature drops, asphalt concretes tend to contract. In the absence of joints, the contraction is restrained and tensile stresses build-up in the material. If the stresses exceed the strength of the material, a thermal crack is initiated. Also, during winter, frost penetrates in pavement materials and subgrade soils. While progressing in the pavement structure, frost cause interstitial water to expand and can also cause ice segregation to form in the unbound granular materials.

Notwithstanding the fact that these phenomena are generally considered insignificant in pavement granular materials, they cause the materials to loosen. When the frost front reaches frost susceptible subgrade soils, water is sucked toward the frozen fringe where ice lenses are formed. Heave of the pavement surface resulting from these phenomena can reach and even exceed 150 mm for climatic conditions prevailing in Canada. The problem with frost heave is mainly due to the fact that the phenomenon is rarely uniform. Surface distortions have a significant impact on the service level of roadways. Differential heaving also occurs as a result of snow accumulation on the pavement sides which affect the thermal regime and result in a greater frost penetration at the center of the pavement than at the edge of the pavement. Transverse differential heaving can generate excessive tensile stresses and initiate longitudinal or meandering cracks. Road users are not directly affected by the phenomena but the resulting cracks can be highly detrimental to the structural performance of the pavement because they intercept running surface water.

Finally, climatic factors also amplify traffic action by modifying the mechanical properties of pavement materials across the seasons. During spring, thaw penetrates into the pavement structure and releases the water accumulated in the interstitial and segregation ice. High water contents combined with lower densities are essentially responsible for the weakening of unbound pavement materials and subgrade soils. The strength is then progressively recovered as soils and materials consolidate (drain) over time. St-Laurent and Roy [1995] have established that the relative damage caused by a given load during springtime is between 1,5 and 3 times higher than the average annual damage. Thaw weakening is a complex process, which is essentially a function of three major factors: the amount of water accumulated in the pavement system by frost heave, the rate at which the system is thawing and the rate at which the layer consolidates [Doré, 2004]. Viscoelastic properties of asphalt bound materials also make them susceptible to temperature variations. High summer temperatures can reduce significantly the stiffness of asphalt bound materials making them susceptible to permanent deformation while low winter temperature make them brittle and prone to cracking.

3. LITERATURE REVIEW

3.1 Synthesis of information on pavement design in Canada

Structural design of pavement structures

Pavement design practice in Canada has evolved rapidly in the last few years. Based on a survey done in 1993, TAC (1997) reports that design practices were much diversified across the country in the early 90s. Based on the survey, pavement design methods used were about evenly split between the 1977 RTAC guide, standard sections (design catalogs) and local agencies manuals. The Asphalt Institute, AASHTO and PCA methods were also used to a lesser extent (TAC, 1997). A more recent survey of Canadian practice (C-SHRP, 2002) shows that the majority of Canadian agencies now use the AASHTO (1986/1993) procedure either as a primary design tool or as verification tool. The AASHTO design procedure is an empirical method relating service life (loading cycles and serviceability level) to several design factors including pavement structure (structural number), soil stiffness (resilient modulus) and reliability of performance prediction. The fact that several Canadian agencies have adopted the 1986/1993 AASHTO design procedure and are currently considering to work together on the adaptation and the implementation of the 2002 Mechanistic-Empirical design procedure will lead to more uniform pavement structures across the country. In the mean time, the diversity of pavement design practices across Canada in the last decades led to a large variability in pavement design thickness ranging from 200 mm for low volume pavements on strong soils to more than 1300 mm for high volume pavements on soft soils. Tables 3-1 to 3-3, from TAC 1997, illustrate the large variability in pavement design practices in Canada which probably still reflects the state of the Canadian pavement network.

Table 3-1: Typical pavement thicknesses (mm) used in Canada for 0,5 X 10^6 cumulative ESALs (TAC, 1997)

Subgrade Type	Conventional Pavement Structure Course	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NF	YT**	PW*** & GSC
"Weak"	Asphalt concrete	75	80	Seal*	85	90	85	140	100		80	100	50
Lacustrine Clay	Asph. stab. gran.		50										
CBR ≅ 3.0	Granular base	300	300	150	150	150	150	150	150		100	150	150
Group Index ~ 20	Granular subbase			470	300	450-600	450-600	450	250	n/a	200		200
Unified Soil Class.-CH	Select granular	300										450	
	Total	675	430	620	535	690-840	685-835	740	500		380	700	400
"Medium"	Asphalt concrete	75	80	Seal**	85	90	85	140	100		80	100	50
Glacial Till	Asph. stab. gran.		50										
CBR ≅ 5	Granular base	300	200	150	100	150	150	150	150		100	150	150
Group Index ~ 10-12	Granular subbase			320	200	450	450-600	450	200	n/a	200		150
Unified Soil Class.-CL	Select granular	300										300	
	Total	675	330	470	385	690	685-835	740	450		380	550	350
"Strong"	Asphalt concrete	75	60	Seal**	85	90	85	140	100		80	100	50
Clayey Gravel	Asph. stab. gran.		50										
CBR ≅ 20	Granular base	300	150	200	100	150	150	150	150		100	150	150
Group Index ~	Granular subbase				100		300-450	450	200	n/a	200		
Unified Soil Class.-GC	Select granular	0-300										150	
	Total	375-675	280	200	285	240	535-685	740	450		380	400	200

* A double seal on base would be used as the surface for up to 1500 AADT
** Yukon has alternative designs of Bituminous Surface Treatment (BST) on 200 mm of granular base on 450, 300 and 150 mm of select granular, respectively, for the three subgrade types
*** Public Works and Goverment Services Canada

Table 3-2: Typical pavement thicknesses (mm) used in Canada for 1 X 10^6 cumulative ESALs (TAC, 1997)

Subgrade Type	Conventional Pavement Structure Course	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NF	YT*	PW & GSC
"Weak"	Asphalt concrete	100	100	100	100	130	105	140	150		120	100	100
Lacustrine Clay	Asph. stab. gran.		50										
CBR ≅ 3.0	Granular base	300	300	150	175	150	200	150	150		150	150	200
Group Index ~ 20	Granular subbase			360	350	450-600	525-675	450	300		300	150	450
Unified Soil Class.-CH	Select granular	300								n/a	500	450	
	Total	700	450	610	625	730-880	830-980	740	600		1070	850	750
"Medium"	Asphalt concrete	100	90	80	100	130	105	140	150		120	100	100
Glacial Till	Asph. stab. gran.		50										
CBR ≅ 5	Granular base	300	230	150	150	150	200	150	150		150	150	200
Group Index ~ 10-12	Granular subbase			260	225	450	525-675	450	250		300	150	300
Unified Soil Class. -CL	Select granular	300								n/a	500	300	
	Total	700	370	490	475	730	830-980	740	550		1070	700	600
"Strong"	Asphalt concrete	100	80	60	100	130	105	140	125		120	100	100
Clayey Gravel	Asph. stab. gran.		50										
CBR ≅ 20	Granular base	300	200	180	100	150	200	150	150		150	150	150
Group Index ~ 2	Granular subbase				100	150	300-450	450	200		300	150	150
Unified Soil Class. -GC	Select granular	0-300								n/a	500	150	
	Total	400-700	330	240	300	430	605-755	740	475		1070	550	400

* Yukon has alternative designs of Bituminous Surface Treatment (BST) on 300 mm of granular base on 450, 300 and 150 mm of select granular, respectively, for the three subgrade types.

Table 3-3: Typical pavement thicknesses (mm) used in Canada for 10 X 10^6 cumulative ESALs (TAC, 1997)

Subgrade Type	Conventional Pavement Structure Course	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NF	YT	PW & GSC
"Weak"	Asphalt concrete	100	120	150	125	180	180	140	200			125	150
Lacustrine Clay	Asph. Stab. Gran.		50										
CBR ≅ 3.0	Granular base	300	400	200	175	150	250	150	150			150	200
Group Index ~ 20	Granular subbase			390	350	600-800	525-900	450	500	n/a	n/a	150	600
Unified Soil Class.-CH	Select granular	650											
	Total	1050	570	740	650	930-1130	955-1330	740	850			875	950
"Medium"	Asphalt concrete	100	120	130	125	180	180	140	200			125	150
Glacial Till	Asph. Stab. Gran.		50										
CBR ≅ 5	Granular base	300	230	200	150	150	250	150	150			150	200
Group Index ~ 10-12	Granular subbase			280	225	450-600	525-675	450	300	n/a	n/a	150	400
Unified Soil Class.-CL	Select granular	425										300	
	Total	825	400	610	500	780-930	955-1105	740	650			725	750
"Strong"	Asphalt concrete	100	100	90	125	180	180	140	200			125	150
Clayey Gravel	Asph. Stab. Gran.		50										
CBR Δ 20	Granular base	300	250	230	100	150	250	150	150			150	200
Group Index ~ 2	Granular subbase				100	300	300-450	450	200	N/A	N/A	150	300
Unified Soil Class.-GC	Select granular	0-300										150	
	Total	400-700	400	320	325	630	730-880	740	550		0	575	650

Seasonal load restrictions

Moisture variations in pavement structures, temperature, frost action and thaw weakening are the most important climatic factors contributing to pavement deterioration in Canada. Most of these factors are dealt with in pavement design procedures. In addition, highway agencies use seasonal load restrictions policies to mitigate the effects of spring thaw weakening. All provincial agencies apply some restrictions during spring thaw. Load restrictions typically vary from 0 % on major highways, generally considered to be « all weather » pavements, to 50 % on local pavements considered to be more vulnerable to climatic effects. The rules and criteria used to apply restrictions also vary considerably from one province to the other. Some agencies use fixed dates policies while other rely on strength or condition measurements to set and remove the restrictions. Seasonal load restrictions practices in Canada are summarized in C-SHRP (2000).

3.2 Studies on relative damage caused by traffic and climate

Several studies have attempted to assess the infrastructure costs attributable to heavy vehicles and, in some cases, have tried to dissociate the effect of climate and traffic. All the studies presented have tried to estimate ratios of road deterioration due to climate and traffic. The information assembled through this literature review (Appendix 1) is summarized in the Table 3-4 at the section 3.3.

<u>Studies conducted in Canada</u>

The Ontario Trucking Industry maintains that climate, mainly freeze-thaw cycles and change of moisture, is the major cause of pavement deterioration. Traffic loads or differences between cars and trucks axles have little influence on pavement damage when they are designed and built adequately. The results of a study done by the Royal Commission on National Passenger Transportation are used to support that statement. Results showed that environmental factors are responsible for at least half of the pavement deterioration on strong pavements (highways) and almost all the deterioration on weaker pavements typical found on low volume roads. It is also stated that studies conducted by the Ontario Ministry of Transportation and the University of Waterloo prove that trucks axle loads on higher volume roads do not impose much damage and consequently do not increase maintenance costs.

The Canadian Long Term Pavement Performance (C-LTPP) started in 1989 and involves 24 different sites containing 65 sections constructed with various asphalt overlay rehabilitation treatments. An evaluation of subgrade and climatic zone influences on pavement performance in the Canadian Strategic Highway Program's (C-SHRP) Long-Term Pavement Performance (LTPP) study was done by Tighe (2002). This study describes impacts of the various treatments on pavement performance in terms of roughness progression under comparative climatic, subgrade soil, and traffic loading conditions. The main conclusions of this study are: (i) in wet, high-freeze zones, thin overlays experience a higher rate of roughness progression than thick overlays; (ii) in dry, high-freeze zones, roughness progression for medium and thick overlays is relatively small; (iii) in wet, low freeze zones, thin overlays combined with fine subgrade soils show the highest rate of roughness progression; (iv) traffic, using equivalent single axle loads, seemed to have a limited effect on all of the above. The last point is due to the fact that all the traffic used fell into the same category. Traffic was classified in two different levels: low and high. In this study, all the traffic fell into one level since 2 000 000 ESALs per year was the reference for high traffic. Using the IRI as a pavement performance indicator and considering only humid and low-freeze zones, it's possible to infer climate and traffic damage ratios from the study results. It has been found that climate is responsible for 60 % to 75 % of road deterioration and traffic for 25 % to 40 % (these ratios were computed from the study results and were not published by the authors of the study). When computing these ratios, it was assumed that fine subgrade soils are more influenced by climate than coarse subgrade soils.

A study made by the *Railway Association of Canada* (2002) identifies what is known and not known about infrastructures costs and revenues due to heavy roads vehicles. It compares results from studies made by the *United State Department of Transportation* (U.S. DOT) and by Fred Nix (for the *Canadian Trucking Alliance*). The U.S. DOT model estimates that vehicles cause 85-90% of pavement damage and that 10-15 % is due to weather. However, a research conducted by Nix (2001) shows that vehicles cause 20-50 % of pavement damage and 50-80 % is due to weather depending on pavement construction and traffic level. Nix concludes that weather, especially freeze-thaw cycles, is the main deterioration factor in Canada. It is also stated that pavements are more vulnerable during spring thaw. Nix also states that there is no strong links between axle loads and pavement damage. It also appears that weather and poor soil conditions amplify the impact of heavy axles. Nix argues that, compared to the U.S., Canada's harsher climate and the freeze-thaw cycles reduce the relative importance of axle loadings on pavement deterioration.

A paper carried out by Transport Quebec (Saint-Laurent et Corbin, 2003) is focused on the effects of loads circulating during the spring period on road deterioration. The focus of the paper was to evaluate the effect of removing load restrictions on pavement maintenance costs. The paper reports that, according to several authors, 30 to 85 % of all annual damages caused to roads occur during the spring thaw period. Usually, when less than 40 % of annual damages occur during spring, pavements deteriorate at a constant rate during spring, summer and fall. This normalized rate is on average 0,025 % per week. This deterioration rate is usually found on highways with strong pavement structure. The paper, based on analytical simulations, shows that for a constant annual traffic without load restrictions, weaker pavement structures with lower traffic levels deteriorate at a normalized rate of 0,077 % per week during spring thaw period. From this information, it is possible to infer that the proportion of pavement damage caused by traffic varies from 100 % on strong pavements to 30 % on weak pavement structures.

Studies conducted in other countries

A cost allocation study conducted by the Federal Highway Administration (1997) in the United States includes a table where are shown the proportion of maintenance of costs estimated to be attributable to non-load factors on flexible and rigid pavements. The study concludes that non-load costs represent a higher proportion of total costs on lower categories of roads than on higher categories. Pavement costs related to non-load factors in rural area vary from 11% (highway) to 14,7 % (local). In urban areas, they range from 10,1 % (highway) to 13,9 % (local). This study also indicates that heavy vehicles cause more pavement damage inducing thus higher maintenance costs than to light vehicles. Also, single axle induces more pavement damage than tandem and tridem axle configurations with comparable weights.

The objective of another study conducted in the United States was to establish the proportion of highway pavement rehabilitation costs attributable to load factors and environmental factors. Road maintenance and rehabilitation activities and road condition were documented in Indiana from 1995 to 1997 in order to assess the relative impact of the two factors on pavement performance. Based on the available information, Sinha and McCarthy (2001) estimated the percentage of road deterioration due to environmental factors to be around 72 % while load factors were responsible for about 28 % of road damage and maintenance costs.

A report from *New Jersey Department of Transportation* (Boilé et al., 2001) presents the results of a study on infrastructure cost attributable to heavy vehicles. The first objective of the study was to estimate highway related costs attributable to heavy vehicles through literature. The second objective was to develop models to estimate pavement deterioration as a result of vehicle-pavement interactions. The *Federal Highway Cost Allocation Study* produced a Highway Performance Monitoring System database. This database was used in the New-Jersey study to produce a model to estimate the proportion of total highway costs that are related to non-load factors (pavement age, climate) relative to load related factors. These costs were allocated in proportion to VMT (vehicle miles traveled) for each vehicle class. In general, the share of costs attributable to non-load factors is about the same for flexible and rigid pavements even if minor differences can be found between highway functional classes. Non-load costs represent about 10 % on rural Interstates to more than 20 % on urban collectors and local roads. The *Nation Pavement Cost Model* used lower non-load percentage of costs. NAPCOM does not use the data from pavement sections for rural local roads. Instead, NAPCOM bases its results on the rate of progression of individual types of pavement distress. Because their results are based on the interaction between axle loads and the environment, they obtain lower percentages. The publication states that NAPCOM would yield higher percentages for non-load factors on these lower level roads if HPMS database were used for the assessment. The study concludes by proposing a typical pavement deterioration system that would be composed of 2 sub-models:

1. Traffic Loading Simulation Model: To analyze effects of heavy vehicles on pavement that includes the following variables: axle load, type of tire, tire pressure, speed and suspension.
2. Analytical Model: To predict the deformation and stresses on pavement by simulated loading from the above model. Climatic conditions damaging pavement such as temperature, precipitation, frost heave and thermal cracking must be considered.

This study also proposes a Mathematical Model of Pavement Performance. This model considers climatic and environmental factors. These factors are known to influence pavement performance. Thus, temperature and freeze-thaw cycles and their effects on outbound materials and subgrade would be included in the model.

An Australian study (Martin, 2002) estimates road deterioration caused by heavy vehicles on fine grading hot-mix asphalt. Results were obtained from a statistical method (based on maintenance road costs and road utilization by trucks), a pavement deterioration model and observations on existing pavements. Based on various maintenance costs models for secondary roads with asphalt surface treatments, the percentage of cost related to heavy load vehicles is estimated to be 25 % on rural roads and 60 % on urban roads. Martin (1995) shows, with observations made on existing pavements, that 39 % of the costs are due to heavy vehicles both on rural and urban roads. When the performance model of the ARRB is used, the percentage estimated is about 65 %. But, according to the author, recent estimation shows that heavy vehicles are responsible for about 55 % to 65 % of road deterioration.

3.3 Summary of ratios found or inferred from the literature

Even if results from all the studies found vary significantly depending on the methodologies used and on the context of the study area, some similarities were identified. Table summarizes the ratios pavement damage attributable to climatic factors to damage caused by traffic and particularly to heavy vehicles.

Table 3-4: Summary of damage ratios obtained from the literature

References	$Ratio = \frac{\%Climate}{\%Traffic}$	Comments/Remarks
NIX, F. 2001. ″Weight-Distance taxes″. Prepared for Canadian Trucking Alliance, Nov 2001, p. 34.	50/50 to 80/20	• Research carried out in Canada • Damage type considered not mentioned
FEDERAL HIGHWAY ADMINISTRATION, 1997. ″Federal Highway Costs Allocation Study″. United States Department of Transportation.	10/90 to 15/85	• Research Carried out in United States • Climate effect more important for low volume roads (weaker structures) • Total costs considered as the performance parameter
SINHA, L. AND MCCARTHY, P., 2001. ″Methodology to determine load- and non-load-related shares of highway pavement rehabilitation″. Transportation Research Record, No. 1747, p.79-88.	72/28	• Research carried out in Indiana • Rehabilitation costs considered as the performance parameter • Least-squares models formulated by an aggregate approach
ST-LAURENT, D. ET CORBIN, G., 2003. ″L'impact des restrictions de charge en période de dégel″. Innovation Transports, numéro 18, pages 25-31.	30/70 to 70/30	• Ratios inferred from the study • Stronger structures (highways) barely sensitive to climate; weaker structures influenced by climate to various degrees • Fatigue damage considered as the performance parameter • Analytic-Empirical simulations calibrated on 9 sites in Québec
MARTIN, T., 2002. ″Estimating heavy vehicles road wear costs for bituminous-surfaced arterial roads″. Journal of Transportation Engineering, March/April, Vol. 128, No. 2, p. 103-110.	35/65 to 45/55	• Australian study on bituminous-surfaced arterial roads • IRI considered as the performance parameter • Climatic effects considered : thermal cracking and pavement deformation due to subgrade water content
TIGHE, S., 2002. ″Evaluation of subgrade and climatic zone influences on pavement performance in the C-SHRP LTPP″. Canadian Geotechnical Journal, Vol 39, p. 377-387.	60/40 to 75/25	• Ratios inferred from the study • Canadian study on pavements rehabilitated with overlays (24 sites, 65 sections) • IRI considered as the performance parameter • Ratios valid for wet low-freeze zones • Lower ratios found for higher volume roads and higher ratios found for lower volume roads • Hypothesis : fine subgrade are climate sensitive while coarse subgrade are not

4. ASSESSMENT OF DAMAGE RATIOS BASED ON CANADIAN SITES

4.1 Methodology

The proposed approach to assess the relative damage caused by traffic and climate is based on the analysis of performance data available on Canadian sites. Experimental sites selected for the study are presented in section 4.2. Data available for those sites reflect the combined effects of traffic and climate. These effects have been separated by removing climatic effects using theoretical simulations. The following five types of distresses have been used to assess pavement performance:

- Rutting (including stability, wear and structural rutting) (Ru);
- Fatigue cracking (Fa);
- Roughness (Ro);
- Longitudinal cracking outside of the wheel paths (LC);
- Transverse cracking (TC).

The first three types of distresses are attributable to the combined effects of traffic and climate. A theoretical simulation is therefore required to extract the climate's effect upon deterioration and thereby isolate the effect of traffic. The last two types of distresses in the list are assumed to be essentially attributed to climatic factors. No simulation is therefore required to separate climate and traffic effects for these two (2) types of deterioration.

4.1.1 Rutting and Fatigue Cracking Simulation

AKFPD Software

The rutting (Ru) and fatigue cracking (Fa) theoretical simulation was carried out using the Alaska Flexible Pavement Design (AKFPD) software. This software tool uses mechanistic-empirical analysis principles. The core of this method consists in the calculation of stresses and strains at critical depths within the pavement structure. The calculation engine used by AKFPD is the ELSYM5. The principals relating to the calculation method are well documented in the software's user manual (Alaska Department of Transportation and Public Facilities, 2004).

AKFPD uses the Asphalt Institute model for calculating fatigue cracking (Fa). This equation is applicable to asphalt concrete pavements and to all highly bounded layers (such as a treated base, for example). The criteria of the Asphalt Institute's model consider a pavement to have reached the end of its useful life due to fatigue when 45 % of the wheel path surface has become affected by this type of degradation, which is equivalent to approximately 20 % of the total pavement surface.

AKFPD uses the Per Ullidtz equation to predict rutting (Ru) behaviour. It must be noted that this equation does not take into account rutting associated with instability on the asphalt concrete. This model applies to unbound or slightly bound layers. It suggests that a pavement has reached the end of its useful life when rutting has attained a depth of 25 mm (1 inch).

The AKFPD data entry parameters include information relating to traffic, the properties of the asphalt concrete layer, the load configuration, and also the pavement structure and subgrade soil. The calculation results generated by the software provide the percentage of the pavement's service life used up by each layer in the structure, whether this is due to fatigue or rutting. These service life percentages are calculated according to the end-of-service-life criteria used by the software (45 % of total wheel path surface affected by fatigue cracking and rutting to a depth of 25 mm).

Modelling Parameters

Information related to traffic includes the number of load repetitions applied to the pavement as well as the duration of each season (spring, summer, fall and winter) as a fraction of the complete year. These parameters are estimated using data from the different databases. They are presented in the test site characteristic summary sheets (Appendix 2). Note that summer and fall were combined into a single season. Spring corresponds to the thaw and recovery period, while winter corresponds to that part of the year where the average temperature remains below 0°C for an extended period of time. The distribution of load repetitions assumed to be uniform throughout the year, and the total number of repetitions is therefore distributed over each season.

The data relating to asphalt concrete include the percentages of air and asphalt, as well as the mixture's density. Furthermore, data relating to load configuration include tire pressure, tire load, and the vertical load location in relation to the evaluation location. AKFPD's default parameters were used for all these parameters, and are summarized in Table 4-1.

The parameters related to the pavement structure include the thickness, modulus and poisson ratio for each pavement layer (pavement, aggregate base, subbase and subgrade) during each season. Pavement layer thicknesses were defined using data from the various databases. These parameters are presented in the test site characteristic summary sheets (Appendix 2). The subgrade thickness was considered to be infinite in every case. The software's default parameters were used for the modulus and poisson ratio of the pavement, aggregate base, and subbase, as well as for the subgrade poisson ratios. These parameters are summarized in Table 4-1.

Table 4-1: AKFPD Software Default Parameters

Asphaltic-Layer Properties			Load Configuration			
% Air	% AC	Density (pcf)	Tire Pressure (psi)	Tire load (lbs)	Load locations (in)	Evaluation location (in)
2	6,5	155	110	4500	13,5	6,75
Pavement Structure						
Layer	Spring		Summer / fall		Winter	
	Modulus (ksi)	Poisson Ratio	Modulus (ksi)	Poisson Ratio	Modulus (ksi)	Poisson Ratio
Asphalt concrete	755	0,3	510	0,3	1500	0,3
Aggregate base	45	0,35	50	0,35	100	0,35
Subbase (Type B materiel)	15	0,4	30	0,4	80	0,4
Subgrade	-	0,45	-	0,45	-	0,45

The subgrade model for the experimental sites was evaluated using test results obtained with a falling weight deflectometer (FWD). This test consists in dropping a mass in such a way that it applies a standard force (generally 40 kN) on the pavement surface. Pavement surface deflections are recorded simultaneously under the load and at various distances from the mass using geophones. The subgrade modulus is deduced from the amplitude of the deflections at large distance from the load.

During the development of the AASHTO method, correlations were established between the deflection results obtained with the FWD and the subgrade resilient modulus (M_R) at a load force of 40 kN (Saint-Laurent, 1995). The Thompson equation (1989) uses deflections measured in thousandths of inches (10^{-3} inches) measured from geophones located 0 mm (d_0), 305 mm (d_{305}) et 914 mm (d_{914}) from the load plate, while the Hall and Elliot equation (1992) is based only on deflections measured from the geophone located at 914 mm.

In both cases, the M_R result is measured in ksi:

$$M_R = 10^{1,61-0,0092*d_0+0,022*d_{305}-0,19*d_{914}} \text{ (Thompson)}$$

$$M_R = 25,0346 - 5,2454 * d_{914} + 0,2864 * (d_{914})^2 \text{ (Hall and Elliot).}$$

Both these equations were used to determine the subgrade resilient modulus at the experimental sites in summer conditions based on FWD tests. Tests from different survey years were used. The determination results for all modulus in summer conditions are presented in the test site characteristic summary sheets (Appendix 2).

Many sources were consulted in order to determine how the winter and spring subgrade moduli vary in relation to the summer modulus. Transport Quebec (MTQ, 2004) describes the reduction in load-bearing capacity during the thaw according to the type of soil in terms of percentage values. This weakening varies from 0 % (clean gravels) to 50 % (silts). Janoo and Berg (1992) measured the modulus of various types of pavement materials and subgrade soils using laboratory tests under freeze and thaw conditions at different moisture levels. It is difficult, however, to associate the results of their study with the in situ losses and gains in load-bearing capacity experienced during the spring and winter seasons.

Ehrola proposes spring / summer modulus ratios for different types of subgrade. This relationship is on average 0,55 for sandy and gravely soils, as opposed to 0,45 for fine-grained soils (silt and clays). Ehrola also proposes winter / summer modulus ratios for the same types of subgrades. The differences are minor depending on the soil type. The average relation is approximately 15. Ehrola's ratios were used to determine the subgrade modulus during the spring and winter. The calculation results for these moduli are presented in the test site characteristic summary sheets (Appendix 2).

Degradation Simulation

Two calculations using AKFPD were carried out for each test site to separate the climate and traffic effects upon fatigue cracking (Fa). The first step involved adjusts the traffic by varying a calibration factor to match the real level of cracking observed at the site. This calculation included both the effect of the climate (variation of moduli with seasons) and the effect of traffic on pavement degradation. The second step consisted in recalculating the damage with the same calibration factor, but this time, by simulating summer conditions (summer moduli) during spring. Figure 4-1 is a schematic illustration of the two-step simulation approach used in the study. The results of these calculations are presented in Appendix 3.

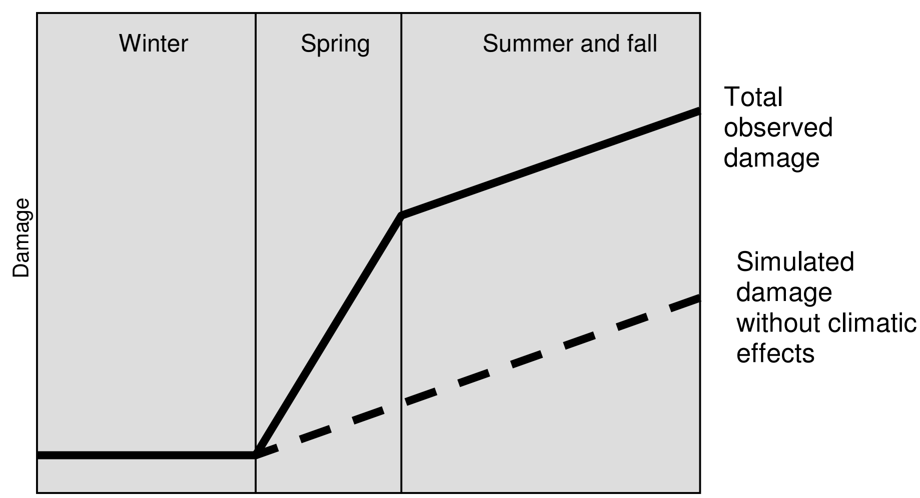

Figure 4-1: Schematic illustration of damage simulation with and without climatic effects

Note that the effect of winter was considered null for both simulations. A first series of simulations, carried out using summer conditions during the whole year, led to unrealistic damage ratios. This is probably due to limitations in the current knowledge on seasonal damage accumulation mechanisms.

The fatigue cracking (Fa) observed at each site is presented in the test site characteristic summary sheets (Appendix 2, in the degradation value column of the degradation table). Certain databases consulted present their results in terms of the total length of cracking (MTQ and C-LTPP), while others propose the pavement surface affected by the degradation (LTPP). These data were all converted to a damage value normalized using the software's performance criteria (100 % damage = cracking on 45 % of the wheel path = cracking on 20 % of the total surface). To do this, one linear meter of fatigue cracking was considered to affect the entire width of one wheel path. The normalized damage is also presented in the test site characteristic summary sheets (Appendix 2, damage column of the degradation table).

Two calculations were carried out at each of the experimental sites using AKFPD to separate the effects of traffic and climate in the prediction of rutting (Ru). As for the fatigue cracking simulations, the first step involved adjusts the model to the real level of rutting observed at the site by varying a calibration factor acting on the traffic level. This calculation included both the effect of the climate and the effect of traffic on pavement degradation. The second step consisted in recalculating the damage with the same calibration factor, but this time by simulating summer conditions (summer modulus) during spring as illustrated in figure 4-1. The results of these calculations are presented in Appendix 3.

The rutting (Ru) level observed at each experimental site is presented in their respective test site characteristic summary sheets (Appendix 2, degradation value column of the degradation table). Every database consulted presented rutting level in terms of maximum depth. These data were all normalized using the software's performance criteria (100 % damage = 25 mm of rutting). The normalized damage is also presented in the test site characteristic summary sheets (Appendix 2, damage column of the degradation table).

4.1.2 Roughness (Ro) Simulation

The model used to carry out the roughness simulation is the empirical model developed for the NCHRP 2002 Mechanistic-Empirical design guide for flexible pavements with granular bases. The parameter used in the model to quantify roughness is the IRI (International Roughness Index). With this model, it is possible to simulate IRI progression over time.

Two categories of input parameters are required for the model. The first category includes several types of degradation observed on the pavement. It includes the initial IRI (Ro_0), the age of the pavement, as well as the extent of transverse (TC), fatigue (Fa), map (BC) and longitudinal (LC) cracking. The second category of input parameters in the model regroups site characteristics. These characteristics include the freezing index, the plasticity index (PI), the 75 µm passing (P_{075}) and the 20 µm passing (P_{020}) of the subgrade, the total average annual precipitation, and the standard monthly deviation in precipitation. A site factor is calculated based on these parameters.

Some of the NCHRP model entry parameters were not present in the databases for the test sites. Values were therefore estimated for these parameters. The initial IRI (Ro_0) was set at 1,0, while the standard monthly deviation in precipitation was set at 20 % of one twelfth of the total average annual precipitation. Furthermore, the plasticity index (PI) and the subgrade 75 µm passing (P_{075}) and 20 µm passing (P_{020}) had to be estimated in certain cases based on the gradation of soils.

Some of the input parameters required for the NCHRP 2002 model are not in the same format than what is available in the databases for the experimental sites. As mentioned in Section 4.1.1, fatigue cracking (Fa) was often presented in the databases in terms of the total length of cracking (m). To convert these values to a unit area, one linear meter of fatigue cracking was considered to affect the entire width of a wheel path. Map cracking (BC) was always presented in terms of the total length of cracking (m) in the database, whereas this parameter needed to be quantified as a percentage of the surface affected for the model. For the purpose of the simulations, one linear meter of map cracking was considered to be equivalent to one meter of the test section affected by this type of degradation along its entire length.

All the input parameters drawn from the databases used in the NCHRP 2002 model are presented in the test site characteristic summary sheets (Appendix 2). The age of the pavement was inferred from the difference between the year in which the degradations were measured and the year in which the pavement was constructed. The different degradations are presented according to the units used in the databases (degradation value column), and also according to the units required in the NCHRP 2002 model (degradation extension column).

Two calculations were carried with the NCHRP 2002 model for each experimental site in order to separate the climate and traffic effects on roughness. The first step consisted in adjusting the model to the real IRI observed at the site by varying a calibration factor. This calculation included the affects of both climate and traffic on pavement degradation. The second step involved recalculating roughness using summer conditions throughout the entire year. This simulation was conducted with transverse cracking (TC), map cracking (BC), longitudinal cracking (LC), freezing index, total average annual precipitation, and the standard monthly deviation in precipitation values set at 0. The results of these calculations are presented in Appendix 3.

4.1.3 Relative Damage Calculation

The climate and traffic relative damage calculation was carried out based on the initial hypothesis that the total damage at each site resulted from the combined damage inflicted by the traffic and climate. The value of this total damage was arbitrarily set at a value of 1.0:

Total damage = *Traffic damage* + *Climate damage* = 1,0

The damage linked to traffic was calculated based on the relationship between a performance index for a pavement subjected only to traffic degradation (PI_t) and a performance index combining both the effects of the climate and traffic (PI_{t+c}). It was thereby possible to deduce the climate related damage:

$$\textit{Traffic damage} = \frac{PI_t}{PI_{t+c}}$$

Climate damage = 1.0 – *Traffic damage*

The performance index combining the traffic and climate effects (PI_{t+c}) was calculated using fatigue cracking (Fa_{t+c}), rutting (Ru_{t+c}), roughness (Ro_{t+c}), longitudinal cracking (LC) outside of the wheel paths and transverse cracking (TC) observed at the test sites. The three first types of degradations were normalized using values corresponding to their end-of-service-life criteria. The two other degradations (LC and TC) were normalized using the highest observed value for these two types of degradations at all the sites: 367,9 m for LC and 454,5 m for TC. Each of the normalized degradations was then multiplied by a weighting factor (ω_i) in order to reflect the relative importance of each degradation mode in the calculation of the damage index. The sum of the ω_i values is fixed at 1:

$$PI_{c+t} = \omega_1 \frac{Ru_{t+c}\,(mm)}{25\,mm} + \omega_2 \frac{Fa_{t+c}\,(\%\,wheel\ path\ area)}{45\%} + \omega_3 \frac{Ro_{t+c}\,(m/km)}{4{,}0\,m/km} + \omega_4 \frac{LC\,(m)}{367{,}9\ m} + \omega_5 \frac{TC\,(m)}{454{,}5\ m}$$

$$\sum \omega_i = 1$$

The performance index for traffic alone (PI_t) was calculated using the fatigue cracking, rutting and roughness simulation results with summer conditions applied during spring (Fa_t, Ru_t and Ro_t). As previously mentioned, longitudinal cracking beyond the wheel paths (LC) and transverse cracking are assumed to be caused solely by climatic effects. These degradations are not therefore included in PI_t calculation. As in the case of the PI_{t+c} calculation, the three simulated degradations (Fa_t, Ru_t and Ro_t) were normalized using a value corresponding to the end-of-service-life criteria for the degradations. All the normalized degradations were then multiplied by the same relative weighting factor (ω_i) as used in the PI_t calculation:

$$PI_t = \omega_1 \frac{Ru_t\,(mm)}{25\,mm} + \omega_2 \frac{Fa_t\,(\%\,wheel\ path\ area)}{45\,\%} + \omega_3 \frac{Ro_t\,(m/km)}{4{,}0\,m/km}$$

Three sets of weighting factors ω_i were taken into consideration, thereby taking into account suggestions made by members of the committee. The calculation was conducted simultaneously based on the three following repartitions:

Weighting factor repartition 1 (Consulting team):

$\omega_1 = \omega_2 = \omega_3 = 0{,}25$

$\omega_4 = \omega_5 = 0{,}125$

Weighting factor repartition 2 (Saskatchewan):

$\omega_1 = \omega_2 = 0{,}2$

$\omega_3 = 0{,}35$

$\omega_4 = \omega_5 = 0{,}125$

Weighting factor repartition 3 (New-Brunswick):

$$\omega_1 = \omega_3 = 0{,}2$$

$$\omega_2 = 0{,}35$$

$$\omega_4 = 0{,}1$$

$$\omega_5 = 0{,}15$$

4.2 Site Selection

Three main databases were consulted in order to populate the experimental factorial matrix: the US-LTPP-GPS-1 project database, the C-LTPP program database and, and the MTQ database. The possibility of using test sections from US-LTPP-SPS-8 (environmental effects on pavements) and US-LTPP-SPS-9 (validation of Superpave mixes) was also investigated. Unfortunately, data from these studies was not readily available through the DATAPAVE web site and time available for the study did not make it possible to obtain the data through a data request process. The first objective was to assemble 32 pavement cases covering the main conditions of Canadian Highway networks. The cases included:

- 2 climatic zones (wet freeze, dry freeze)
- 2 soil types (fine, coarse)
- 2 levels of frost intensity (low, high)
- 4 road classes
- 2 levels of traffic for each class (high and low).

The factorial design of the proposed matrix is illustrated in the following table. The classification of the study of Mr. Hajek of *Ara inc*. is also presented in the table.

Table 4-2: Proposed experimental factorial matrix

ARA classification	BPR classification	Traffic volume	Fine grained soils			Coarse
			Wet freeze		Dry freeze	Average conditions
			High frost	Low Frost	High frost	
Freeway	Major HWY	H	1	9	17	25
Arterial		L	2	10	18	26
	Other HWY	H	3	11	19	27
Collector		L	4	12	20	28
Local	Local Roads	H	5	13	21	29
		L	6	14	22	30
Arterial Collector Local	Munic. Roads	H	7	15	23	31
		L	8	16	24	32

It was anticipated that certain cells in the experimental matrix would be difficult to populate. Once the different databases had been examined (LTPP, C-LTPP and MTQ), the conclusion was drawn that the average annual traffic volume used to separate the high and low levels of traffic would be fixed at 200 kESAL for the Major Highway and Other Highway categories, and 100 kESAL for the Local Roads category. No Municipal Roads sites were recorded in the databases. In addition, it was decided that the limit between High Frost and Low Frost zones should be characterized by a freezing index of 800°C*d. It was therefore possible to locate all the available sites within the inference space of the experimental matrix. The result is illustrated in table 4-3. It can be seen that a maximum of 30 sites covering 13 of the 32 experimental cells are available in the existing databases. The table also shows that certain C-LTPP sites are characterized by a number of adjacent experimental pavement sections.

Table 4-3: Available sites in the proposed experimental factorial matrix

Highway classification	Traffic volume (ann. kESAL)	Fine grained soils			Coarse
		Wet freeze		Dry freeze	Average conditions
		High frost	Low frost	High frost	
Major HWY	H > 200	~~SHRP 891127~~[8] (1) MTQ SPE5423[8] (1) MTQ 53V96D11[8] (1) MTQ 54V96D11[8] (1)	C-SHRP 860501[5] (3)	C-SHRP 900802[9] (2) C-SHRP 900803[9] (2) ~~SHRP 811804~~ (1)	C-SHRP 840604[3] (4) MTQ 891021[8] (1) MTQ 89A340[8] (1)
	L < 200	2	10	C-SHRP 810404[1] (4) ~~SHRP 831801~~[2] (1)	C-SHRP 850201[4] (1) C-SHRP 850206[4] (2) C-SHRP 850601[4] (1) C-SHRP 860603[5] (1) ~~SHRP 851801~~[4] (1) ~~SHRP 851803~~[4] (1) ~~SHRP 881645~~[7] (1) ~~SHRP 906405~~[9] (1)
Other HWY	H > 200	MTQ 63E98D11[8] (1) MTQ 89090[8] (1) MTQ 53E93M14[8] (1)	11	19	27
	L < 200	MTQ 34E98T[8] (1)	C-SHRP 870102[6] (2)	C-SHRP 830403[2] (3)	28
Local Roads	H > 100	5	13	C-SHRP 900402[9] (1)	29
	L < 100	MTQ 892011[8] (1)	14	22	C-SHRP 840204[3] (2)
Munic. Roads	H > 100	7	15	23	31
	L < 100	8	16	24	32

Notes:

(1) (2) (3) (4) Number of sections present at site.

[1] Located in Alberta

[2] Located in Manitoba

[3] Located in New Brunswick

[4] Located in Newfoundland

[5] Located in Nova Scotia

[6] Located in Ontario

[7] Located in Prince Edward Island

[8] Located in Quebec

[9] Located in Saskatchewan

Following the analysis of the available data, it was considered appropriate to conduct calculations for a number of sites within the same cell. Furthermore, certain C-LTPP sites contain a number of distinct sections. A total of 42 simulations were carried out for the 30 available sites; that is to say one simulation for each available pavement section. This approach made possible to increase the precision of the covered cells and to compensate for shortcomings in relation to uncovered cells, thereby providing more reliable estimates for these uncovered cells.

As indicated in Table 4-3, the sites from LTPP database were rejected for two reasons. First, they only cover cells already populated by sections found in the C-LTPP and the MTQ databases. Second, the units used in the LTPP database to quantify the degradations were not the compatible with those used in the C-LTPP and MTQ databases. The characteristics of all the MTQ and C-LTPP sites are summarized in their respective summary sheets in Appendix 2.

4.3 Example of a Damage Calculation

The site C-LTPP 900402 (section 2) was selected to provide an example of a traffic damage and climate damage calculation. Table 4-4 contains all the parameters used for the calculation. The weighting factor repartition proposed by the consulting team was selected for demonstration purposes. The table contains the observations of Ru, Fa and Ro combining the effects of climate and traffic (t+c) and the results of the simulations which only take into account the effects of traffic (t). It also presents the observations for longitudinal cracking outside of the wheel path (LC) and for transverse cracking at the site. Finally, the normalization parameters for the degradations representing the end-of-service-life values (terminal conditions) are also presented.

Table 4-4: Parameters used for the calculation of traffic and climate damage at the site C-LTPP 900402 (section 2)

Degradation type	Unit	Weighting factor (ω_i)	Degradation values		
			Terminal	t+c	t
Ru	mm	0,25	25	10,6	8,4
Fa	% of wheel path area	0,25	45	5,1	5,0
Ro	m/km	0,25	4,0	2,6	1,0
LC	m	0,125	367,9	252,4	0
TC	m	0,125	454,5	251,3	0

The calculation is carried out using the equations described in section 4.1.3:

$$PI_{c+t} = 0{,}25\frac{10{,}6mm}{25mm} + 0{,}25\frac{5{,}1\%}{45\%} + 0{,}25\frac{2{,}6m/km}{4{,}0m/km} + 0{,}125\frac{252{,}4m}{367{,}9m} + 0{,}125\frac{251{,}3m}{454{,}5m} = 0{,}45$$

$$PI_t = 0{,}25\frac{8{,}4mm}{25mm} + 0{,}25\frac{5\%}{45\%} + 0{,}25\frac{1{,}0m/km}{4{,}0m/km} = 0{,}17$$

$$Traffic\ damage = \frac{PI_t}{PI_{t+c}} = \frac{0{,}17}{0{,}45} = 0{,}38$$

$$Climate\ damage = 1{,}0 - Traffic\ damage = 1{,}0 - 0{,}38 = 0{,}62$$

4.4 Relationship between damage ratios and the age of the pavement

Based on the calculation procedure used in the study, it is expected that young pavements will show less climate related damage (essentially associated with cracking) and should be less subjected to climatic effects due to the low level of cracking at young ages.

Therefore, a bias might have been introduced in the study by the use of two main sources of data to populate the experimental matrix. Data from C-LTPP test sections were collected at the end of the service life of an original pavement prior to the application of a rehabilitation treatment. These sections are therefore generally old (typically between 14 and 29 years) and damaged pavements. MTQ sections were selected to fill areas in the experimental matrix poorly covered by C-LTPP sections, mainly in the low volume roads, wet freeze and fine-grained soil areas. MTQ pavement monitoring program is relatively recent and reference pavement sections included in the program had to be constructed or reconstructed in order to document adequately pavement characteristics in the database. MTQ test sections are therefore relatively young ranging between 5 and 12 year-old (with one exception at 24 years). In order to assess the influence of the bias on the results of the analysis, a relationship was established between the ratios calculated and the age of the pavement. The relationship is shown in Figure 4-2.

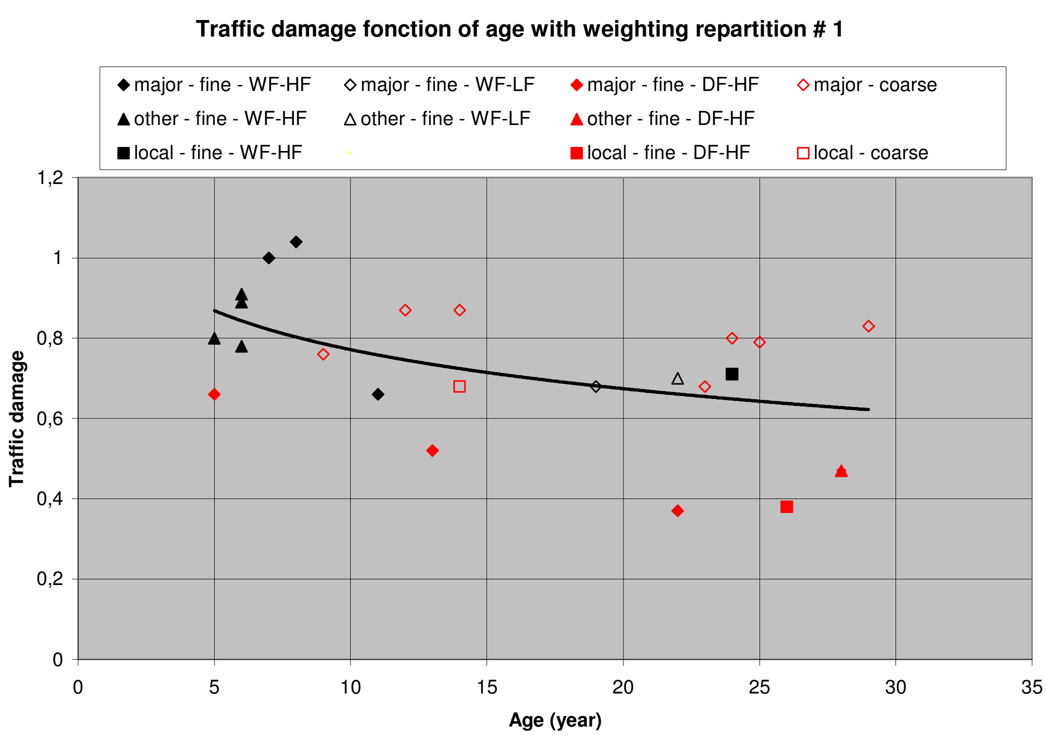

Figure 4-2: Relationship between damage ratios and pavement age (for weights distribution 1)

Figure 4-2 shows a clear trend for a higher effect of climate on pavement deterioration with increasing age. In order to compensate the bias resulting from the effect of age, a correction factor was established based on the trend observed in the relationship. The correction factor (CF) is given by:

$$CF = -0{,}1403\ln(age) + 1{,}0946$$

The correction factor was used to bring all test section to an equivalent old age (≈30 years) condition.

4.5 Summary of Ratios Obtained from Canadian sites

Tables 4-5 to 4-7 contain the damage calculation results related to traffic and climate according to the three weighting factor repartitions. For the C-LTPP sites, for which two or more sections were available, the results shown in the tables represent an average of the results obtained for each one of the sections within these sites. However, it is important to refer to Appendix 3 to see the details relating to these results. The tables show that traffic is responsible for 31 % to 87 % of damage depending on site conditions and weighting factor repartition used, while the climate is responsible for between 23 % and 69 % of the damage.

Table 4-5: Calculation results of traffic damage at Canadian sites with a weighting factor repartition 1 (proposed by the research team)

Highway classification	Traffic volume (ann. kESAL)	Fine grained soils			Coarse
		Wet freeze		Dry freeze	Average conditions
		High frost	Low frost	High frost	
Major HWY	H > 200	MTQ SPE5423 = 0,52 MTQ 53V96D11 = 0,86 MTQ 54V96D11 = 0,80	C-SHRP 860501 = 0,62	C-SHRP 900802 = 0,33 C-SHRP 900803 = 0,41	C-SHRP 840604 = 0,65 MTQ 891021 = 0,60 MTQ 89A340 = 0,75
	L < 200			C-SHRP 810404 = 0,41	C-SHRP 850201 = 0,77 C-SHRP 850206 = 0,77 C-SHRP 850601 = 0,83 C-SHRP 860603 = 0,77
Other HWY	H > 200	MTQ 63E98D11 = 0,56 MTQ 89090 = 0,67 MTQ 53E93M14 = 0,69			
	L < 200	MTQ 34E98T = 0,55	C-SHRP 870102 = 0,66	C-SHRP 830403 = 0,47	
Local Roads	H > 100			C-SHRP 900402 = 0,36	
	L < 100	MTQ 892011 = 0,68			C-SHRP 840204 = 0,58
Munic. Roads					

Table 4-6: Calculation results of traffic damage at Canadian sites with a weighting factor repartition 2 (Proposed by Saskatchewan)

Highway classification	Traffic volume (ann. kESAL)	Fine grained soils			Coarse
		Wet freeze		Dry freeze	Average conditions
		High frost	Low frost	High frost	
Major HWY	H > 200	MTQ SPE5423 = 0,47 MTQ 53V96D11 = 0,85 MTQ 54V96D11 = 0,77	C-SHRP 860501 = 0,61	C-SHRP 900802 = 0,33 C-SHRP 900803 = 0,36	C-SHRP 840604 = 0,60 MTQ 891021 = 0,56 MTQ 89A340 = 0,72
	L < 200			C-SHRP 810404 = 0,37	C-SHRP 850201 = 0,72 C-SHRP 850206 = 0,70 C-SHRP 850601 = 0,80 C-SHRP 860603 = 0,74
Other HWY	H > 200	MTQ 63E98D11 = 0,54 MTQ 89090 = 0,55 MTQ 53E93M14 = 0,65			
	L < 200	MTQ 34E98T = 0,52	C-SHRP 870102 = 0,58	C-SHRP 830403 = 0,42	
Local Roads	H > 100			C-SHRP 900402 = 0,34	
	L < 100	MTQ 892011 = 0,60			C-SHRP 840204 = 0,54
Munic. Roads					

Table 4-7: Calculation results of traffic damage at Canadian sites with a weighting factor repartition 3 (proposed by New Brunswick)

Highway classification	Traffic volume (ann. kESAL)	Fine grained soils			Coarse
		Wet freeze		Dry freeze	Average conditions
		High frost	Low frost	High frost	
Major HWY	H > 200	MTQ SPE5423 = 0,60 MTQ 53V96D11 = 0,87 MTQ 54V96D11 = 0,83	C-SHRP 860501 = 0,63	C-SHRP 900802 = 0,31 C-SHRP 900803 = 0,47	C-SHRP 840604 = 0,67 MTQ 891021 = 0,66 MTQ 89A340 = 0,79
	L < 200			C-SHRP 810404 = 0,44	C-SHRP 850201 = 0,80 C-SHRP 850206 = 0,82 C-SHRP 850601 = 0,84 C-SHRP 860603 = 0,79
Other HWY	H > 200	MTQ 63E98D11 = 0,58 MTQ 89090 = 0,62 MTQ 53E93M14 = 0,73			
	L < 200	MTQ 34E98T = 0,60	C-SHRP 870102 = 0,70	C-SHRP 830403 = 0,53	
Local Roads	H > 100			C-SHRP 900402 = 0,37	
	L < 100	MTQ 892011 = 0,74			C-SHRP 840204 = 0,63
Munic. Roads					

5. ANALYSIS AND DISCUSSION

5.1 Effect of different contribution factors

The experimental matrix used for the project has been designed in order to take into consideration the major factors contributing to pavement deterioration in the Canadian context. The effect of each one of the main factors has been assessed based on the average traffic damage index calculated using the procedure described in section 4 of the report. This analysis is limited to the weighting factor repartition proposed by the consulting team. The results of the analysis are summarized in Figure 5-1.

Effect of subgrade type

15 of the 23 pavement sections used for the study are underlain by fine-grained soils. Because of the water and frost susceptibility of these soils, it is expected that climatic factors are going to have more influence on the performance of these sites. As a matter of fact, test sections built on fine-grained soils have an average traffic damage index of 0,57 as compared to 0,71 for sections built on coarse-grained soils.

Effect of road classification

It is generally expected that major highways are less sensitive to climatic effects than local roads. Many highway jurisdictions are confirming this statement by classifying their major highways as being « all weather » pavements. As it was expected at the beginning of the project, due to the requirements of national pavement monitoring programs, most of the test sections available in the databases are major highways. Out of the 23 test sections used in the study, 14 are classified as « Major Highways », 6 are classified « Other Highways » while only 3 are considered « Local Roads ». As mentioned earlier, no test section was found in the « Municipal Road » category. As expected, the results show clearly that, on average, « Major Highways » have a higher traffic damage index (0,65) than pavements classified in the other two categories. Moreover, our results do not show any significant difference between traffic damage indices for « Other Highways » (0,52) and « Local Roads » (0,54). The limited number of observations in the last category might be an explanation for the fact that no difference is observed.

Effect of moisture

It would normally be expected that pavements in wet environments might be more affected by climatic effects than pavements constructed in dry climates. The results of the study are somewhat counterintuitive since they indicate a much higher average traffic damage factor for pavements in wet climates (0,69; 18 observations) than for those in dry climates (0,40; 5 observations). There are two possible explanations for these results. First, the limited number of observations available for dry conditions does not allow for a reliable statistical analysis of that particular group of pavements. The other possible explanation is the fact that pavements built in the prairies (where dry conditions are found in Canada) are thinner than elsewhere in the country. This situation is confirmed by the information provided in Tables 3-1 to 3-3. In that case, it is possible that pavement thickness overcompensates the effect of moisture on pavement performance.

Effect of frost action

Frost action, expressed in this study in terms of the intensity of cold temperature acting on the pavement and quantified by the freezing index at the pavement site, is also considered to be a factor increasing the influence of climate on pavement damage. The results of the study support the expectation that, on average, pavement sections located in a high frost environment have a traffic damage index of 0,61 while pavement sections located in the low frost environment have a traffic damage index of 0,69. It is however important to note that only three sections are located in a low frost environment which reduces the reliability of the results of this analysis.

Effect of traffic

As being the prime factor of traffic damage to pavements, traffic level should normally have an important incidence on the traffic damage index. It is however interesting to note that the 13 sections in the high traffic category have the exact same average traffic damage index than the 10 sections in the low traffic category. A plausible explanation for these results is that pavement design engineers are doing a very good job when taking traffic into consideration for pavement design. It is thus likely that traffic action is adequately compensated by pavement thickness making the effect of traffic on the traffic damage index negligible.

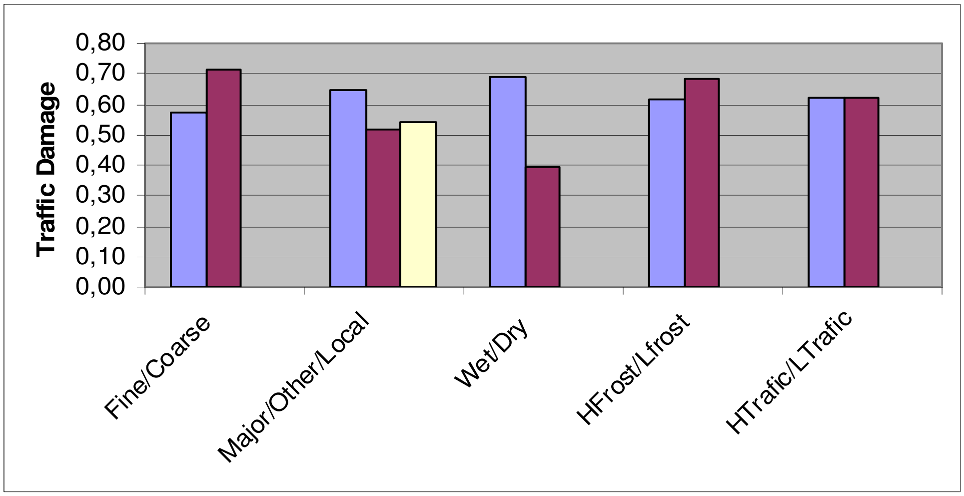

Figure 5-1: Effect of the main contributing factors on the traffic damage index

5.2 Proposed traffic damage indices for Canadian conditions

The results of the study and the analysis described in section 5.1 of the report have guided our efforts in the development of a set of recommended traffic damage indices applicable to Canadian Conditions. These recommended indices are outlined in Table 5-1.

Table 5-1: Proposed traffic damage indices for Canadian conditions

Highway classification	Fine grained soils			Coarse
	Wet freeze		Dry freeze	Average conditions
	High frost	Low Frost	High frost	
Major HWY	0,65	0,7	0,5	0,8
Other HWY	0,6	0,65	0,45	0,7
Local Roads	0,55	0,6	0,45	0,6
Munic. Roads	0,55	0,6	0,45	0,6

First, it should be noted that traffic levels for each road class have been removed from the matrix. As indicated earlier, traffic level does not appear to have any effect on the average traffic damage index. This factor has therefore been removed from the matrix. This simplification is also likely to facilitate the use of the damage indices for cost allocation studies.

Indices provided in Table 5-1 are essentially based on those given in Table 4-5, obtained from the calculation of traffic damage indices as described in section 4 of the report. They have however been smoothed to assure continuity across the matrix. Existing data points were used to interpolate and extrapolate values to cells where no observation was available. The influence of each individual factor, as quantified in the analysis described in section 5.1 was instrumental in inferring these values. Indices proposed for low volume roads are expected to be valid for municipal roads as well. This extrapolation is however only valid for municipal roads in rural areas. The use of traffic damage indices in the municipal environment is further discussed in section 5.5.

5.3 Comparison with ratios obtained from the literature

To our knowledge, the study done as part of this project is one of the most comprehensive study on the relative impact of traffic and climate on pavement damage. When compared with other studies, the results of the Transport Canada study appear to be consistent. Figure 5-2 illustrates the range of traffic damage indices obtained from the literature as compared with the values obtained in this study.

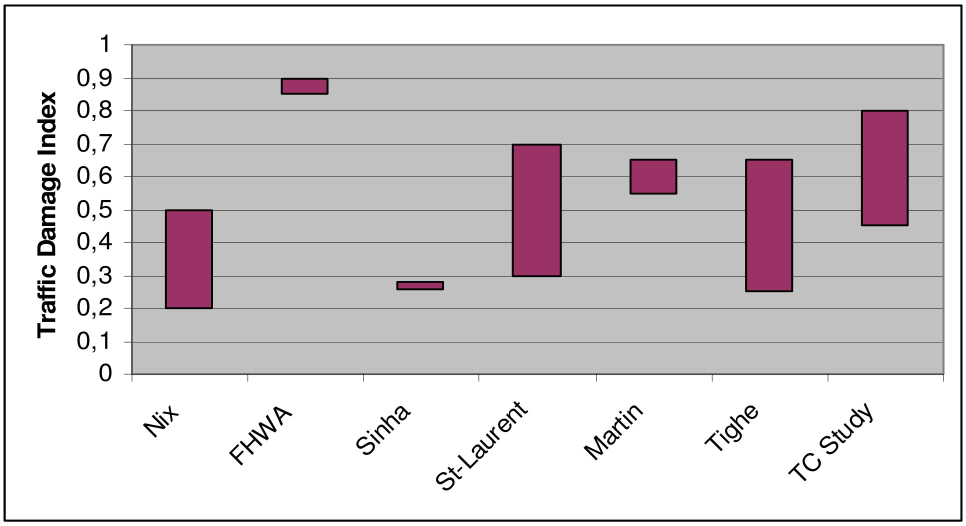

Figure 5-2: Comparison between traffic damage index obtained in the Transport Canada Study and those from other studies documented in the literature

The indices obtained in the *Transport Canada* study are significantly higher than those obtained by Nix in another Canadian study done for the Canadian Trucking Alliance. Very little information was found on Nix's study making it difficult to comment on the difference between the two studies. When compared to indices inferred from studies done by St-Laurent and Corbin (2003) and Tighe (2002), indices proposed in this study appear to be consistent considering that the two other studies are based on a single performance indicator (fatigue cracking and roughness respectively).

The proposed indices also appear to be consistent with the study conducted by Martin in Australia. The later study was the only comprehensive study found in the literature including mechanistic assessment combined with observations of real pavements. Pavements studied by Martin are however thin structures and climatic conditions prevailing in Australia are milder and less variable than those prevailing in Canada.

Finally, the proposed indices can not really be compared with those obtained from the two American studies (which are in total disagreement). The difference is probably due, in good part, to the indicators used in those studies (total costs and maintenance costs) which are very different in nature to those used in the Transport Canada study (condition index).

5.4 Validity of the methodology used in the study

Considering the time and the resources available for the project, the research team believes that the results obtained from the study are sound and meet the objectives of the project. The study however has several limitations that are likely to limit the reliability and the applicability of the traffic damage indices resulting from the study. The most important limitation is related to the lack of data available in existing databases on the performance of local roads and municipal roads. This shortfall is likely to reduce the reliability of the indices proposed for these categories of roads. The problem of the bias caused by the young pavement group obtained from the MTQ database was addressed by the application of a correction factor which is also likely to reduce the reliability of the indices obtained for those sections.

Several assumptions were made through the study. Each one of these assumption is a possible source of error in the calculation of the indices. Among other, it was assumed that the test sections were adequately designed for traffic and climate conditions prevailing at the site. Each case where pavement structure was not adequate will induce an error in the assessment of the indices. Other assumptions made on soils and pavement characteristics might have induced errors in the analysis.

5.5 Applicability of the traffic damage indices to other pavement

Pavement performance data applicable to Canadian conditions and readily available in databases had important limitations, particularly with respect to municipal pavements, surface treated roads, unpaved roads as well as concrete and composite pavements. The applicability of the indices to these types of pavements is therefore risky.

Municipal roads

There are three main categories of municipal roads: Urban arterials, residential streets and rural roads. The distresses used to calculate the traffic damage index in this study are all present in municipal context and the mechanisms involved are the same. Because of the presence of curbs, gutters and internal drainage systems, urban pavements are likely to be less affected by moisture effects. The presence of utility trenches is however likely to make these pavements behave differently with respect to roughness. The applicability of traffic damage indices to these roads can probably be done with a reasonable level of confidence if those differences are properly taken into consideration. In the absence of data for the validation of the traffic damage index in municipal conditions, the following recommendations are made:

- Indices proposed for local roads can probably be applied to municipal rural roads with asphalt concrete surfaces with a reasonable level of reliability;
- indices proposed for local roads should be reduced by approximately 20 before being applied to residential streets with a low level of reliability;
- indices proposed for « other highways » can probably be applied to urban arterials with a low level of reliability.

Other types of roads

It is not recommended to use the proposed traffic damage indices to bituminous treated roads, unsurfaced roads as well as rigid and semi rigid pavements due to the difference in damage mechanisms acting on those roads compared to the ones acting on flexible pavements.

Another limit of the road performance data used in the present study is due to the various management of maintenance by the political authorities (provinces, municipalities, cities). The roads in the databases are generally arteries of importance and the maintenance are made in a more systematic way than the average of the whole road network. The damage ratios are doubtless influenced by the history of maintenance of the roads. The extrapolation of the ratios obtained in the study for roads of smaller importance and whose mode of management is unknown remains risky.

6. FUTURE WORK

The study done as part of the project awarded to BPR consulting group and Laval University was done with limited resources in a very short timeframe. Considering these constraints, the project has led to interesting results with respect to relative damage caused to pavements by traffic and climate. It is however recommended to continue the research effort in order to adequately cover all pavement types used and to assure a good coverage of Canadian conditions. The following activities are recommended in order to obtain more accurate damage indices covering the full range of the Canadian road networks:

1. Review and refine the analysis method
   - Examine the possibility to use the 2002 MEPDG software to perform the complete analysis of pavement damage;
   - assess the relative damage caused by light-weight passenger vehicles (surface wear);
   - consider doing an assessment of the structural adequacy of the pavement test sections used in the analysis (overdesigned vs underdesigned pavement sections);
   - perform additional simulations and sensitivity analysis using additional sets of weights for the performance indicators.
2. Collect data on pavement types missing from existing Canadian databases
   - With the collaboration of provincial and municipal agencies, sample and document test sections in the following categories:
     a) Exposed concrete pavements;
     b) semi-rigid pavements;
     c) bituminous treated roads;
     d) unpaved roads;
     e) residential streets;
     f) urban arterials.
3. Update, refine and expand the table of traffic damage indices in order to fully address road wear in the Canadian context.

7. CONCLUSION AND RECOMMENDATIONS

As part of a mandate awarded by Transport Canada to BPR consulting group and Laval University, the effect of traffic and climate on road wear was investigated. The objective of the study was to **provide estimates on the nature of the contribution of traffic and climate to wear of pavements.** The project involved a detailed review of existing information available in the literature. It also involved a review of existing design practices in Canada and of available data to support the assessment of pavement deterioration, validation and calibration of performance models. The project also involves running a limited number of performance simulations in order to assess preliminary estimates of rates of wear to be attributed to traffic and climate. The main conclusions of the project are the following:

- Information available from the literature on the relative contribution of traffic and climate on pavement deterioration is scarce and damage ratios reported or inferred from these studies are variable and somewhat inconsistent.
- A rigorous study methodology has been developed for this study. The general approach is based on observations on test sections and mechanistic analysis to separate the effects of climate and traffic on the observed pavement damage. The study has led to the development of a table of traffic damage indices for various Canadian conditions.
- Traffic damage indices appear to be a function of pavement age. In order to compensate the bias caused by the use of a group of relatively young pavements in the analysis, a correction factor, inferred from the relationship between damage index and age, has been applied to all sections included in the study.
- Several factors appear to have an influence on the traffic damage index from the most important influence to the least, these factors are:
  a) Moisture;
  b) road classification;
  c) soil type;
  d) frost intensity.
- Traffic damage indices proposed for Canadian conditions vary from 0,45 for local roads on fine grained soils in dry, high-frost conditions to 0,8 for major highways on coarse grained soils. These indices are supported by indices reported or inferred from a few other studies. They however are inconsistent with indices reported in a few other studies.

The proposed indices have a level of reliability ranging from fair to low due to the limited resources and time available to complete the study. They should be used with caution, especially in the municipal context. The use of the proposed indices to assess the relative damage caused by traffic and climate to rigid and composite pavements as well as to bituminous treated and unsurfaced roads is not recommended. Additional work is needed to refine the indices calculated within the inference space covered in this study and to develop additional indices for situations not covered in this study.

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APPENDICES

APPENDIX 1

Literature review sheets

APPENDIX 2

Test site characteristics

APPENDIX 3

Damage simulation for all Canadian sites

APPENDIX 1

Literature review sheets

Literature review sheets

Reference:

Ontario Trucking Association, *Paying Our Fair Share: Today's Trucking Industry*

Summary:

This article explains why the Ontario Trucking Industry is one of the most taxed in this province. It demonstrated how the trucking industry already pays its fair share for highway maintenance and how trucks cannot be held solely responsible for the highway deteriorations.

According to the Ontario Trucking Industry, the climatic conditions, especially the freezing and thawing cycles and the variations in moisture, are the major causes of pavement deterioration. Traffic loads and differences between cars and trucks axles are of little importance provided that the pavement base is thick enougn. The results of a research work carried out by the Royal Commission on National Passenger Transportation tend to support this conclusion. It was found that the environmental factors are responsible for at least one half of the pavement deterioration on strong pavements (highways) and for almost all the deterioration on weaker pavements used for low volume roads. Futhermore, studies carried out by the Ontario Ministry of Transportation and by the University of Waterloo have concluded that trucks axle loads on higher volume roads do not have a significant influence on the road maintenance costs.

Ratio (% Climate / % Traffic) :

50% / 50% to mostly due to climate

Literature review sheets

Reference:

The Railway Association of Canada (2002) *Heavy Goods Vehicles : Infrastructure Costs and Revenue*, Research Paper, 38 p.

Summary:

This paper identifies what is known and unknown about infrastructures costs and revenues due to heavy roads vehicles. It compares results from studies made by the United State Department of Transportation (U.S. DOT) and by Fred Nix (for the Canadian Trucking Alliance).

The U.S. DOT model estimates that vehicles cause 85 to 90% of pavement damage and that the other 10 to 15% is due to weather conditions.
A research conducted by Nix shows that vehicles cause 20 to 50% of pavement damage while 50 to 80% is due to the weather conditions depending on pavement construction and traffic level. Nix concluded that weather, especially freezing and thawing cycles, is the main source of deterioration in Canada. He also observed that pavements are more vulnerable during spring thawing periods. He found no strong links between axle loads and pavement damage. It also appears that weather and poor soil conditions amplify rather than reduce the impact of heavy axles. Nix argues that, compared to the U.S., Canada's harsher climate and the higher number of freezing and thawing cycles reduce the importance of axle loadings on pavements. Finally, weather and axle loadings amplify rather than exclude each other's impact.

Notes:

Nix, F. (2001) *Weight-Distance Taxes*, prepared for Canadian Trucking Alliance.

Ratio (% Climate / % Traffic) :

10-15% / 85-90% by US DOT
50-80% / 20-50% by Nix

Literature review sheets

Reference:

Raymond, C., Tighe, S. et al.(2003), *Development of Canadian asphalt pavement deterioration models to benchmark performance*, Department of Civil Engineering, University of Waterloo, 7 p.

Summary:

The Canadian Long Term Pavement Performance (C-LTPP) study was initiated in 1989 and involves 24 different sites containing 65 sections constructed with various asphalt overlay rehabilitation treatments. The objective of this study is to investigate the impacts of the various alternative rehabilitation treatments on pavement roughness progression. Models, considering in-site and between-site factors, have been developed to predict pavement deterioration over the first 8 years of utilization. This study concludes that the site location is the main factor on the rate of pavement deterioration.

In order to develop the best model, analysis show that the variables used should be the annual freezing index, the annual number of days with precipitation and the accumulated ESAL applications after 8 years. These variables influence the site effect and consequently the rate of pavement deterioration. The site effect decreases with a larger freezing index, increases with more annual days with precipitation and increases with more ESALs. It was shown that annual freezing index provides the strongest influence in the model but has a weak statistical relationship.

Ratio (% Climate / % Traffic) :

No percentage was found. The study only states "site location is found to be the primary influence on the rate of pavement deterioration" (RAYMOND, 2003).

Literature review sheets

Reference:

Tighe, S. (2002), *Evaluation of subgrade and climatic zone influences on pavement performance in the Canadian Strategic Highway Program's (C-SHRP) Long-Term Pavement Performance (LTPP) study*, Canadian Geotechnical Journal, vol. 39, p.377-387.

Summary:

The Canadian Long Term Pavement Performance (C-LTPP) was initiated in 1989 and involves 24 different sites containing 65 sections constructed with various asphalt overlay rehabilitation treatments. This article describes impacts of the various treatments on pavement performance in terms of roughness progression under comparative weather, subgrade soil, and traffic loading conditions.

The main conclusions of this study are: (i) in wet, high-freeze zones, thinner overlays show a higher rate of roughness progression than thicker overlays; (ii) in dry, high-freeze zones, roughness progression for medium and thick overlays is relatively small; (ii) in wet, low freeze zones, thinner overlays combined with fine subgrade soils show the highest rate of roughness progression; (iv) traffic, using equivalent single axle loads, seemed to have a limited effect on all of the above. The last point is due to the fact that all the traffic used fell into the same category. Traffic was classified in two different levels: low and high. In this study, all the traffic fell into one level since 2000 000ESALs per year was the reference for high traffic.

Using the IRI as a performance index of pavements and considering only humid and low-freeze zones, it is possible to estimate ratios of road deterioration due to the climate and to the traffic. It has been found that climate is responsible for 60% to 75% of road deterioration as compared with 25% to 40% for traffic. When computing these ratios, it was assumed that fine subgrade soils are more influenced by climate than coarser ones.

Ratio (% Climate / % Traffic) :

75% / 25% to 60% / 40%

Literature review sheets

Reference:

Kenis, W., Wang, W., Liu, C., *Truck Pavement Interaction Research at FHWA (A Synopsis)*, The Railway Association of Canada, 9 p.

Summary:

The Truck Pavement Interaction (TPI) is a research program issued from the Federal Highway Administration (FHWA) of the United States. Its goal is to develop a better understanding of the interactions between heavy vehicles, climate and pavements. Topic areas include the combined effect of load and environment on pavement performance and pavement damage from non-load associated causes. This paper discusses and summarizes research activities of the program.

Ratio (% Climate / % Traffic) :

None.

Literature review sheets

Reference:

Federal Highway (1997) *Pavement Cost Allocation Methods*, Cost Allocation Study

Summary:

The cost allocation study made in the United States provides a table showing the different percentages of cost estimated to be attributable to non-load factors on flexible and rigid pavements. The study concludes that non-load costs represent a higher proportion of total costs on lower order systems than on higher order systems.

This study attribute higher cost responsibility to heavy vehicles than to light ones. Also, single axles contribute more to pavement costs than dual axles and, similarly, tandem axles contribute more than tridem axles for vehicles with comparable weight.

Ratio (% Climate / % Traffic) :

Pavement costs attributable to non-load factors:
Rural: 11% (highway) to 14.7% (local)
Urban: 10.1% (highway) to 13.9% (local)

Reference:

Martin, T. C. (2002) *Estimating heavy vehicles road wear costs for bituminous-surfaced arterial roads*, Journal of Transportation Engineering, March/April, vol. 128, n°2, p.103-110

Summary:

The objective of this Australian study was to estimate the road deterioration caused by heavy vehicles on fine grading hot-mix asphalt. Results were obtained from a statistical method (based on maintenance road costs and the road utilisation by trucks), a pavement deterioration model, and direct measurements.

Based on various maintenance costs relations obtained for secondary roads with asphalt surface treatments, the percentage of cost related to heavy load vehicles is 25% on rural roads and 60% on urban roads. Martin (1995) shows, with direct measurements taken on pavements, that 39% of the costs are due to heavy weight trucks both on rural and urban roads. When the performance model of the ARRB is used, the percentage estimated is about 65%. But, according to the author, recent estimates shows that heavy vehicles are responsible for about 55% to 65% of road deterioration.

Ratio (% Climate / % Traffic) :

35% / 65% to 45% / 55%

Literature review sheets

Reference:

Saint-Laurent, D., Gervais, C. (2003) *L'impact des restrictions de charge en période de dégel*, Innovation Transport, n° 18, p. 25-31

Summary:

This paper identifies the effects of load restrictions during the spring period on road deterioration. The results were based on various theoretical simulations.

According to many studies, 30 to 85% of all annual damages caused to roads occur during the spring thaw period. Usually, when less than 40% of annual damages occur during spring, pavements deteriorate at the same rate over summer and fall than during spring. The rate calculated is 0.025 of normal damages per week. This rate is usually found on highways and heavy traffic roads.

The simulation study shows that for a constant annual traffic without load restrictions, less important structures with lower traffic deteriorate at a rate of 0.0075 normalised damages per week. This rate is valid for weeks after the load restrictions in spring. During the thaw period, this rate goes up to 0.077. If those weaker structures would be in a free thaw environment, it is possible to estimate that only 30% of the damages would be due to the traffic. The climate is held responsible for up to 70% of all the damages on this type of structure.

Ratio (% Climate / % Traffic) :

30% / 70% to 70% / 30%

Literature review sheets

Reference:

Federal Highway Administration (1997) *Federal Highway Costs Allocation Study*, United States Department of Transportation.

Summary:

Usually, division of costs due to loads and environmental factors are the same for asphalt pavements and concrete pavements. But, there are some minor differences for certain types of roads. Cost associated with loads for rural roads are more important than the total cost for an urban pavement. It is estimated to be 10% on a rural road and more than 20% on an urban road.

In United States, taxes collected for roads maintenance represent about 11 billions dollars each year. Heavy weight vehicles pay about 80% of the bill to fix roads damages caused by them. Light vehicles and cars pay 10%.

Ratio (% Climate / % Traffic) :

10% / 90% to 15% / 85%

Literature review sheets

Reference:

Nix, F. (2001)*Weight-Distance taxes,* prepared for the Canadian Trucking Alliance, p. 34

Summary:

A study conducted by Nix (2001) shows that heavy weight vehicles are responsible for 20 to 50% of the total road damages while climate is responsible for 50 to 80% of those dames. The percentages depend on the quality of the road and type of traffic. Nix argues that the relation between the axle charge and road damages is weak due to the Canadian climate. Freezing and thawing cycles are the main source of road deterioration, especially during the spring thawing period. Nix argues that Canada's harsh climate along with the freezing and thawing cycles reduce the importance of axle loadings on pavements. Finally, weather and axle loadings amplify rather than exclude each other's impact

Ratio (% Climate / % Traffic) :

50% / 50% to 80% / 20%

Reference:

Sinha, L. and McCarthy, P. (2001) *Methodology to determine load and non-load related shares of highway pavement rehabilitation*, Transportation Research Record, n° 1747, p.79-88.

Summary:

The object of this paper is to study how the share of highway pavement rehabilitation is divided between load factors and environmental factors.

Various measurements, taken in Indiana from 1995 to 1997, were used to learn more about pavement performance. Road maintenance, rehabilitation and road conditions were reviewed. This allowed SINHA (2001) to estimate the percentage of road deterioration due to environmental factors and load factors. This study found that 28% of road rehabilitation expenses are due to loads while 72% are due to environmental factors.

Ratio (% Climate / % Traffic) :

72% / 28%

Reference:

Boilé, M., Ozbay, K., Narayanan, P. (2001) *Infrastructures Costas Attributable to Commercial Vehicles*, New Jersey Department of Transportation, report n° FHWA-NJ-2001-030, 66p.

Summary:

This report presents the results of a study on infrastructure costs associated with heavy vehicles. The first objective was to estimate, from a literature survey, the costs caused by heavy vehicles in highways. The second objective was to develop models to estimate the pavement deteriorations resulting from vehicle-pavement interactions.

The Federal Highway Cost Allocation Study analysed pavements and produced a Highway Performance Monitoring System database. This database was used to produce a model to estimate the shares of total costs that are related to non-load factors (pavement age, climate) rather than axle load. These costs were allocated in proportion to VMT (vehicle miles traveled) for each vehicle class. In general, the share of costs attributable to non-load factors is about the same for flexible and rigid pavements even if minor differences can be found between highway functional classes. Non-load costs represent about 10% on rural Interstates to more than 20% on urban collectors and local roads.

The Nation Pavement Cost Model used lower non-load percentage of costs. NAPCOM does not use the data from pavement sections for rural local roads. Instead, NAPCOM based their results on the rate of progression of individual types of pavement distress. Because their results are based on the interaction between axle loads and the environment, they obtain lower percentages. This paper concluded that NAPCOM would find higher percentages for non-load factors on these lower level roads if they would use the HPMS database.

This study also proposed a typical pavement deterioration system that would be composed of 3 sub-models:

1. Traffic Loading Simulation Model: To analyse effects of heavy vehicles on pavement that includes the following variables: axle load, type of tire, tire pressure, speed and suspension.
2. Analytical Model: To predict the deformation and stresses on pavement by simulated loading from the above model. Climatic conditions damaging pavement such as temperature, precipitation, frost heave and thermal cracking must be considered.

This study also proposes a Mathematical Model of Pavement Performance. This model take into account climatic and environmental factors. These factors are known to influence pavement performance. The influence of temperature and freezing and thawing

cycles, as well as their effects on outbound materials and subgrade, were thus included in this model.

Ratio (% Climate / % Traffic) :

10% / 90% to 20% / 80%

Reference:

Organisation for Economic Cooperation and Development (1988) *Heavy trucks, climate and pavement damage*, Road Transport Research, OECD Publications, Paris, 175 p.

Summary:

13 countries members of the OECD have supported this study. It describes the effects of heavy vehicles on the road pavement performance and also assess the combined effects of load and climatic conditions as causes of pavement distress.

This study concludes that pavement damages are due to vehicle loads and climatic factors. In the case of structural damages, it is impossible to distinguish between the damages caused by loads and the damages due to the climate since they occur at the same time and their influence varies over time. Temperature fluctuations in flexible pavement and variations of the water content in subgrade soil, combined with freezing and thawing cycle,s detrimentally influenced the mechanical properties of pavement structures. Thus, they amplify the effects of loads on pavements.

It was found that variations in traffic have only a little influence on the required road thickness. However, a slight increase in pavement thickness can lower the probability of distress and maintenance costs.

Ratio (% Climate / % Traffic) :

None

Literature review sheets

Reference:

Organisation for Economic Cooperation and Development (1997) *Dynamic interaction of heavy vehicles with roads and bridges*, final report of DIVINE concluding conference, Ottawa

Summary:

The objective of the DIVINE project (Dynamic Interaction between Vehicle and Infrastructure Experiment) is to provide scientific evidences of the influence of heavy vehicles, and their suspension system, on pavements and bridges.

According to the DIVINE results, current design pavement and evaluation techniques over-estimate the direct contribution of heavy vehicles loads to road deteriorations. This study concluded that it is difficult to distinguisn between the influences of the vehicle and of the pavement design since they should be considered in an interactive way.

The DIVINE project shows that spatial repeatability on a smooth road would increase total wheel loading at certain locations by about 10% and it was estimated that this could reduce the pavement service life at those locations by approximately 35 to 50%.

Experiments have shown that on thick pavements, a 10% load increase would produce a 7 to 12% increase in strain level. This implies that pavements wear increases significantly under traffic that constantly applies those loads. This study also discovered that dynamic axle load increments not only influence the pavement fatigue damage but it also increases the damage by up to 5% on roads of good evenness and up to 30 to 50% where evenness is poor.

Ratio (% Climate / % Traffic) :

None

APPENDIX 2

Test site characteristics

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Summary of the test site characteristics

Site identification				Traffic	Climate	Pavement layers (Summer / Fall) [3]				Degradations [4]						
Number	Province	Func. Class. [1]	Orig. constr.	mean annual kESAL	Type [2]	AC H(po) / M_R(ksi)	B H(po) / M_R(ksi)	SB H(po) / M_R(ksi)	Subgrade M_R(ksi)	Year	Ru (mm)	Fa (m)	Ro (m/km)	LC (m)	TC (m)	BC (m)
810404-1	Alberta	1	1977	12	DF-HF	6.5 / 510	3.1 / 50	9.8 / 30	13.1	1990	5.8	9.0	2.54	12.0	1.3	0.0
810404-2	Alberta	1	1977	12	DF-HF	6.6 / 510	3.1 / 50	9.8 / 30	13.1	1990	7.5	12.0	2.25	70.2	0.0	0.0
810404-3	Alberta	1	1977	12	DF-HF	6.9 / 510	3.1 / 50	9.8 / 30	13.1	1990	6.6	8.0	2.39	49.3	0.0	0.0
810404-4	Alberta	1	1977	12	DF-HF	7.6 / 510	3.1 / 50	9.8 / 30	13.1	1990	6.0	4.0	2.15	41.7	0.0	0.0
830403-1	Manitoba	2	1962	28	DF-HF	3.6 / 510	5.6 / 50	0.0 / 30	5.1	1990	9.2	20.6	3.18	195.1	344.6	0.0
830403-2	Manitoba	2	1962	28	DF-HF	3.6 / 510	5.6 / 50	0.0 / 30	5.1	1990	10.7	110.1	3.11	237.2	390.1	0.0
830403-3	Manitoba	2	1962	28	DF-HF	3.6 / 510	5.6 / 50	0.0 / 30	5.1	1990	8.4	122.1	3.83	149.8	454.5	0.0
840204-1	New-Brunswick	3	1975	16	WF-HF	3.7 / 510	3.9 / 50	6.7 / 30	8.0	1989	2.4	120.8	3.70	23.0	20.8	0.0
840204-2	New-Brunswick	3	1975	16	WF-HF	3.9 / 510	3.9 / 50	6.7 / 30	8.0	1989	1.2	6.0	3.00	34.1	38.4	0.0
840604-1	New-Brunswick	1	1966	565	DF-HF	4.5 / 510	6.5 / 50	13.6 / 30	18.9	1989	6.4	52.8	2.30	47.1	9.6	0.0
840604-2	New-Brunswick	1	1966	565	DF-HF	3.4 / 510	6.5 / 50	13.6 / 30	18.9	1989	9.5	18.0	1.80	110.1	11.3	0.0
840604-3	New-Brunswick	1	1966	565	DF-HF	4.1 / 510	6.5 / 50	13.6 / 30	18.9	1989	6.4	5.5	1.60	43.3	11.3	0.0
840604-4	New-Brunswick	1	1966	565	DF-HF	4.5 / 510	6.5 / 50	13.6 / 30	18.9	1989	5.4	26.4	1.90	31.5	14.3	0.0
850201-1	Newfoundland	1	1965	24	WF-HF	2.5 / 510	10.2 / 50	15.7 / 30	18.1	1989	8.2	82.8	3.20	9.0	15.6	0.0
850201-2	Newfoundland	1	1965	24	WF-HF	2.0 / 510	10.2 / 50	15.7 / 30	18.1	1989	12.5	56.5	3.40	25.9	24.8	0.0
850206-1	Newfoundland	1	1965	24	WF-HF	3.6 / 510	10.2 / 50	15.7 / 30	19.6	1990	1.7	127.3	2.40	63.0	33.3	0.0
850206-2	Newfoundland	1	1965	24	WF-HF	3.7 / 510	10.2 / 50	15.7 / 30	19.6	1990	9.4	163.4	2.90	2.9	29.4	0.0
850601-1	Newfoundland	1	1960	30	WF-HF	6.0 / 510	7.9 / 50	17.7 / 30	17.4	1989	9.8	17.8	1.66	66.5	0.0	0.0
850601-2	Newfoundland	1	1960	30	WF-HF	6.2 / 510	7.9 / 50	17.7 / 30	17.4	1989	13.6	5.1	1.46	15.6	0.0	0.0
860501-1	Nova-Scotia	1	1970	437	WF-LF	6.2 / 510	12.2 / 50	3.1 / 30	16.0	1989	6.1	24.0	1.70	27.4	0.0	0.0
860501-2	Nova-Scotia	1	1970	437	WF-LF	6.9 / 510	12.2 / 50	3.1 / 30	16.0	1989	3.1	1.0	1.40	68.5	0.0	0.0
860501-3	Nova-Scotia	1	1970	437	WF-LF	5.9 / 510	12.2 / 50	3.1 / 30	16.0	1989	1.9	4.3	1.40	68.2	0.0	0.0
860603-1	Nova-Scotia	1	1975	98	WF-LF	7.1 / 510	13.8 / 50	10.6 / 30	18.9	1989	11.5	97.0	5.90	8.4	13.8	0.0
860603-2	Nova-Scotia	1	1975	98	WF-LF	5.4 / 510	13.8 / 50	10.6 / 30	18.9	1989	9.4	22.1	3.10	2.0	0.0	0.0
860603-3	Nova-Scotia	1	1975	98	WF-LF	6.4 / 510	13.8 / 50	10.6 / 30	18.9	1989	2.2	3.0	1.85	0.0	0.0	0.0
870102-1	Ontario	2	1967	14	WF-LF	6.6 / 510	18.3 / 50	4.4 / 30	8.0	1989	22.2	156.0	3.40	10.0	118.9	2.1
870102-2	Ontario	2	1967	14	WF-LF	6.6 / 510	18.3 / 50	4.4 / 30	8.0	1989	28.0	67.0	3.20	58.7	118.2	9.0
900402-2	Saskatchewan	3	1963	133	DF-HF	5.7 / 510	5.5 / 50	5.1 / 30	11.6	1989	10.6	15.2	2.60	252.4	251.3	0.0
900802-1	Saskatchewan	1	1968	209	DF-HF	4.8 / 510	4.7 / 50	7.5 / 30	10.9	1990	7.3	4.0	2.00	153.7	226.8	0.0
900802-2	Saskatchewan	1	1968	209	DF-HF	4.6 / 510	4.7 / 50	7.5 / 30	10.9	1990	5.1	6.0	2.30	150.0	273.1	0.0
900803-1	Saskatchewan	1	1984	238	DF-HF	3.0 / 510	5.9 / 50	5.5 / 30	5.8	1989	14.2	138.0	2.18	107.9	290.3	0.0
900803-2	Saskatchewan	1	1984	238	DF-HF	3.0 / 510	5.9 / 50	5.5 / 30	5.8	1989	7.7	169.5	2.30	120.0	215.0	0.0
34E98T	Quebec	2	1998	25	WF-HF	4.5 / 510	5.9 / 50	23.6 / 30	7.3	2003	3.5	153.5	1.47	65.3	72.3	0.0
53E93M14	Quebec	2	1994	184	WF-HF	4.5 / 510	13.8 / 50	17.7 / 30	5.5	2003	9.5	143.6	1.66	3.8	23.8	0.0
53V96D11	Quebec	1	1994	694	WF-HF	6.7 / 510	15.7 / 50	36.6 / 30	10.9	2002	9.1	12.3	0.99	2.1	0.0	0.0
54V96D11	Quebec	1	1995	673	WF-HF	7.5 / 510	31.9 / 50	31.5 / 30	10.9	2002	4.6	91.8	1.13	15.7	16.2	0.0
63E98D11	Quebec	2	1998	622	WF-HF	7.1 / 510	13.8 / 50	17.7 / 30	7.3	2004	6.7	2.8	1.43	1.7	3.9	0.0
89090	Quebec	2	1996	433	WF-HF	5.1 / 510	14.8 / 50	11.8 / 30	26.1	2002	9.3	10.4	2.08	28.0	7.7	0.0
891021	Quebec	1	1983	488	WF-HF	5.1 / 510	14.8 / 50	0.0 / 30	10.9	1992	9.2	129.5	1.75	161.9	113.5	0.0
892011	Quebec	3	1979	52	WF-HF	6.3 / 510	6.7 / 50	32.2 / 30	7.3	2003	9.4	219.8	3.30	6.0	175.0	0.0
89A340	Quebec	1	1983	488	WF-HF	5.1 / 510	14.8 / 50	0.0 / 30	10.9	1995	14.5	140.7	2.74	51.8	48.4	0.0
SPE5423	Quebec	1	1992	404	WF-HF	4.7 / 510	14.8 / 50	14.8 / 30	26.1	2003	6.3	315.7	2.23	367.9	158.8	0.0

(1) 1 = Major HWY
2 = Other HWY
3 = Local roads

(2) DF-HF = dry freeze high frost
WF-HF = wet freeze high frost
WF-LF = wet freeze low frost

(3) AC = asphalt concrete
B = base
SB = subbase

(4) Ru = rutting LC = longitudinal cracking
Fa = fatigue TC = transverse cracking
Ro = roghnes BC = bloc cracking

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
810404-1	Alberta	1	1990	1977

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic					
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1990-1999	5200	18	936	12

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1665	Winter	37	526
		Spring	8	
		Summer/fall	55	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
195.8	5.9	13.1	Sandy and silty clay	87.8	68	21

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.5	1500	755	510	150	3.6
B	3.1	100	45	50		
SB	9.8	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		5.8 mm	NA	23.2 %
Fa		9.0 m	1.7 % lane area	6.7 %
Ro		2.54 m/km	NA	NA
LC	Center line	12.0 m	80.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		1.3 m	8.7 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class.[1]	Overlay	Orig. constr.
810404-2	Alberta	1	1990	1977

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1990-1999	5200	18	936	12

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1665	Winter	37	526
		Spring	8	
		Summer/fall	55	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
195.8	5.9	13.1	Sandy and silty clay	87.8	68	21

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.6	1500	755	510	150	3.6
B	3.1	100	45	50		
SB	9.8	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		7.5 mm	NA	30.0 %
Fa		12.0 m	2.2 % lane area	8.9 %
Ro		2.25 m/km	NA	NA
LC	Center line	70.2 m	468.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
810404-3	Alberta	1	1990	1977

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1990-1999	5200	18	936	12

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1665	Winter	37	526
		Spring	8	
		Summer/fall	55	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
195.8	5.9	13.1	Sandy and silty clay	87.8	68	21

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.9	1500	755	510	150	3.6
B	3.1	100	45	50		
SB	9.8	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.6 mm	NA	26.4 %
Fa		8.0 m	1.5 % lane area	5.9 %
Ro		2.39 m/km	NA	NA
LC	Center line	49.3 m	328.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

P:\M610407\DOC-PROJ\60\60COL\Sites modelisation sans hiver\[C-SHRP_810404-3_calcul.xls]Site parameters

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
810404-4	Alberta	1	1990	1977

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1990-1999	5200	18	936	12

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1665	Winter	37	526
		Spring	8	
		Summer/fall	55	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
195.8	5.9	13.1	Sandy and silty clay	87.8	68	21

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	7.6	1500	755	510	150	3.6
B	3.1	100	45	50		
SB	9.8	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.0 mm	NA	24.0 %
Fa		4.0 m	0.7 % lane area	3.0 %
Ro		2.15 m/km	NA	NA
LC	Center line	41.7 m	278.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
830403-1	Manitoba	6	1990	1962

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1992	1175	8.2	96	28

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1666	Winter	43	382
		Spring	8	
		Summer/fall	49	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
76.1	2.3	5.1	Stiff brown sandy clay with some stone (0.340 retained), soft black organic clay (0.410 retained)	91.5	80	29

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.6	1500	755	510	150	3.7
B	5.6	100	45	50		
SB	-	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.2 mm	NA	36.8 %
Fa		20.6 m	3.7 % lane area	15.3 %
Ro		3.184 m/km	NA	NA
LC	Center line	119.1 m	1300.7 m/km	NA
	Meandering	12 m		
	Mid-lane	64 m		
TC		344.6 m	2297.3 m/km	NA
BC		0 m	0.0 % lane area	NA

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
830403-2	Manitoba	6	1990	1962

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1992	1175	8.2	96	28

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1666	Winter	43	382
		Spring	8	
		Summer/fall	49	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
76.1	2.3	5.1	Stiff brown sandy clay with some stone (0.340 retained), soft black organic clay (0.410 retained)	91.5	80	29

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.6	1500	755	510	150	3.7
B	5.6	100	45	50		
SB	-	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		10.7 mm	NA	42.8 %
Fa		110.1 m	19.8 % lane area	81.6 %
Ro		3.106 m/km	NA	NA
LC	Center line	139.1 m	1581.3 m/km	NA
	Meandering	22.1 m		
	Mid-lane	76 m		
TC		390.1 m	2600.7 m/km	NA
BC		0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
830403-3	Manitoba	6	1990	1962

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic					
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1992	1175	8.2	96	28

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1666	Winter	43	382
		Spring	8	
		Summer/fall	49	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
76.1	2.3	5.1	Stiff brown sandy clay with some stone (0.340 retained), soft black organic clay (0.410 retained)	91.5	80	29

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.6	1500	755	510	150	3.7
B	5.6	100	45	50		
SB	-	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		8.4 mm	NA	33.6 %
Fa		122.1 m	22.0 % lane area	90.4 %
Ro		3.827 m/km	NA	NA
LC	Center line	74.4 m	998.7 m/km	NA
	Meandering	17.2 m		
	Mid-lane	58.2 m		
TC		454.5 m	3030.0 m/km	NA
BC		0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840204-1	New-Brunswick	8	1989	1975

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	11200	4.9	548.8	16

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF	875	Winter	36	1069.7
		Spring	17	
		Summer/fall	47	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
119.6	3.6	8.0	Silty sand and clay	22.1	15	0

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.7	1500	755	510	150	3.8
B	3.9	100	45	50		
SB	6.7	80	15	30		

Degradations: 1989

Degradation type		Degradation value	Degradation extension	Damage
Ru		2.4 mm	NA	9.6 %
Fa		120.8 m	21.2 % lane area	89.5 %
Ro		3.7 m/km	NA	NA
LC	Center line	23.0 m	153.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		20.8 m	138.7 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840204-2	New-Brunswick	8	1989	1975

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	11200	4.9	548.8	16

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF	875	Winter	36	1069.7
		Spring	17	
		Summer/fall	47	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
119.6	3.6	8.0	Silty sand and clay	22.1	15	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.9	1500	755	510	150	3.8
B	3.9	100	45	50		
SB	6.7	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		1.2 mm	NA	4.8 %
Fa		6.0 m	1.1 % lane area	4.4 %
Ro		3.0 m/km	NA	NA
LC	Center line	20.9 m	227.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	13.2 m		
TC		38.4 m	256.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840604-1	New-Brunswick	1	1989	1966

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	5250	22.5	1181	565

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1030	Winter	33	1070
		Spring	17	
		Summer/fall	50	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	8.5	18.9	Silty sand and gravel, trace of clay	34.9	28	2

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.5	1500	755	510	150	3.75
B	6.5	100	45	50		
SB	13.6	80	15	30		

Degradations: 1989

Degradation type		Degradation value	Degradation extension	Damage
Ru		6.4 mm	NA	25.6 %
Fa		52.8 m	9.4 % lane area	39.1 %
Ro		2.3 m/km	NA	NA
LC	Center line	47.1 m	314.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		9.6 m	64.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840604-2	New-Brunswick	1	1989	1966

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	5250	22.5	1181	565

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1030	Winter	33	1070
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	8.5	18.9	Silty sand and gravel, trace of clay	34.9	28	2

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.4	1500	755	510	150	3.75
B	6.5	100	45	50		
SB	13.6	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.5 mm	NA	38.0 %
Fa		18.0 m	3.2 % lane area	13.3 %
Ro		1.8 m/km	NA	NA
LC	Center line	110.1 m	734.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		11.3 m	75.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840604-3	New-Brunswick	1	1989	1966

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	5250	22.5	1181	565

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1030	Winter	33	1070
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	8.5	18.9	Silty sand and gravel, trace of clay	34.9	28	2

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.1	1500	755	510	150	3.75
B	6.5	100	45	50		
SB	13.6	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.4 mm	NA	25.6 %
Fa		5.5 m	1.0 % lane area	4.1 %
Ro		1.6 m/km	NA	NA
LC	Center line	43.3 m	288.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		11.3 m	75.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. [1]	Overlay	Orig. constr.
840604-4	New-Brunswick	1	1989	1966

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	5250	22.5	1181	565

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1030	Winter	33	1070
		Spring	17	
		Summer/fall	50	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	8.5	18.9	Silty sand and gravel, trace of clay	34.9	28	2

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.5	1500	755	510	150	3.75
B	6.5	100	45	50		
SB	13.6	80	15	30		

Degradations: 1989

Degradation type		Degradation value	Degradation extension	Damage
Ru		5.4 mm	NA	21.6 %
Fa		26.4 m	4.7 % lane area	19.6 %
Ro		1.9 m/km	NA	NA
LC	Center line	31.5 m	210.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		14.3 m	95.6 m/km	NA
BC		0.0 m	0.0 % lane area	NA

P:\M610407\DOC-PROJ\50\50CCL\Sites modelisation sans hiver\[C-SHRP_840604-4_calcul.xls]Site parameters

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850201-1	Newfounland	1	1989	1965

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	2800	11.5	322	23.5

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1000	Winter	33	1180
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
271.9	10.0	18.1	Silty gravel with sand	27.5	4	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	2.5	1500	755	510	150	3.75
B	10.2	100	45	50		
SB	15.7	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		8.2 mm	NA	32.8 %
Fa		82.8 m	14.7 % lane area	61.3 %
Ro		3.20 m/km	NA	NA
LC	Center line	7.0 m	60.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	2.0 m		
TC		15.6 m	103.7 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850201-2	Newfounland	1	1989	1965

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	2800	11.5	322	23.5

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1000	Winter	33	1180
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
271.9	10.0	18.1	Silty gravel with sand	27.5	4	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	2.0	1500	755	510	150	3.75
B	10.2	100	45	50		
SB	15.7	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		12.5 mm	NA	50.0 %
Fa		56.5 m	10.0 % lane area	41.9 %
Ro		3.40 m/km	NA	NA
LC	Center line	4.9 m	172.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	21.0 m		
TC		24.8 m	165.6 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850206-1	Newfoundland	1	1990	1965

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	2500	13	325	23.5

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1500	Winter	35	1251
		Spring	17	
		Summer/fall	48	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
293.6	8.8	19.6	Silty gravel with sand	27.5	7.3	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.6	1500	755	510	150	3.75
B	10.2	100	45	50		
SB	15.7	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		1.7 mm	NA	6.8 %
Fa		127.3 m	22.6 % lane area	94.3 %
Ro		2.4 m/km	NA	NA
LC	Center line	61.6 m	420.0 m/km	NA
	Meandering	1.4 m		
	Mid-lane	0.0 m		
TC		33.3 m	222.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850206-2	Newfoundland	1	1990	1965

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	2500	13	325	23.5

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1500	Winter	35	1251
		Spring	17	
		Summer/fall	48	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
293.6	8.8	19.6	Silty gravel with sand	27.5	7.3	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.7	1500	755	510	150	3.75
B	10.2	100	45	50		
SB	15.7	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.4 mm	NA	37.6 %
Fa		163.4 m	29.0 % lane area	121.0 %
Ro		2.9 m/km	NA	NA
LC	Center line	2.9 m	19.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		29.4 m	196.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850601-1	Newfounland	1	1989	1960

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	9000	5.5	495	30

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1000	Winter	33	1418
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
261.0	9.6	17.4	Poorly grade gravel	3	0.8	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.0	1500	755	510	150	3.75
B	7.9	100	45	50		
SB	17.7	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.8 mm	NA	39.2 %
Fa		17.8 m	3.2 % lane area	13.2 %
Ro		1.66 m/km	NA	NA
LC	Center line	63.3 m	443.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	3.2 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
850601-2	Newfounland	1	1989	1960

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1992-1998	9000	5.5	495	30

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1000	Winter	33	1418
		Spring	17	
		Summer/fall	50	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
261.0	9.6	17.4	Poorly grade gravel	3	0.8	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.2	1500	755	510	150	3.75
B	7.9	100	45	50		
SB	17.7	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		13.6 mm	NA	54.4 %
Fa		5.1 m	0.9 % lane area	3.8 %
Ro		1.46 m/km	NA	NA
LC	Center line	15.6 m	104.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860501-1	Nova-Scotia	1	1989	1970

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	14000	12.5	1750	437

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	746	Winter	32	1184.63
		Spring	17	
		Summer/fall	51	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
239.3	7.2	16.0	Sandy clay with gravel	47	32	6

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.2	1500	755	510	150	3.8
B	12.2	100	45	50		
SB	3.1	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.1 mm	NA	24.4 %
Fa		24.0 m	4.2 % lane area	17.8 %
Ro		1.7 m/km	NA	NA
LC	Center line	27.4 m	182.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860501-2	Nova-Scotia	1	1989	1970

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	14000	12.5	1750	437

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	746	Winter	32	1184.63
		Spring	17	
		Summer/fall	51	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
239.3	7.2	16.0	Sandy clay with gravel	47	32	6

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.9	1500	755	510	150	3.8
B	12.2	100	45	50		
SB	3.1	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		3.1 mm	NA	12.4 %
Fa		1.0 m	0.2 % lane area	0.7 %
Ro		1.4 m/km	NA	NA
LC	Center line	68.5 m	456.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860501-3	Nova-Scotia	1	1989	1970

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	14000	12.5	1750	437

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	746	Winter	32	1184.63
		Spring	17	
		Summer/fall	51	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
239.3	7.2	16.0	Sandy clay with gravel	47	32	6

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.9	1500	755	510	150	3.8
B	12.2	100	45	50		
SB	3.1	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		1.9 mm	NA	7.6 %
Fa		4.3 m	0.8 % lane area	3.2 %
Ro		1.4 m/km	NA	NA
LC	Center line	68.2 m	454.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860603-1	Nova-Scotia	1	1989	1975

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic					
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	4250	9	382.5	97.66

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	526	Winter	25	1217
		Spring	17	
		Summer/fall	58	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	10.4	18.9	Silty sand with gravel	9	5	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	7.1	1500	755	510	150	3.15
B	13.8	100	45	50		
SB	10.6	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		11.5 mm	NA	46.0 %
Fa		97.0 m	20.5 % lane area	71.9 %
Ro		5.90 m/km	NA	NA
LC	Center line	2.8 m	56.1 m/km	NA
	Meandering	5.6 m		
	Mid-lane	0.0 m		
TC		13.8 m	91.8 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860603-2	Nova-Scotia	1	1989	1975

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	4250	9	382.5	97.66

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	526	Winter	25	1217
		Spring	17	
		Summer/fall	58	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	10.4	18.9	Silty sand with gravel	9	5	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.4	1500	755	510	150	3.15
B	13.8	100	45	50		
SB	10.6	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.4 mm	NA	37.6 %
Fa		22.1 m	4.7 % lane area	16.4 %
Ro		3.10 m/km	NA	NA
LC	Center line	0.0 m	13.3 m/km	NA
	Meandering	2.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
860603-3	Nova-Scotia	1	1989	1975

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	4250	9	382.5	97.66

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	526	Winter	25	1217
		Spring	17	
		Summer/fall	58	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
282.8	10.4	18.9	Silty sand with gravel	9	5	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.4	1500	755	510	150	3.15
B	13.8	100	45	50		
SB	10.6	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		2.2 mm	NA	8.8 %
Fa		3.0 m	0.6 % lane area	2.2 %
Ro		1.85 m/km	NA	NA
LC	Center line	0.0 m	0.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		0.0 m	0.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
870102-1	Ontario	6	1989	1967

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1993	1150	14.5	166.8	14

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	875	Winter	24	822
		Spring	17	
		Summer/fall	59	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
119.6	3.6	8.0	Clay	94.6	86	34

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.6	1500	755	510	150	3.4
B	18.3	100	45	50		
SB	4.4	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		22.2 mm	NA	88.8 %
Fa		156.0 m	30.6 % lane area	115.6 %
Ro		3.4 m/km	NA	NA
LC	Center line	3.8 m	66.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	6.2 m		
TC		118.9 m	792.7 m/km	NA
BC		2.1 m	1.4 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. [1]	Overlay	Orig. constr.
870102-2	Ontario	6	1989	1967

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1993	1150	14.5	166.8	14

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-LF	875	Winter	24	822
		Spring	17	
		Summer/fall	59	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
119.6	3.6	8.0	Clay	94.6	86	34

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.6	1500	755	510	150	3.4
B	18.3	100	45	50		
SB	4.4	80	15	30		

Degradations: 1989

Degradation type		Degradation value	Degradation extension	Damage
Ru		28.0 mm	NA	112.0 %
Fa		67.0 m	13.1 % lane area	49.6 %
Ro		3.2 m/km	NA	NA
LC	Center line	58.7 m	391.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		118.2 m	788.0 m/km	NA
BC		9.0 m	6.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
900402-2	Saskatchewan	7	1989	1963

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	2650	13	344.5	133

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1775	Winter	40	358
		Spring	8	
		Summer/fall	52	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
174.0	5.2	11.6	Sandy silt with rock	67.5	29	10.2

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.7	1500	755	510	150	3.35
B	5.5	100	45	50		
SB	5.1	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		10.6 mm	NA	42.4 %
Fa		15.2 m	3.0 % lane area	11.3 %
Ro		2.6 m/km	NA	NA
LC	Center line	65.0 m	1682.7 m/km	NA
	Meandering	184.9 m		
	Mid-lane	2.5 m		
TC		251.3 m	1675.3 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
900802-1	Saskatchewan	2	1989	1968

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	2500	15	375	209

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1950	Winter	43	457
		Spring	8	
		Summer/fall	49	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.1	4.9	10.9	Sandy silt	67.5	29	10.2

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.8	1500	755	510	150	3.65
B	4.7	100	45	50		
SB	7.5	80	15	30		

Degradations: 1990				
Degradation type		Degradation value	Degradation extension	Damage
Ru		7.3 mm	NA	29.2 %
Fa		4.0 m	0.7 % lane area	3.0 %
Ro		2.0 m/km	NA	NA
LC	Center line	153.7 m	1024.7 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		226.8 m	1512.0 m/km	NA
BC		0.0 m	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. [1]	Overlay	Orig. constr.
900802-2	Saskatchewan	2	1989	1968

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	2500	15	375	209

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1950	Winter	43	457
		Spring	8	
		Summer/fall	49	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.1	4.9	10.9	Sandy silt	67.5	29	10.2

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.6	1500	755	510	150	3.65
B	4.7	100	45	50		
SB	7.5	80	15	30		

Degradations: 1989

Degradation type		Degradation value	Degradation extension	Damage
Ru		5.1 mm	NA	20.4 %
Fa		6.0 m	1.1 % lane area	4.4 %
Ro		2.3 m/km	NA	NA
LC	Center line	150.0 m	1000.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		273.1 m	1820.7 m/km	NA
BC		0.0 m	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
900803-1	Saskatchewan	1	1989	1984

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	2500	19	475	237.66

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1800	Winter	44	468
		Spring	8	
		Summer/fall	48	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
87.0	3.2	5.8	Clayey gravel with sandy and clayey silt	30	48	19.1

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.0	1500	755	510	150	3.7
B	5.9	100	45	50		
SB	5.5	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		14.2 mm	NA	56.8 %
Fa		138.0 m	24.9 % lane area	102.2 %
Ro		2.18 m/km	NA	NA
LC	Center line	107.9 m	719.3 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		290.3 m	1935.1 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
900803-2	Saskatchewan	1	1989	1984

(1) 1 = Rural principal arterial - Interstate = Major HWY
2 = Rural principal arterial - Other = Major HWY
6 = Rural minor arterial = Other HWY
7 = Rural major collector = Local roads
8 = Rural minor collector = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
1989-1997	2500	19	475	237.66

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
DF-HF	1800	Winter	44	468
		Spring	8	
		Summer/fall	48	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
87.0	3.2	5.8	Clayey gravel with sandy and clayey silt		48	19.1

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	3.0	1500	755	510	150	3.7
B	5.9	100	45	50		
SB	5.5	80	15	30		

Degradations: 1989				
Degradation type		Degradation value	Degradation extension	Damage
Ru		7.7 mm	NA	30.8 %
Fa		169.5 m	30.5 % lane area	125.6 %
Ro		2.30 m/km	NA	NA
LC	Center line	120.0 m	800.0 m/km	NA
	Meandering	0.0 m		
	Mid-lane	0.0 m		
TC		215.0 m	1433.1 m/km	NA
BC		0.0 m	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
34E98T	Quebec	2		1998

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	577.9	9	52.011	24.8

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1260	Winter	48	1066
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
109.5	3.3	7.3	Silty sand whith gravel	39.6	11	5

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.5	1500	755	510	150	3.3
B	5.9	100	45	50		
SB	23.6	80	15	30		

Degradations: 2003				
Degradation type		Degradation value	Degradation extension	Damage
Ru		3.5 mm	NA	14.0 %
Fa		153.5 m	31.0 % lane area	113.7 %
Ro		1.47 m/km	NA	NA
LC	Center line	65.3 m	435.6 m/km	NA
	Meandering			
	Mid-lane			
TC		72.3 m	481.8 m/km	NA
BC		m²	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
53E93M14	Quebec	2		1994

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	828.3	19	157.377	184

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1100	Winter	48	954.3
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
82.5	2.5	5.5	Low plasticity sandy clay(CL)	69	18	5

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.5	1500	755	510	150	3.6
B	13.8	100	45	50		
SB	17.7	80	15	30		

Degradations: 2003				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.5 mm	NA	38.0 %
Fa		143.6 m	26.6 % lane area	106.4 %
Ro		1.66 m/km	NA	NA
LC	Center line	3.8 m	25.2 m/km	NA
	Meandering			
	Mid-lane			
TC		23.8 m	158.4 m/km	NA
BC		m²	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification

Number	Province	Func. Class. (1)	Overlay	Orig. constr.
53V96D11	Quebec	1		1994

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic

Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	38270.4	8	3061.632	693.5

Climate

Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	974	Winter	48	902.9
		Spring	17	
		Summer/fall	35	

Subgrade

M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.5	4.9	10.9	Clayed till (SC)	25	7	5

Site description

Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.7	1500	755	510	150	3.6
B	15.7	100	45	50		
SB	36.6	80	15	30		

Degradations: 2002

Degradation type		Degradation value	Degradation extension	Damage
Ru		9.1 mm	NA	36.4 %
Fa		12.3 m	2.3 % lane area	9.1 %
Ro		0.99 m/km	NA	NA
LC	Center line	2.1 m	13.7 m/km	NA
	Meandering			
	Mid-lane			
TC		0.0 m	0.0 m/km	NA
BC		m²	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
54V96D11	Quebec	1		1995

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	10050	12	1206	673.4

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	810	Winter	48	902.9
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.5	4.9	10.9	Low plasticity clay with sand (CL)	83.2	22	10

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	7.5	1500	755	510	150	3.6
B	31.9	100	45	50		
SB	31.5	80	15	30		

Degradations: 2002				
Degradation type		Degradation value	Degradation extension	Damage
Ru		4.6 mm	NA	18.4 %
Fa		91.8 m	17.0 % lane area	68.0 %
Ro		1.13 m/km	NA	NA
LC	Center line	15.7 m	104.4 m/km	NA
	Meandering			
	Mid-lane			
TC		16.2 m	108.0 m/km	NA
BC		m²	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
63E98D11	Quebec	2		1998

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	3013.6	18	542.448	621.6

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1131	Winter	48	936.3
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
109.5	3.3	7.3	Low plasticity clay (CL)	92.5	25	10

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	7.1	1500	755	510	150	3.7
B	13.8	100	45	50		
SB	17.7	80	15	30		

Degradations: 2004				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.7 mm	NA	26.8 %
Fa		2.8 m	0.5 % lane area	2.1 %
Ro		1.43 m/km	NA	NA
LC	Center line	1.7 m	11.1 m/km	NA
	Meandering			
	Mid-lane			
TC		3.9 m	25.9 m/km	NA
BC		m²	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
89090	Quebec	2		1996

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	4712.5	10	471.25	432.9

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1648	Winter	48	929.7
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
391.5	11.7	26.1	Silty clay	90	24	10

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.1	1500	755	510	150	3.7
B	14.8	100	45	50		
SB	11.8	80	15	30		

Degradations: 2002				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.3 mm	NA	37.2 %
Fa		10.4 m	1.9 % lane area	7.7 %
Ro		2.08 m/km	NA	NA
LC	Center line	28.0 m	186.7 m/km	NA
	Meandering			
	Mid-lane			
TC		7.7 m	51.2 m/km	NA
BC		m²	0.0 % lane area	NA

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
891021	Quebec	1		1983

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	4178.8	16	668.608	488.4

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1252	Winter	48	1075.5
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.5	6.0	10.9	Sand with clay and gravel (SP-SC)	10.3	3	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.1	1500	755	510	152	3.7
B	14.8	100	45	50		
SB	0.0	80	15	30		

Degradations: 1992				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.2 mm	NA	36.8 %
Fa		129.5 m	23.3 % lane area	94.4 %
Ro		1.75 m/km	NA	NA
LC	Center line	161.9 m	1062.2 m/km	NA
	Meandering			
	Mid-lane			
TC		113.5 m	744.6 m/km	NA
BC		m²	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
892011	Quebec	3		1979

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	382.6	15	57.39	52.2

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1200	Winter	48	1297.1
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
109.5	3.3	7.3	Sandy and silty clay (CL-ML)	60.5	16	5

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	6.3	1500	755	510	152	3.3
B	6.7	100	45	50		
SB	32.2	80	15	30		

Degradations: 2003				
Degradation type		Degradation value	Degradation extension	Damage
Ru		9.4 mm	NA	37.6 %
Fa		219.8 m	43.7 % lane area	160.2 %
Ro		3.30 m/km	NA	NA
LC	Center line	6.0 m	39.6 m/km	NA
	Meandering			
	Mid-lane			
TC		175.0 m	1148.4 m/km	NA
BC		m²	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
89A340	Quebec	1		1983

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	4178.8	16	668.608	488.4

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1252	Winter	48	1075.5
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
163.5	6.0	10.9	Sand with clay and gravel (SP-SC)	10.3	3	0

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	5.1	1500	755	510	152	3.7
B	14.8	100	45	50		
SB	0.0	80	15	30		

Degradations: 1995				
Degradation type		Degradation value	Degradation extension	Damage
Ru		14.5 mm	NA	58.0 %
Fa		140.7 m	25.3 % lane area	102.6 %
Ro		2.74 m/km	NA	NA
LC	Center line	51.8 m	339.8 m/km	NA
	Meandering			
	Mid-lane			
TC		48.4 m	317.6 m/km	NA
BC		m^2	0.0 % lane area	NA

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Test site characteristics

Site identification				
Number	Province	Func. Class. [1]	Overlay	Orig. constr.
SPE5423	Quebec	1		1992

(1) 1 = Autoroute = Major HWY
2 = Route nationale = Other HWY
3 = Route régionale = Local roads

Traffic				
Time interval	mean AADT all veh.	mean % truck	mean AADT truck	mean an. kESAL
	2700.4	15	405.06	404.1

Climate				
Type	Fr.-index (°C*d)	Season	% year	Mean an. precip. (mm)
WF-HF	1200	Winter	48	1108.9
		Spring	17	
		Summer/fall	35	

Subgrade						
M_R (ksi)			Classification / description	Particule size (%)		Plastic index (%)
Winter	Spring	Summer/fall		P_{080}	P_{020}	
391.5	11.7	26.1	Clayed sand with gravel (SC)	48.3	13	5

Site description						
Pavement layers		M_R (ksi)			Section lenght (m)	Lane width (m)
Layer	H (po)	Winter	Spring	Summer/fall		
AC	4.7	1500	755	510	300	3.7
B	14.8	100	45	50		
SB	14.8	80	15	30		

Degradations: 2003				
Degradation type		Degradation value	Degradation extension	Damage
Ru		6.3 mm	NA	25.2 %
Fa		315.7 m	28.8 % lane area	116.9 %
Ro		2.23 m/km	NA	NA
LC	Center line	367.9 m	1226.4 m/km	NA
	Meandering			
	Mid-lane			
TC		158.8 m	529.3 m/km	NA
BC		m²	0.0 % lane area	NA

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APPENDIX 3

Damage simulation for all Canadian sites

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 810404-1

Monitored traffic (kESAL): 12

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
1900	23.33	16.22	158	4000	6.62	6.13	333

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

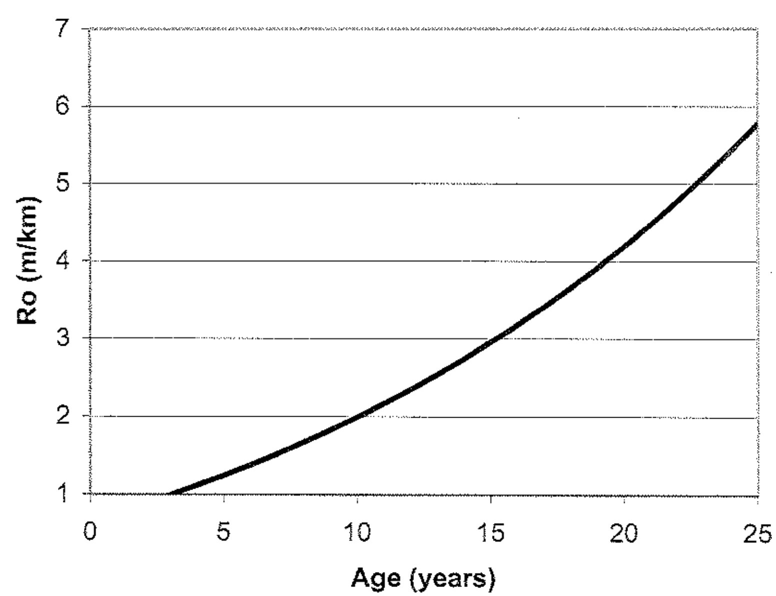
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 810404-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	13	
TC	m/km	8.7	0
Fa	% lane area	1.7	1.7
BC	% lane area	0.0	0
LC	m/km	80.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1665	0
Subgrade PI	%	21	
Subgrade P_{075}	%	87.8	
Subgrade P_{020}	%	68	
Annuel precipitation	mm	526.0	0
Precipitation s.-d.	mm	8.8	0
Site factor	-	321.6	0
Calibration factor	-	0.138	

	t + c	t
Final roughness (m/km)	2.54	1.00



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 810404-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	5.8	4.1	0.24	0.12	0.12	**0.50**	**0.50**
Fa	%w.path area	**0.25**	45	3.0	2.8					
Ro	m/km	**0.25**	4	2.5	1.0					
LC	m	**0.125**	367.9	12.0	0					
TC	m	**0.125**	454.5	1.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.8	4.1	0.29	0.13	0.15	**0.46**	**0.54**
Fa	%w.path area	**0.2**	45	3.0	2.8					
Ro	m/km	**0.35**	4	2.5	1.0					
LC	m	**0.125**	367.9	12.0	0					
TC	m	**0.125**	454.5	1	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.8	4.1	0.20	0.10	0.10	**0.52**	**0.48**
Fa	%w.path area	**0.35**	45	3.0	2.8					
Ro	m/km	**0.2**	4	2.5	1.0					
LC	m	**0.1**	367.9	12.0	0					
TC	m	**0.15**	454.5	1	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 810404-2

Monitored traffic (kESAL): 12

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
2625	30.13	21.03	219	5725	8.83	8.19	477

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

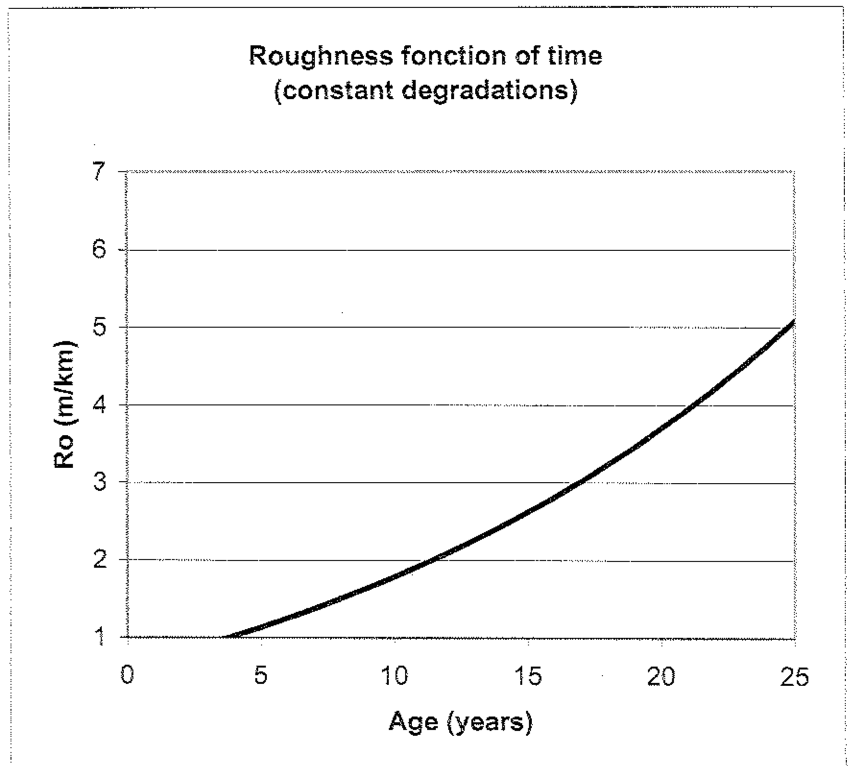
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 810404-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	13	
TC	m/km	0.0	0
Fa	% lane area	2.2	2.2
BC	% lane area	0.0	0
LC	m/km	468.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1665	0
Subgrade PI	%	21	
Subgrade P_{075}	%	87.8	
Subgrade P_{020}	%	68	
Annuel precipitation	mm	526.0	0
Precipitation s.-d.	mm	8.8	0
Site factor	-	321.6	0
Calibration factor	-	0.12	

	With CE	Without CE
Final roughness (m/km)	2.26	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 810404-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	7.5	5.3	0.26	0.14	0.13	**0.52**	**0.48**
Fa	%w.path area	**0.25**	45	4.0	3.7					
Ro	m/km	**0.25**	4	2.3	1.0					
LC	m	**0.125**	367.9	70.2	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.5	5.3	0.30	0.15	0.15	**0.49**	**0.51**
Fa	%w.path area	**0.2**	45	4.0	3.7					
Ro	m/km	**0.35**	4	2.3	1.0					
LC	m	**0.125**	367.9	70.2	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.5	5.3	0.22	0.12	0.10	**0.54**	**0.46**
Fa	%w.path area	**0.35**	45	4.0	3.7					
Ro	m/km	**0.2**	4	2.3	1.0					
LC	m	**0.1**	367.9	70.2	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 810404-3

Monitored traffic (kESAL): 12

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3300	26.4	21.9	275	4750	5.9	5.74	396

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

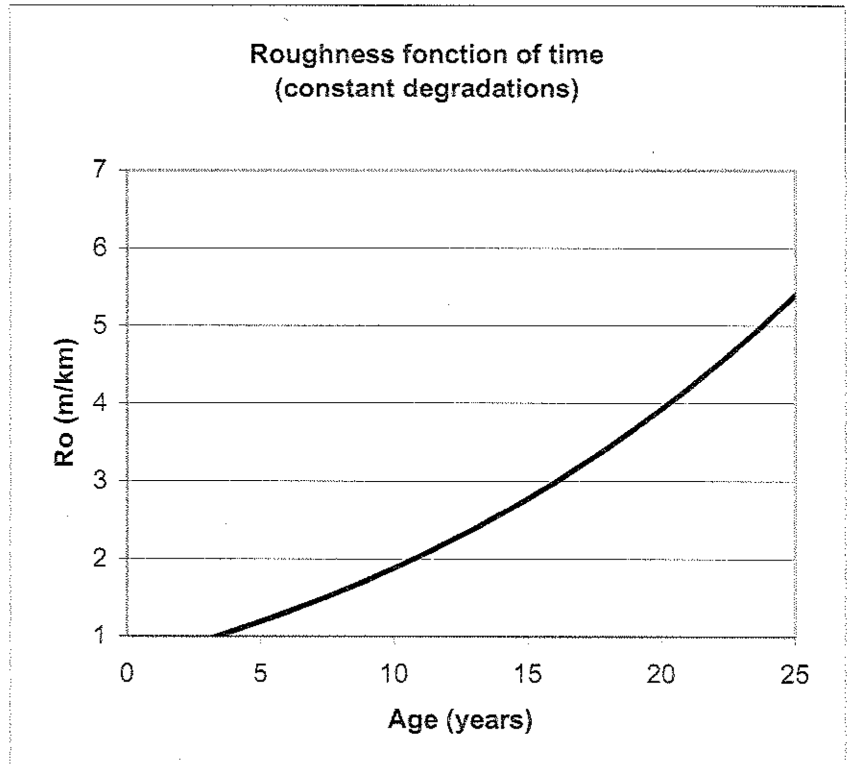
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 810404-3

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	13	
TC	m/km	0.0	0
Fa	% lane area	1.5	1.5
BC	% lane area	0.0	0
LC	m/km	328.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1665	0
Subgrade PI	%	21	
Subgrade P_{075}	%	87.8	
Subgrade P_{020}	%	68	
Annuel precipitation	mm	526.0	0
Precipitation s.-d.	mm	8.8	0
Site factor	-	321.6	0
Calibration factor	-	0.128	

Final roughness (m/km)	With CE	Without CE
	2.39	1.00



Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 810404-3

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.6	5.5	0.25	0.13	0.12	**0.53**	**0.47**
Fa	%w.path area	**0.25**	45	2.7	2.6					
Ro	m/km	**0.25**	4	2.4	1.0					
LC	m	**0.125**	367.9	49.3	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.6	5.5	0.29	0.14	0.15	**0.49**	**0.51**
Fa	%w.path area	**0.2**	45	2.7	2.6					
Ro	m/km	**0.35**	4	2.4	1.0					
LC	m	**0.125**	367.9	49.3	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.6	5.5	0.21	0.11	0.09	**0.55**	**0.45**
Fa	%w.path area	**0.35**	45	2.7	2.6					
Ro	m/km	**0.2**	4	2.4	1.0					
LC	m	**0.1**	367.9	49.3	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 810404-4

Monitored traffic (kESAL): 12

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3825	24.03	16.95	319	3425	3.01	2.8	285

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

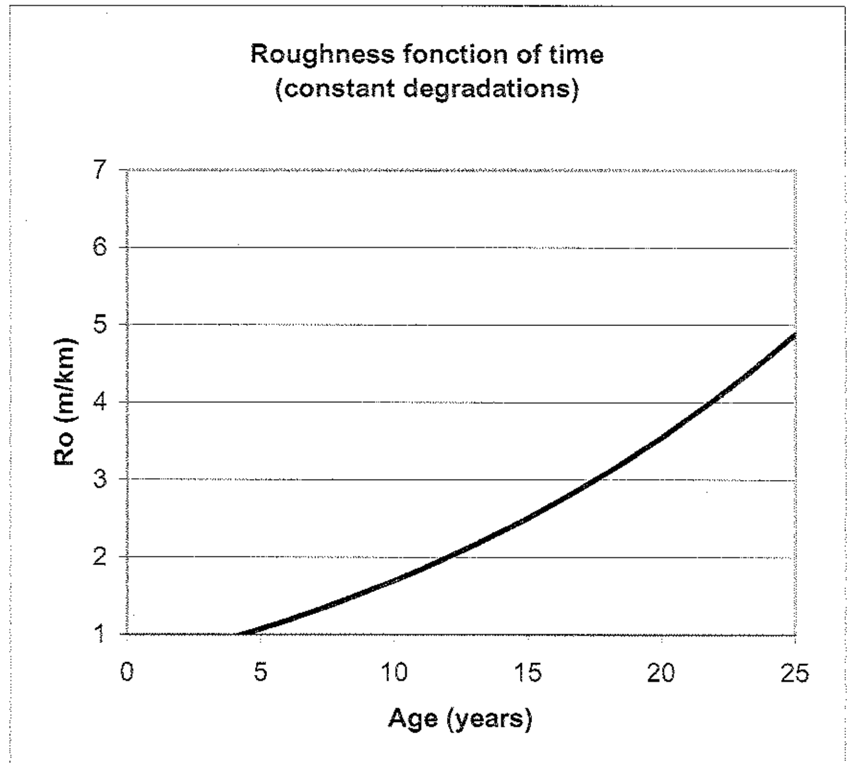
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 810404-4

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	13	
TC	m/km	0.0	0
Fa	% lane area	0.7	0.7
BC	% lane area	0.0	0
LC	m/km	278.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1665	0
Subgrade PI	%	21	
Subgrade P_{075}	%	87.8	
Subgrade P_{020}	%	68	
Annuel precipitation	mm	526.0	0
Precipitation s.-d.	mm	8.8	0
Site factor	-	321.6	0
Calibration factor	-	0.116	

Final roughness (m/km)	With CE	Without CE
	2.16	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 810404-4

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.0	4.2	0.22	0.11	0.10	**0.52**	**0.48**
Fa	%w.path area	**0.25**	45	1.4	1.3					
Ro	m/km	**0.25**	4	2.2	1.0					
LC	m	**0.125**	367.9	41.7	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.0	4.2	0.26	0.13	0.13	**0.49**	**0.51**
Fa	%w.path area	**0.2**	45	1.4	1.3					
Ro	m/km	**0.35**	4	2.2	1.0					
LC	m	**0.125**	367.9	41.7	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.0	4.2	0.18	0.09	0.08	**0.53**	**0.47**
Fa	%w.path area	**0.35**	45	1.4	1.3					
Ro	m/km	**0.2**	4	2.2	1.0					
LC	m	**0.1**	367.9	41.7	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 830403-1

Monitored traffic (kESAL): 28

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
40.3	36.8	25.8	1.4	1010	15.3	14.6	36

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

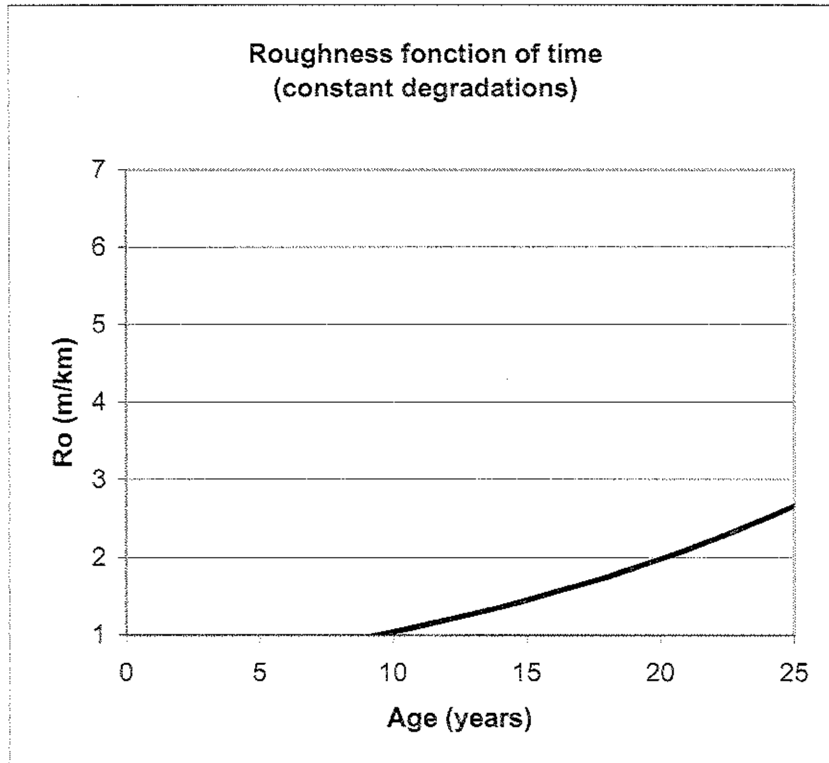
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 830403-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	28	
TC	m/km	2297.3	0
Fa	% lane area	3.7	3.7
BC	% lane area	0.0	0
LC	m/km	1300.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1666	0
Subgrade PI	%	29	
Subgrade P_{075}	%	91.54	
Subgrade P_{020}	%	80	
Annuel precipitation	mm	382.0	0
Precipitation s.-d.	mm	6.4	0
Site factor	-	358.3	0
Calibration factor	-	0.053	

	With CE	Without CE
Final roughness (m/km)	3.16	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 830403-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.2	6.4	0.49	0.16	0.33	**0.33**	**0.67**
Fa	%w.path area	**0.25**	45	6.9	6.6					
Ro	m/km	**0.25**	4	3.2	1.0					
LC	m	**0.125**	367.9	195.1	0					
TC	m	**0.125**	454.5	344.6	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.2	6.4	0.54	0.17	0.37	**0.31**	**0.69**
Fa	%w.path area	**0.2**	45	6.9	6.6					
Ro	m/km	**0.35**	4	3.2	1.0					
LC	m	**0.125**	367.9	195.1	0					
TC	m	**0.125**	454.5	344.6	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.2	6.4	0.45	0.15	0.30	**0.34**	**0.66**
Fa	%w.path area	**0.35**	45	6.9	6.6					
Ro	m/km	**0.2**	4	3.2	1.0					
LC	m	**0.1**	367.9	195.1	0					
TC	m	**0.15**	454.5	344.6	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 830403-2

Monitored traffic (kESAL): 28

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
46.5	42.4	29.8	1.7	5400	81.8	77.8	193

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

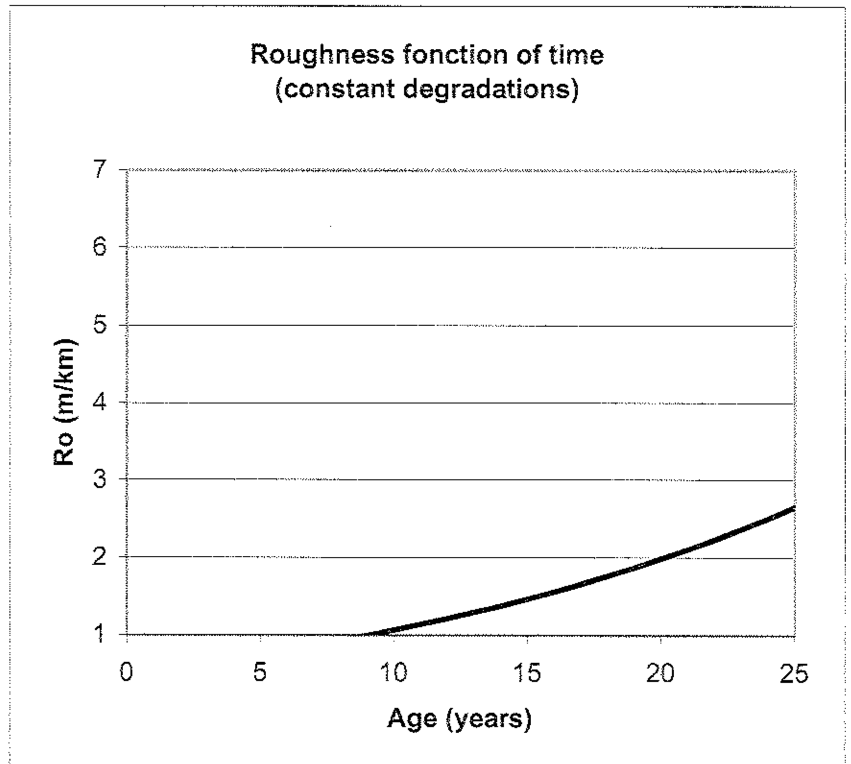
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 830403-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	28	
TC	m/km	2600.7	0
Fa	% lane area	19.8	19.8
BC	% lane area	0.0	0
LC	m/km	1581.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1666	0
Subgrade PI	%	29	
Subgrade P_{075}	%	91.54	
Subgrade P_{020}	%	80	
Annuel precipitation	mm	382.0	0
Precipitation s.-d.	mm	6.4	0
Site factor	-	358.3	0
Calibration factor	-	0.052	

Final roughness (m/km)	With CE	Without CE
	3.14	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 830403-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	10.6	7.4	0.69	0.33	0.36	**0.48**	**0.52**
Fa	%w.path area	**0.25**	45	36.8	35.0					
Ro	m/km	**0.25**	4	3.1	1.0					
LC	m	**0.125**	367.9	237.2	0					
TC	m	**0.125**	454.5	390.1	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	10.6	7.4	0.71	0.30	0.41	**0.43**	**0.57**
Fa	%w.path area	**0.2**	45	36.8	35.0					
Ro	m/km	**0.35**	4	3.1	1.0					
LC	m	**0.125**	367.9	237.2	0					
TC	m	**0.125**	454.5	390.1	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	10.6	7.4	0.72	0.38	0.34	**0.53**	**0.47**
Fa	%w.path area	**0.35**	45	36.8	35.0					
Ro	m/km	**0.2**	4	3.1	1.0					
LC	m	**0.1**	367.9	237.2	0					
TC	m	**0.15**	454.5	390.1	0					

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 830403-3

Monitored traffic (kESAL): 28

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
36.775	33.6	23.5	1.3	5960	90.3	85.9	213

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

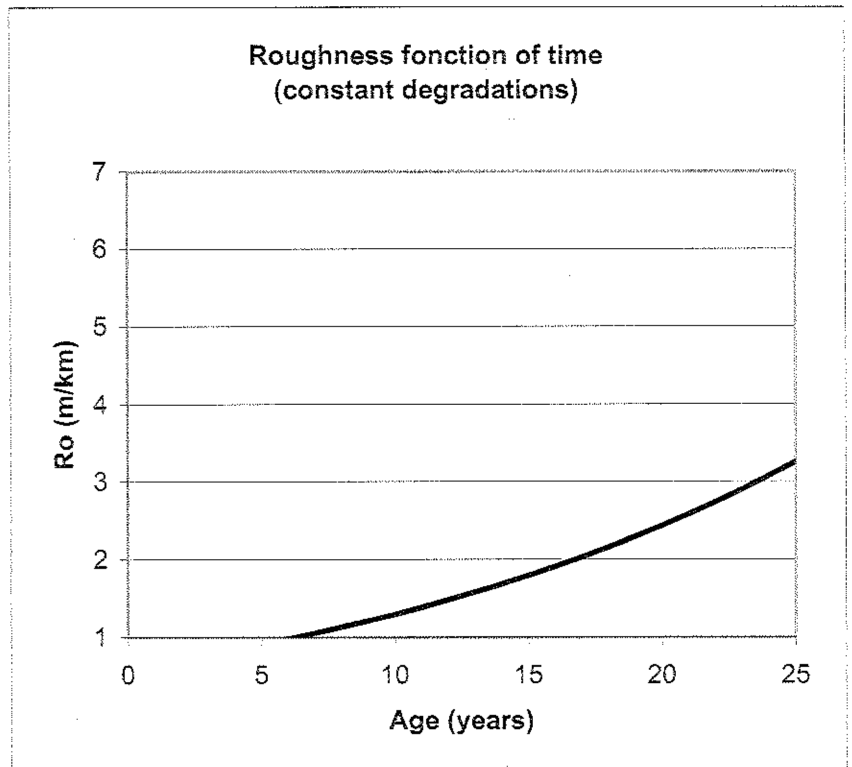
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 830403-3

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	28	
TC	m/km	3030.0	0
Fa	% lane area	22.0	22.0
BC	% lane area	0.0	0
LC	m/km	998.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1666	0
Subgrade PI	%	29	
Subgrade P_{075}	%	91.54	
Subgrade P_{020}	%	80	
Annuel precipitation	mm	382.0	0
Precipitation s.-d.	mm	6.4	0
Site factor	-	358.3	0
Calibration factor	-	0.064	

	With CE	Without CE
Final roughness (m/km)	3.85	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 830403-3

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	8.4	5.9	0.73	0.34	0.39	**0.46**	**0.54**
Fa	%w.path area	**0.25**	45	40.6	38.7					
Ro	m/km	**0.25**	4	3.9	1.0					
LC	m	**0.125**	367.9	149.8	0					
TC	m	**0.125**	454.5	454.5	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	8.4	5.9	0.76	0.31	0.45	**0.40**	**0.60**
Fa	%w.path area	**0.2**	45	40.6	38.7					
Ro	m/km	**0.35**	4	3.9	1.0					
LC	m	**0.125**	367.9	149.8	0					
TC	m	**0.125**	454.5	454.5	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	8.4	5.9	0.77	0.40	0.37	**0.52**	**0.48**
Fa	%w.path area	**0.35**	45	40.6	38.7					
Ro	m/km	**0.2**	4	3.9	1.0					
LC	m	**0.1**	367.9	149.8	0					
TC	m	**0.15**	454.5	454.5	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840204-1

Monitored traffic (kESAL): 16

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
46	9.63	5.25	2.9	8065	89.43	77.81	504

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840204-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	14	
TC	m/km	138.7	0
Fa	% lane area	21.2	21.2
BC	% lane area	0.0	0
LC	m/km	153.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	875	0
Subgrade PI	%	0	
Subgrade P_{075}	%	22.1	
Subgrade P_{020}	%	15	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	75.6	0
Calibration factor	-	0.43	

Final roughness (m/km)	With CE	Without CE
	3.72	2.04

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840204-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	2.4	1.3	0.49	0.34	0.16	**0.68**	**0.32**
Fa	%w.path area	**0.25**	45	40.2	35.0					
Ro	m/km	**0.25**	4	3.7	2.0					
LC	m	**0.125**	367.9	23.0	0					
TC	m	**0.125**	454.5	20.8	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	2.4	1.3	0.54	0.34	0.19	**0.64**	**0.36**
Fa	%w.path area	**0.2**	45	40.2	35.0					
Ro	m/km	**0.35**	4	3.7	2.0					
LC	m	**0.125**	367.9	23.0	0					
TC	m	**0.125**	454.5	20.8	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	2.4	1.3	0.53	0.38	0.15	**0.72**	**0.28**
Fa	%w.path area	**0.35**	45	40.2	35.0					
Ro	m/km	**0.2**	4	3.7	2.0					
LC	m	**0.1**	367.9	23.0	0					
TC	m	**0.15**	454.5	20.8	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840204-2

Monitored traffic (kESAL): 16

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
32	4.7	4.8	2.0	460	4.4	3.92	29

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

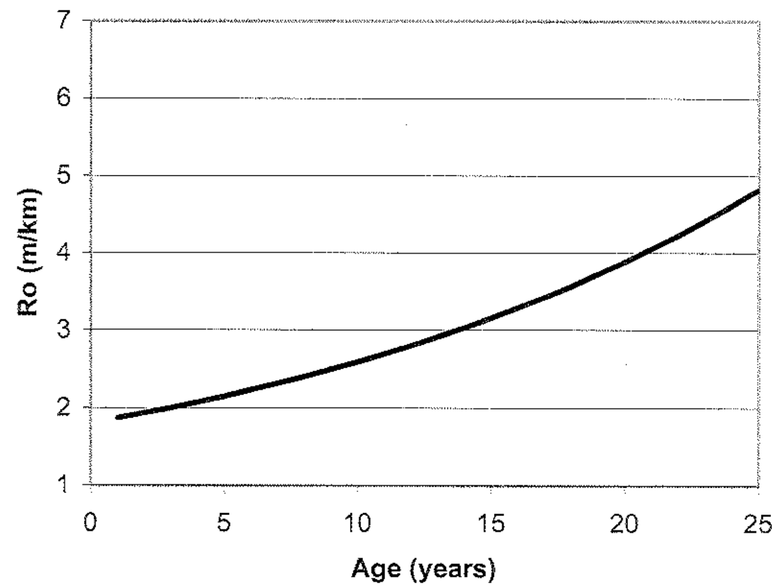
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840204-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	14	
TC	m/km	256.0	0
Fa	% lane area	1.1	1.1
BC	% lane area	0.0	0
LC	m/km	227.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	875	0
Subgrade PI	%	0	
Subgrade P_{075}	%	22.1	
Subgrade P_{020}	%	15	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	75.6	0
Calibration factor	-	0.345	

Final roughness (m/km)	With CE	Without CE
	3.03	1.61



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840204-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	1.2	1.2	0.23	0.12	0.11	**0.52**	**0.48**
Fa	%w.path area	**0.25**	45	2.0	1.8					
Ro	m/km	**0.25**	4	3.0	1.6					
LC	m	**0.125**	367.9	34.1	0					
TC	m	**0.125**	454.5	38.4	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.2	1.2	0.31	0.16	0.15	**0.52**	**0.48**
Fa	%w.path area	**0.2**	45	2.0	1.8					
Ro	m/km	**0.35**	4	3.0	1.6					
LC	m	**0.125**	367.9	34.1	0					
TC	m	**0.125**	454.5	38.4	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.2	1.2	0.20	0.10	0.09	**0.52**	**0.48**
Fa	%w.path area	**0.35**	45	2.0	1.8					
Ro	m/km	**0.2**	4	3.0	1.6					
LC	m	**0.1**	367.9	34.1	0					
TC	m	**0.15**	454.5	38.4	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840604-1

Monitored traffic (kESAL): 565

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
935	25.61	24.06	1.7	9000	39.05	37.69	16

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

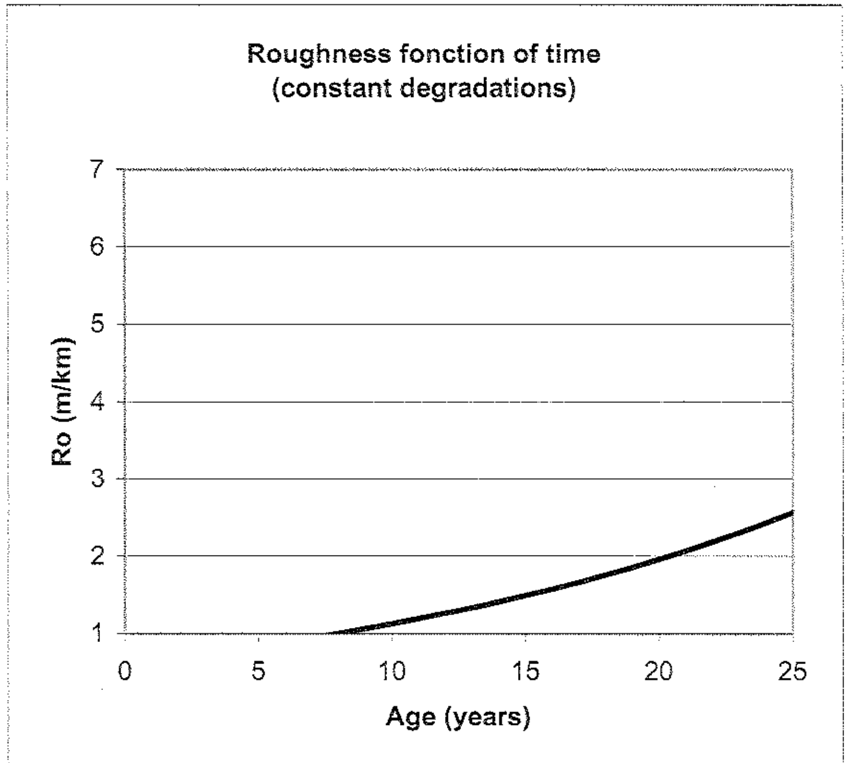
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840604-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	23	
TC	m/km	64.0	0
Fa	% lane area	9.4	9.4
BC	% lane area	0.0	0
LC	m/km	314.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1030	0
Subgrade PI	%	2	
Subgrade P_{075}	%	34.9	
Subgrade P_{020}	%	28	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	140.4	0
Calibration factor	-	0.12	

Final roughness (m/km)	With CE	Without CE
	2.30	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840604-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.4	6.0	0.32	0.22	0.11	**0.67**	**0.33**
Fa	%w.path area	**0.25**	45	17.6	17.0					
Ro	m/km	**0.25**	4	2.3	1.0					
LC	m	**0.125**	367.9	47.1	0					
TC	m	**0.125**	454.5	9.6	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.4	6.0	0.35	0.21	0.14	**0.60**	**0.40**
Fa	%w.path area	**0.2**	45	17.6	17.0					
Ro	m/km	**0.35**	4	2.3	1.0					
LC	m	**0.125**	367.9	47.1	0					
TC	m	**0.125**	454.5	9.6	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.4	6.0	0.32	0.23	0.09	**0.72**	**0.28**
Fa	%w.path area	**0.35**	45	17.6	17.0					
Ro	m/km	**0.2**	4	2.3	1.0					
LC	m	**0.1**	367.9	47.1	0					
TC	m	**0.15**	454.5	9.6	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840604-2

Monitored traffic (kESAL): 565

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
495	37.94	36.77	0.9	1465	13.27	12.58	2.6

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

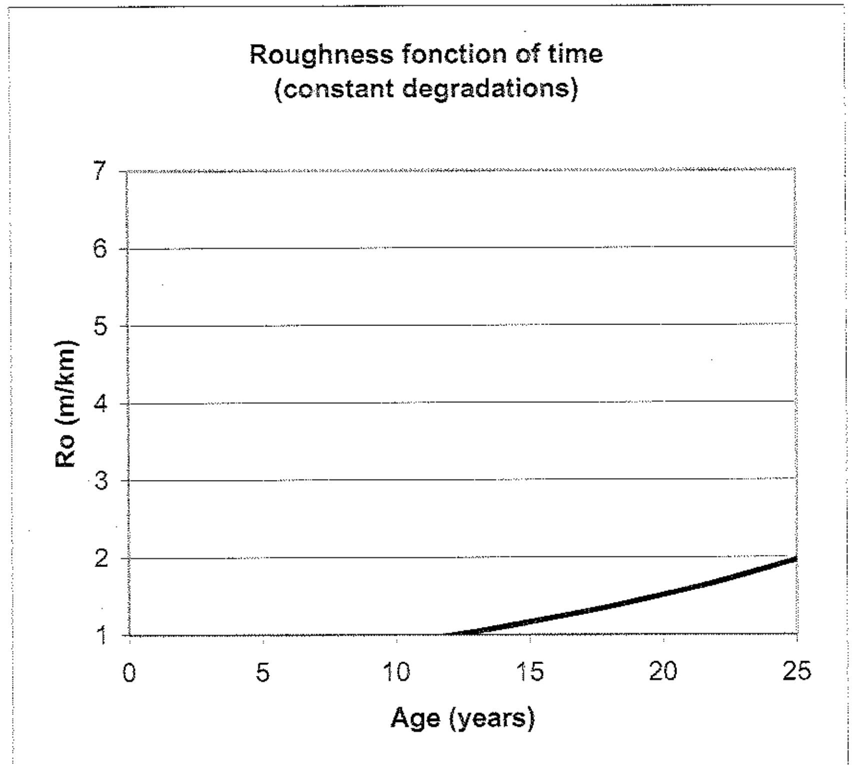
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840604-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	23	
TC	m/km	75.0	0
Fa	% lane area	3.2	3.2
BC	% lane area	0.0	0
LC	m/km	734.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1030	0
Subgrade PI	%	2	
Subgrade P_{075}	%	34.9	
Subgrade P_{020}	%	28	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	140.4	0
Calibration factor	-	0.09	

Final roughness (m/km)	With CE	Without CE
	1.77	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840604-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.5	9.2	0.28	0.19	0.09	**0.67**	**0.33**
Fa	%w.path area	**0.25**	45	6.0	5.7					
Ro	m/km	**0.25**	4	1.8	1.0					
LC	m	**0.125**	367.9	110.1	0					
TC	m	**0.125**	454.5	11.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.5	9.2	0.30	0.19	0.11	**0.63**	**0.37**
Fa	%w.path area	**0.2**	45	6.0	5.7					
Ro	m/km	**0.35**	4	1.8	1.0					
LC	m	**0.125**	367.9	110.1	0					
TC	m	**0.125**	454.5	11.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.5	9.2	0.24	0.17	0.08	**0.69**	**0.31**
Fa	%w.path area	**0.35**	45	6.0	5.7					
Ro	m/km	**0.2**	4	1.8	1.0					
LC	m	**0.1**	367.9	110.1	0					
TC	m	**0.15**	454.5	11.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840604-3

Monitored traffic (kESAL): 565

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
660	25.68	24.36	1.2	720	4.1	3.94	1.3

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

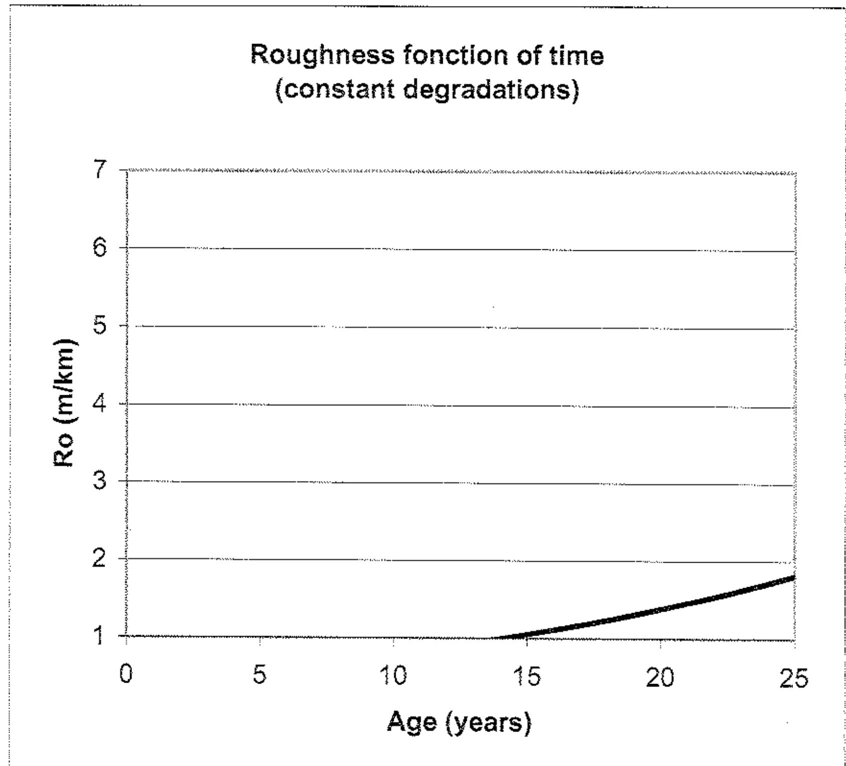
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840604-3

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	23	
TC	m/km	75.0	0
Fa	% lane area	1.0	1.0
BC	% lane area	0.0	0
LC	m/km	288.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1030	0
Subgrade PI	%	2	
Subgrade P_{075}	%	34.9	
Subgrade P_{020}	%	28	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	140.4	0
Calibration factor	-	0.085	

Final roughness (m/km)	With CE	Without CE
	1.63	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840604-3

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.4	6.1	0.19	0.13	0.06	**0.69**	**0.31**
Fa	%w.path area	**0.25**	45	1.8	1.8					
Ro	m/km	**0.25**	4	1.6	1.0					
LC	m	**0.125**	367.9	43.3	0					
TC	m	**0.125**	454.5	11.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.4	6.1	0.22	0.14	0.08	**0.66**	**0.34**
Fa	%w.path area	**0.2**	45	1.8	1.8					
Ro	m/km	**0.35**	4	1.6	1.0					
LC	m	**0.125**	367.9	43.3	0					
TC	m	**0.125**	454.5	11.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.4	6.1	0.16	0.11	0.05	**0.69**	**0.31**
Fa	%w.path area	**0.35**	45	1.8	1.8					
Ro	m/km	**0.2**	4	1.6	1.0					
LC	m	**0.1**	367.9	43.3	0					
TC	m	**0.15**	454.5	11.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 840604-4

Monitored traffic (kESAL): 565

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
790	21.6	20.33	1.4	4525	19.5	18.95	8.0

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

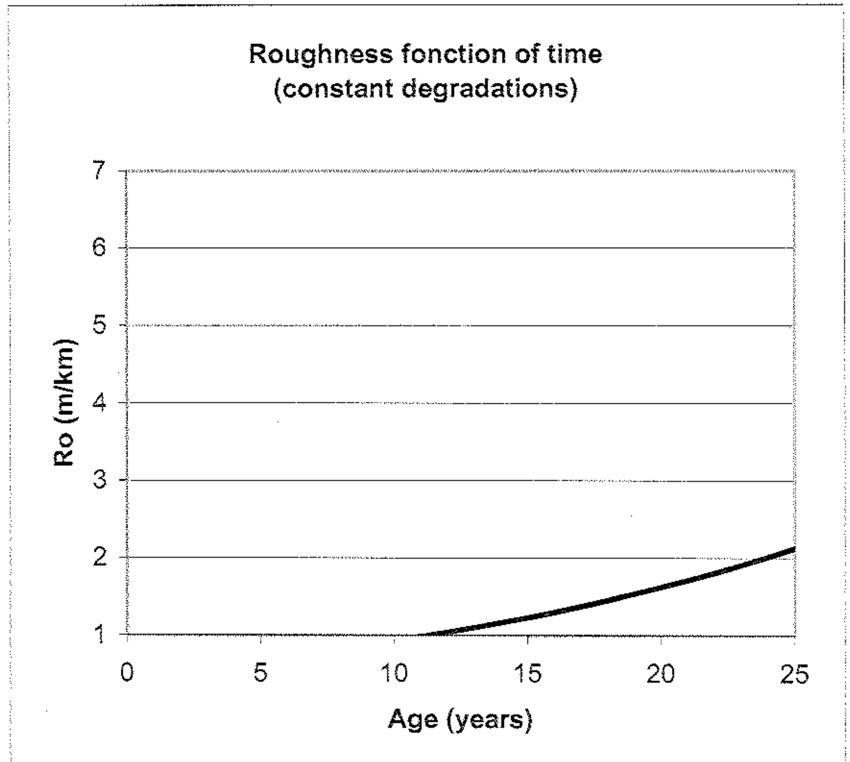
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 840604-4

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	23	
TC	m/km	95.6	0
Fa	% lane area	4.7	4.7
BC	% lane area	0.0	0
LC	m/km	210.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1030	0
Subgrade PI	%	2	
Subgrade P_{075}	%	34.9	
Subgrade P_{020}	%	28	
Annuel precipitation	mm	1069.7	0
Precipitation s.-d.	mm	17.8	0
Site factor	-	140.4	0
Calibration factor	-	0.1	

Final roughness (m/km)	With CE	Without CE
	1.91	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 840604-4

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	5.4	5.1	0.24	0.16	0.08	**0.68**	**0.32**
Fa	%w.path area	**0.25**	45	8.8	8.5					
Ro	m/km	**0.25**	4	1.9	1.0					
LC	m	**0.125**	367.9	31.5	0					
TC	m	**0.125**	454.5	14.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.4	5.1	0.26	0.17	0.10	**0.63**	**0.37**
Fa	%w.path area	**0.2**	45	8.8	8.5					
Ro	m/km	**0.35**	4	1.9	1.0					
LC	m	**0.125**	367.9	31.5	0					
TC	m	**0.125**	454.5	14.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.4	5.1	0.22	0.16	0.06	**0.71**	**0.29**
Fa	%w.path area	**0.35**	45	8.8	8.5					
Ro	m/km	**0.2**	4	1.9	1.0					
LC	m	**0.1**	367.9	31.5	0					
TC	m	**0.15**	454.5	14.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850201-1

Monitored traffic (kESAL): 23.5

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
163.5	32.79	34.14	7.0	4375	61.26	59.25	186

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

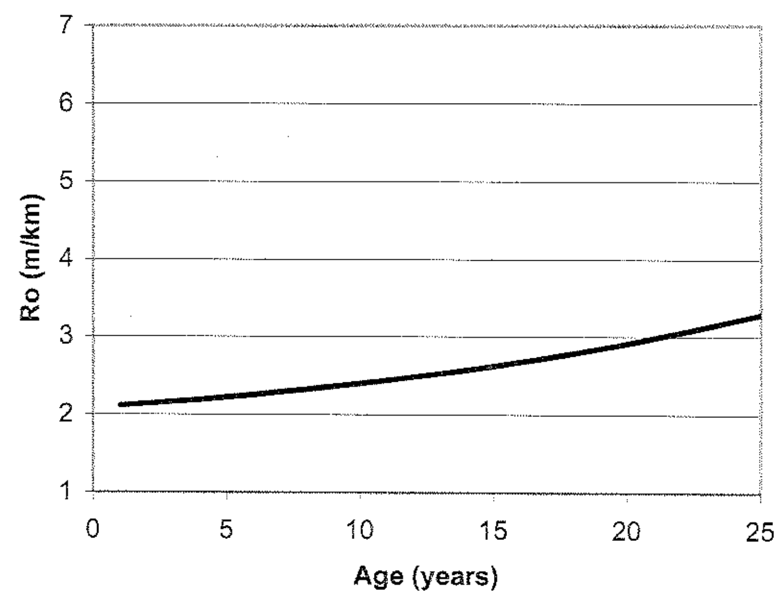
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850201-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	24	
TC	m/km	103.7	0
Fa	% lane area	14.7	14.7
BC	% lane area	0.0	0
LC	m/km	60.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1000	0
Subgrade PI	%	0	
Subgrade P_{075}	%	27.5	
Subgrade P_{020}	%	4	
Annuel precipitation	mm	1180.0	0
Precipitation s.-d.	mm	19.7	0
Site factor	-	24.4	0
Calibration factor	-	0.425	

	With CE	Without CE
Final roughness (m/km)	3.21	2.01



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 850201-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	8.2	8.5	0.44	0.36	0.08	**0.81**	**0.19**
Fa	%w.path area	**0.25**	45	27.6	26.7					
Ro	m/km	**0.25**	4	3.2	2.0					
LC	m	**0.125**	367.9	9.0	0					
TC	m	**0.125**	454.5	15.56	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	8.2	8.5	0.48	0.36	0.11	**0.76**	**0.24**
Fa	%w.path area	**0.2**	45	27.6	26.7					
Ro	m/km	**0.35**	4	3.2	2.0					
LC	m	**0.125**	367.9	9.0	0					
TC	m	**0.125**	454.5	16	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	8.2	8.5	0.45	0.38	0.07	**0.84**	**0.16**
Fa	%w.path area	**0.35**	45	27.6	26.7					
Ro	m/km	**0.2**	4	3.2	2.0					
LC	m	**0.1**	367.9	9.0	0					
TC	m	**0.15**	454.5	16	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850201-2

Monitored traffic (kESAL): 23.5

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
121.8	49.9	51.46	5.2	2335	41.87	39.49	99

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850201-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	24	
TC	m/km	165.6	0
Fa	% lane area	10.0	10.0
BC	% lane area	0.0	0
LC	m/km	172.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1000	0
Subgrade PI	%	0	
Subgrade P_{075}	%	27.5	
Subgrade P_{020}	%	4	
Annuel precipitation	mm	1180.0	0
Precipitation s.-d.	mm	19.7	0
Site factor	-	24.4	0
Calibration factor	-	0.44	

Final roughness (m/km)	With CE	Without CE
	3.40	2.07

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Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 850201-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	12.5	12.9	0.46	0.36	0.10	**0.78**	**0.22**
Fa	%w.path area	**0.25**	45	18.8	17.8					
Ro	m/km	**0.25**	4	3.4	2.1					
LC	m	**0.125**	367.9	25.9	0					
TC	m	**0.125**	454.5	24.84	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	12.5	12.9	0.50	0.36	0.13	**0.73**	**0.27**
Fa	%w.path area	**0.2**	45	18.8	17.8					
Ro	m/km	**0.35**	4	3.4	2.1					
LC	m	**0.125**	367.9	25.9	0					
TC	m	**0.125**	454.5	25	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	12.5	12.9	0.43	0.34	0.09	**0.80**	**0.20**
Fa	%w.path area	**0.35**	45	18.8	17.8					
Ro	m/km	**0.2**	4	3.4	2.1					
LC	m	**0.1**	367.9	25.9	0					
TC	m	**0.15**	454.5	25	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850206-1

Monitored traffic (kESAL): 23.5

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
125	6.7	6.94	5.3	14000	94.41	93.51	596

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

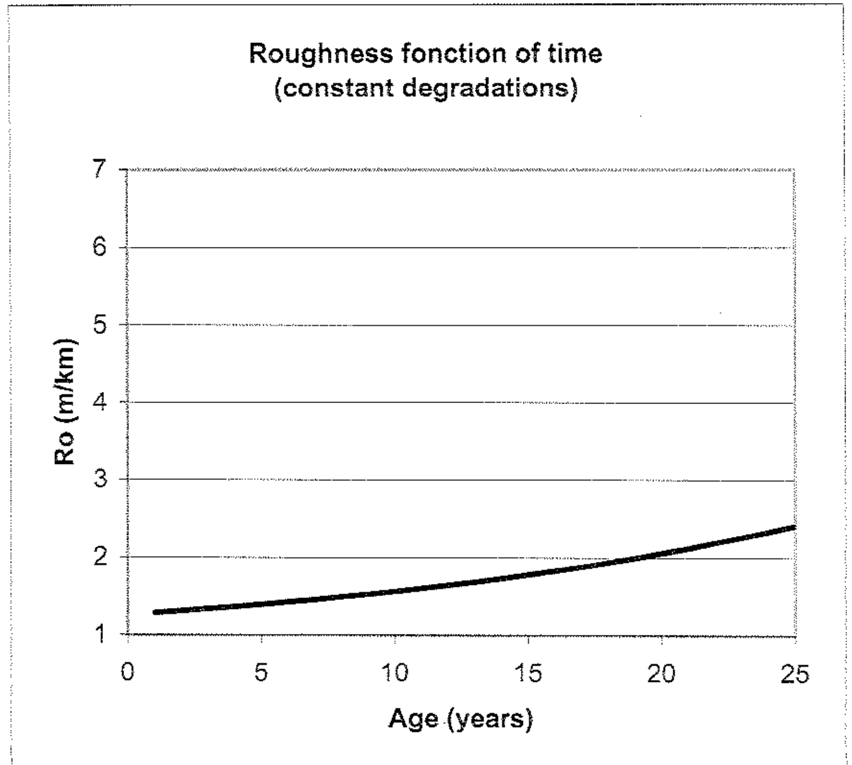
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850206-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	25	
TC	m/km	222.0	0
Fa	% lane area	22.6	22.6
BC	% lane area	0.0	0
LC	m/km	420.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1500	0
Subgrade PI	%	0	
Subgrade P_{075}	%	27.5	
Subgrade P_{020}	%	7.3	
Annuel precipitation	mm	1250.9	0
Precipitation s.-d.	mm	20.8	0
Site factor	-	43.3	0
Calibration factor	-	0.23	

Final roughness (m/km)	With CE	Without CE
	2.41	1.09



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 850206-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	1.7	1.7	0.43	0.32	0.11	**0.74**	**0.26**
Fa	%w.path area	**0.25**	45	42.5	42.1					
Ro	m/km	**0.25**	4	2.4	1.1					
LC	m	**0.125**	367.9	63.0	0					
TC	m	**0.125**	454.5	33.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.7	1.7	0.44	0.30	0.15	**0.67**	**0.33**
Fa	%w.path area	**0.2**	45	42.5	42.1					
Ro	m/km	**0.35**	4	2.4	1.1					
LC	m	**0.125**	367.9	63.0	0					
TC	m	**0.125**	454.5	33.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.7	1.7	0.49	0.40	0.10	**0.80**	**0.20**
Fa	%w.path area	**0.35**	45	42.5	42.1					
Ro	m/km	**0.2**	4	2.4	1.1					
LC	m	**0.1**	367.9	63.0	0					
TC	m	**0.15**	454.5	33.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850206-2

Monitored traffic (kESAL): 23.5

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
777	37.66	40	33	19105	121.01	120.02	813

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

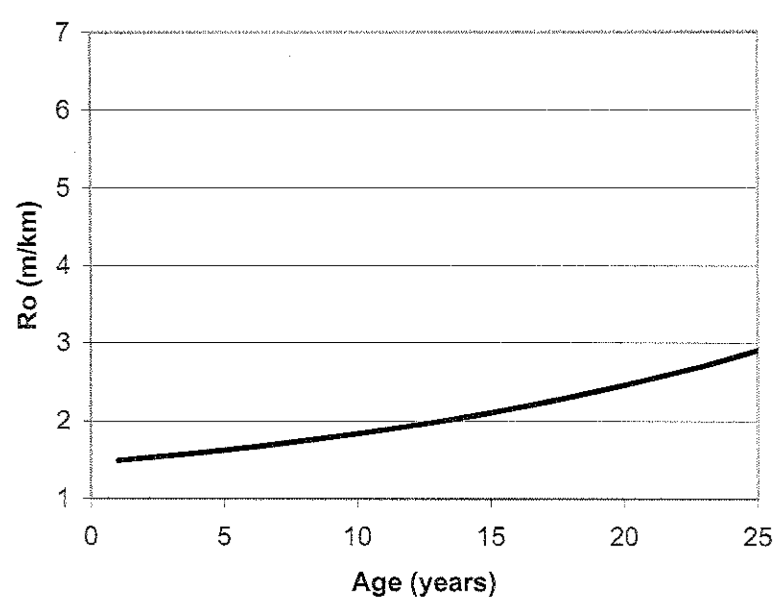
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850206-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	25	
TC	m/km	196.0	0
Fa	% lane area	29.0	29.0
BC	% lane area	0.0	0
LC	m/km	19.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1500	0
Subgrade PI	%	0	
Subgrade P_{075}	%	27.5	
Subgrade P_{020}	%	7.3	
Annuel precipitation	mm	1250.9	0
Precipitation s.-d.	mm	20.8	0
Site factor	-	43.3	0
Calibration factor	-	0.29	

Final roughness (m/km)	With CE	Without CE
	2.91	1.39



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 850206-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.4	10.0	0.59	0.49	0.10	**0.83**	**0.17**
Fa	%w.path area	**0.25**	45	54.5	54.0					
Ro	m/km	**0.25**	4	2.9	1.4					
LC	m	**0.125**	367.9	2.9	0					
TC	m	**0.125**	454.5	29.4	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	10.0	0.58	0.44	0.14	**0.76**	**0.24**
Fa	%w.path area	**0.2**	45	54.5	54.0					
Ro	m/km	**0.35**	4	2.9	1.4					
LC	m	**0.125**	367.9	2.9	0					
TC	m	**0.125**	454.5	29.4	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	10.0	0.65	0.57	0.09	**0.87**	**0.13**
Fa	%w.path area	**0.35**	45	54.5	54.0					
Ro	m/km	**0.2**	4	2.9	1.4					
LC	m	**0.1**	367.9	2.9	0					
TC	m	**0.15**	454.5	29.4	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850601-1

Monitored traffic (kESAL): 30

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
5000	39.21	37.24	167	8700	13.22	13.09	290

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

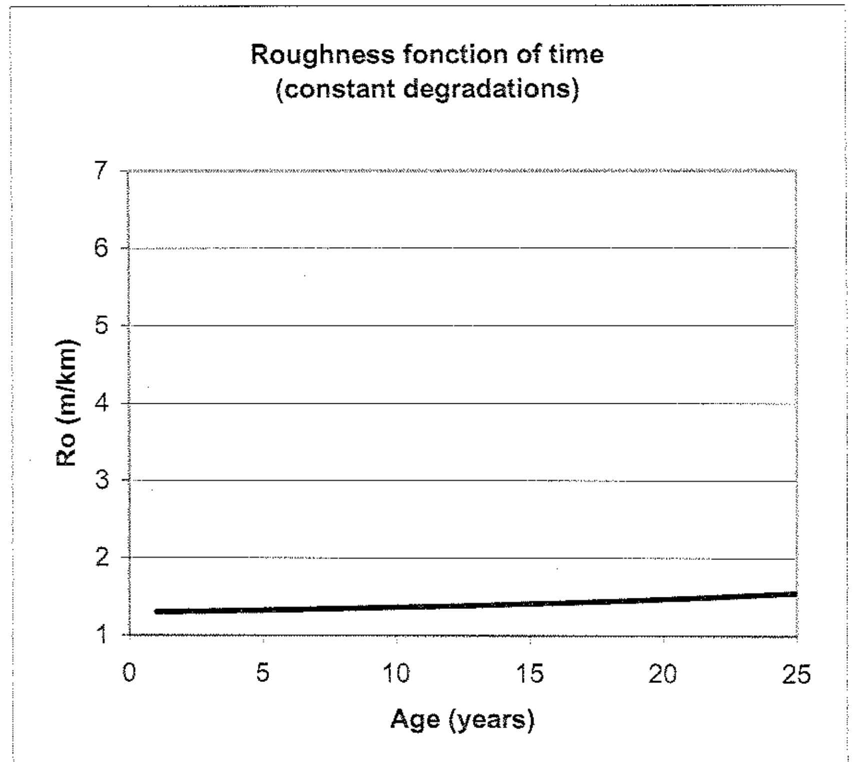
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850601-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	29	
TC	m/km	0.0	0
Fa	% lane area	3.2	3.2
BC	% lane area	0.0	0
LC	m/km	443.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1000	0
Subgrade PI	%	0	
Subgrade P_{075}	%	3	
Subgrade P_{020}	%	0.8	
Annuel precipitation	mm	1418.0	0
Precipitation s.-d.	mm	23.6	0
Site factor	-	9.0	0
Calibration factor	-	0.25	

Final roughness (m/km)	With CE	Without CE
	1.64	1.17



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Calculation of traffic and climatic damages

Site number: 850601-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.8	9.3	0.26	0.20	0.06	**0.78**	**0.22**
Fa	%w.path area	**0.25**	45	5.9	5.9					
Ro	m/km	**0.25**	4	1.6	1.2					
LC	m	**0.125**	367.9	66.5	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.8	9.3	0.27	0.20	0.07	**0.75**	**0.25**
Fa	%w.path area	**0.2**	45	5.9	5.9					
Ro	m/km	**0.35**	4	1.6	1.2					
LC	m	**0.125**	367.9	66.5	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.8	9.3	0.22	0.18	0.05	**0.80**	**0.20**
Fa	%w.path area	**0.35**	45	5.9	5.9					
Ro	m/km	**0.2**	4	1.6	1.2					
LC	m	**0.1**	367.9	66.5	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 850601-2

Monitored traffic (kESAL): 30

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
8040	54.44	52.56	268	2800	3.79	3.73	93

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

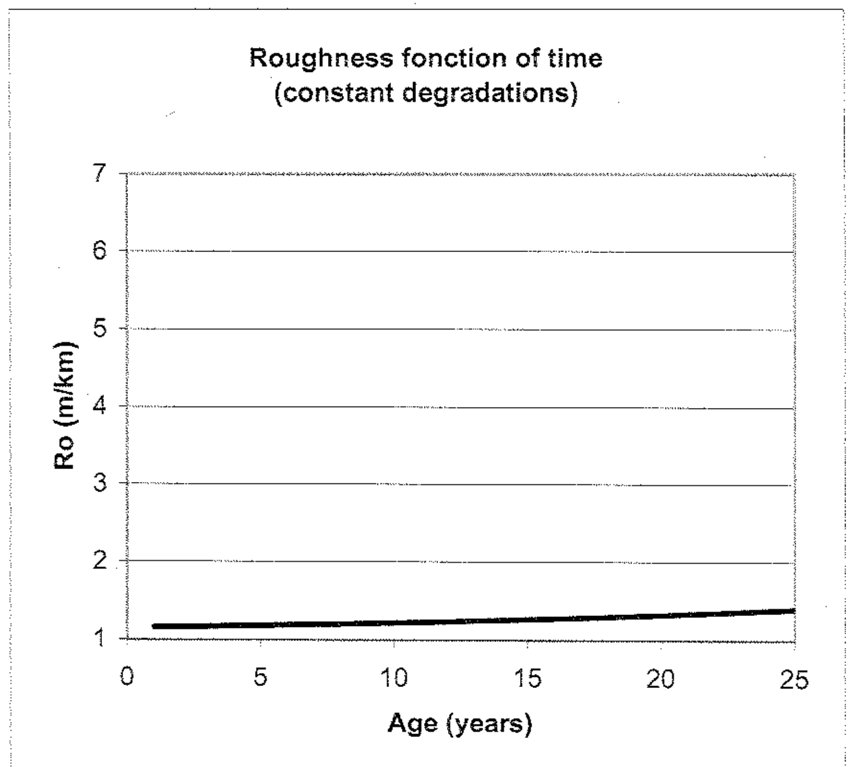
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 850601-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	29	
TC	m/km	0.0	0
Fa	% lane area	0.9	0.9
BC	% lane area	0.0	0
LC	m/km	104.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1000	0
Subgrade PI	%	0	
Subgrade P_{075}	%	3	
Subgrade P_{020}	%	0.8	
Annuel precipitation	mm	1418.0	0
Precipitation s.-d.	mm	23.6	0
Site factor	-	9.0	0
Calibration factor	-	0.24	

Final roughness (m/km)	With CE	Without CE
	1.48	1.12



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 850601-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	13.6	13.1	0.24	0.21	0.03	**0.87**	**0.13**
Fa	%w.path area	**0.25**	45	1.7	1.7					
Ro	m/km	**0.25**	4	1.5	1.1					
LC	m	**0.125**	367.9	15.6	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	13.6	13.1	0.25	0.21	0.04	**0.84**	**0.16**
Fa	%w.path area	**0.2**	45	1.7	1.7					
Ro	m/km	**0.35**	4	1.5	1.1					
LC	m	**0.125**	367.9	15.6	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	13.6	13.1	0.20	0.17	0.03	**0.87**	**0.13**
Fa	%w.path area	**0.35**	45	1.7	1.7					
Ro	m/km	**0.2**	4	1.5	1.1					
LC	m	**0.1**	367.9	15.6	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860501-1

Monitored traffic (kESAL): 437

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3250	24.4	22.39	7.4	13650	17.8	17.9	31

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

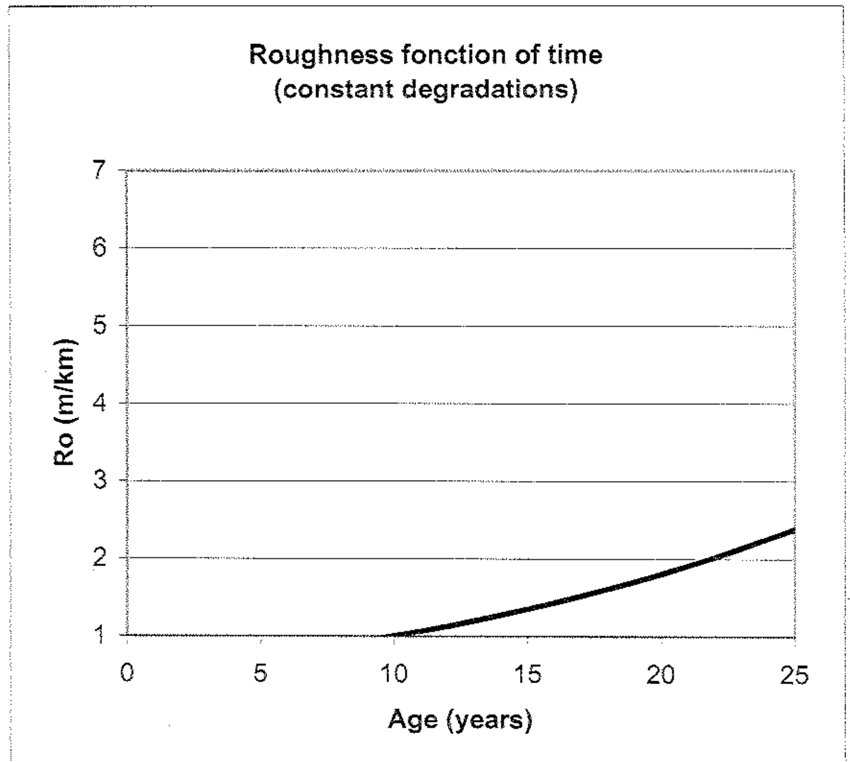
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860501-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	19	
TC	m/km	0.0	0
Fa	% lane area	4.2	4.2
BC	% lane area	0.0	0
LC	m/km	182.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	746	0
Subgrade PI	%	6	
Subgrade P_{075}	%	47	
Subgrade P_{020}	%	32	
Annuel precipitation	mm	1184.6	0
Precipitation s.-d.	mm	19.7	0
Site factor	-	154.8	0
Calibration factor	-	0.105	

Final roughness (m/km)	With CE	Without CE
	1.71	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860501-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.1	5.6	0.22	0.16	0.06	**0.74**	**0.26**
Fa	%w.path area	**0.25**	45	8.0	8.1					
Ro	m/km	**0.25**	4	1.7	1.0					
LC	m	**0.125**	367.9	27.4	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.1	5.6	0.24	0.17	0.08	**0.69**	**0.31**
Fa	%w.path area	**0.2**	45	8.0	8.1					
Ro	m/km	**0.35**	4	1.7	1.0					
LC	m	**0.125**	367.9	27.4	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.1	5.6	0.20	0.16	0.05	**0.77**	**0.23**
Fa	%w.path area	**0.35**	45	8.0	8.1					
Ro	m/km	**0.2**	4	1.7	1.0					
LC	m	**0.1**	367.9	27.4	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860501-2

Monitored traffic (kESAL): 437

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
2580	12.35	11.18	5.9	800	0.7	0.71	1.8

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

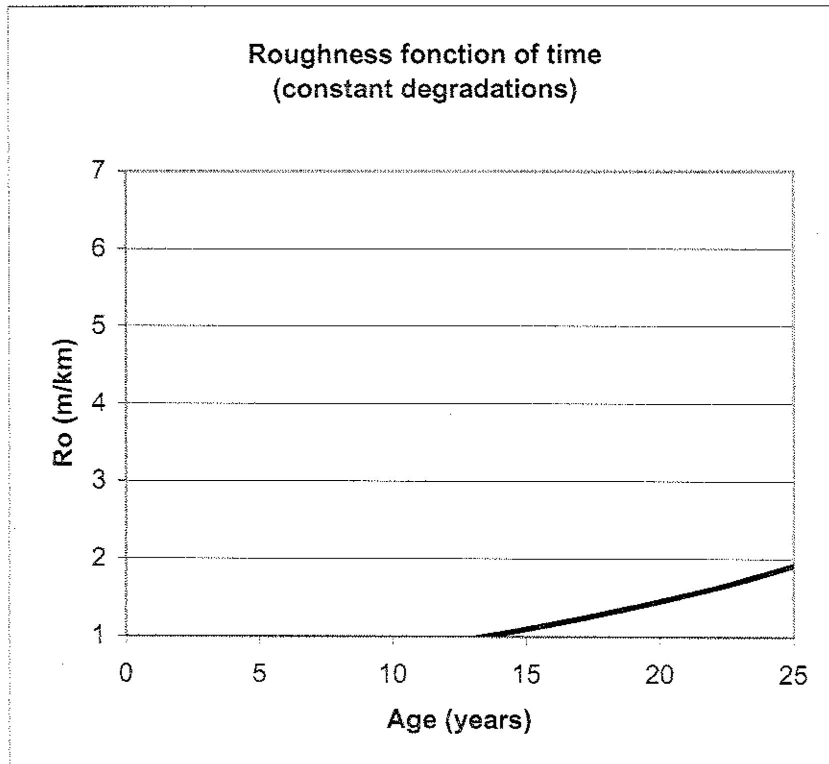
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860501-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	19	
TC	m/km	0.0	0
Fa	% lane area	0.2	0.2
BC	% lane area	0.0	0
LC	m/km	456.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	746	0
Subgrade PI	%	6	
Subgrade P_{075}	%	47	
Subgrade P_{020}	%	32	
Annuel precipitation	mm	1184.6	0
Precipitation s.-d.	mm	19.7	0
Site factor	-	154.8	0
Calibration factor	-	0.083	

Final roughness (m/km)	With CE	Without CE
	1.37	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860501-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	3.1	2.8	0.14	0.09	0.05	**0.65**	**0.35**
Fa	%w.path area	**0.25**	45	0.3	0.3					
Ro	m/km	**0.25**	4	1.4	1.0					
LC	m	**0.125**	367.9	68.5	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	3.1	2.8	0.17	0.11	0.06	**0.66**	**0.34**
Fa	%w.path area	**0.2**	45	0.3	0.3					
Ro	m/km	**0.35**	4	1.4	1.0					
LC	m	**0.125**	367.9	68.5	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	3.1	2.8	0.11	0.07	0.04	**0.65**	**0.35**
Fa	%w.path area	**0.35**	45	0.3	0.3					
Ro	m/km	**0.2**	4	1.4	1.0					
LC	m	**0.1**	367.9	68.5	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860501-3

Monitored traffic (kESAL): 437

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
840	7.65	7.07	1.9	2075	3.27	3.3	4.7

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

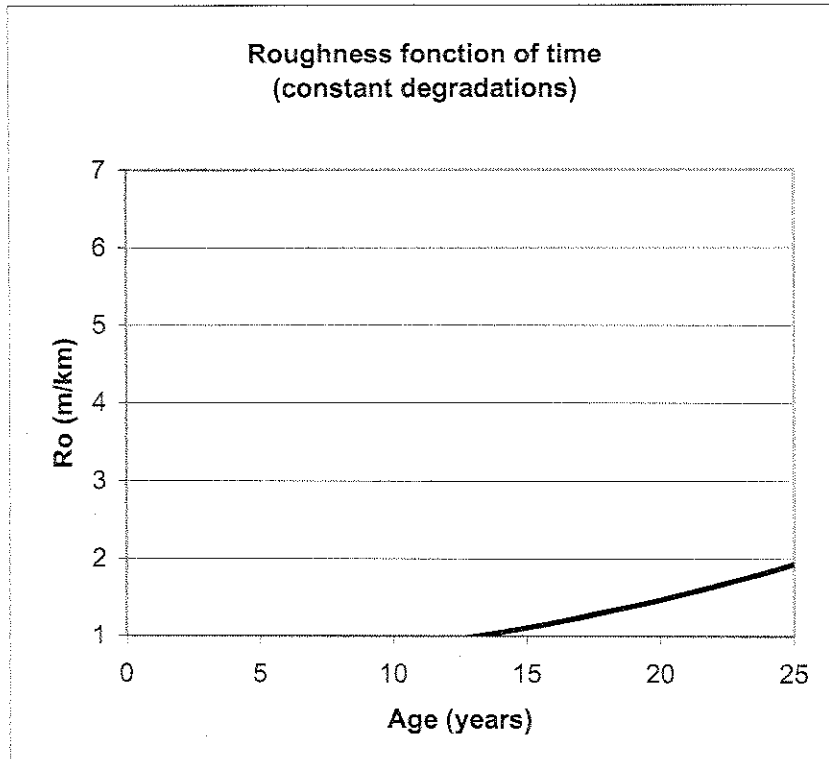
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860501-3

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	19	
TC	m/km	0.0	0
Fa	% lane area	0.8	0.8
BC	% lane area	0.0	0
LC	m/km	454.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	746	0
Subgrade PI	%	6	
Subgrade P_{075}	%	47	
Subgrade P_{020}	%	32	
Annuel precipitation	mm	1184.6	0
Precipitation s.-d.	mm	19.7	0
Site factor	-	154.8	0
Calibration factor	-	0.084	

	With CE	Without CE
Final roughness (m/km)	1.39	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860501-3

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	1.9	1.8	0.14	0.09	0.05	**0.64**	**0.36**
Fa	%w.path area	**0.25**	45	1.5	1.5					
Ro	m/km	**0.25**	4	1.4	1.0					
LC	m	**0.125**	367.9	68.2	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.9	1.8	0.17	0.11	0.06	**0.65**	**0.35**
Fa	%w.path area	**0.2**	45	1.5	1.5					
Ro	m/km	**0.35**	4	1.4	1.0					
LC	m	**0.125**	367.9	68.2	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	1.9	1.8	0.11	0.08	0.04	**0.66**	**0.34**
Fa	%w.path area	**0.35**	45	1.5	1.5					
Ro	m/km	**0.2**	4	1.4	1.0					
LC	m	**0.1**	367.9	68.2	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860603-1

Monitored traffic (kESAL): 97.66

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
13000	46.1	47.7	133	95000	71.84	73.3	973

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860603-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	14	
TC	m/km	91.8	0
Fa	% lane area	20.5	20.5
BC	% lane area	0.0	0
LC	m/km	56.1	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	526	0
Subgrade PI	%	0	
Subgrade P_{075}	%	9	
Subgrade P_{020}	%	5	
Annuel precipitation	mm	1217.0	0
Precipitation s.-d.	mm	20.3	0
Site factor	-	26.7	0
Calibration factor	-	0.95	

Final roughness (m/km)	With CE	Without CE
	5.87	4.51

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860603-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	11.5	11.9	0.67	0.58	0.08	**0.87**	**0.13**
Fa	%w.path area	**0.25**	45	32.3	33.0					
Ro	m/km	**0.25**	4	5.9	4.5					
LC	m	**0.125**	367.9	8.4	0					
TC	m	**0.125**	454.5	13.77	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	11.5	11.9	0.76	0.64	0.12	**0.84**	**0.16**
Fa	%w.path area	**0.2**	45	32.3	33.0					
Ro	m/km	**0.35**	4	5.9	4.5					
LC	m	**0.125**	367.9	8.4	0					
TC	m	**0.125**	454.5	14	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	11.5	11.9	0.64	0.58	0.07	**0.90**	**0.10**
Fa	%w.path area	**0.35**	45	32.3	33.0					
Ro	m/km	**0.2**	4	5.9	4.5					
LC	m	**0.1**	367.9	8.4	0					
TC	m	**0.15**	454.5	14	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860603-2

Monitored traffic (kESAL): 97.66

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3220	37.69	39.46	33	7700	16.49	16.77	79

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

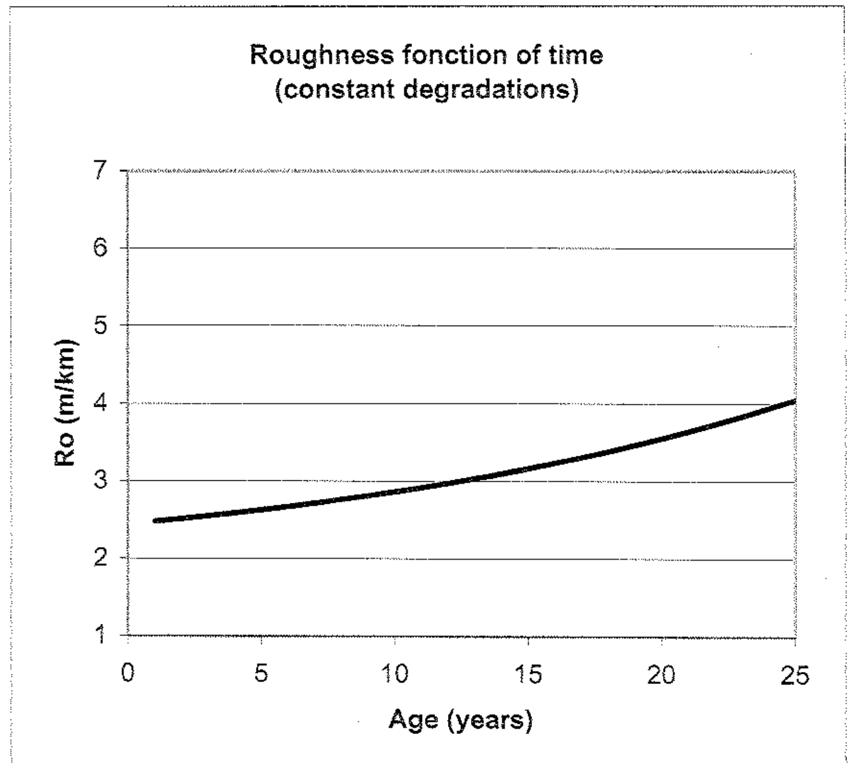
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860603-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	14	
TC	m/km	0.0	0
Fa	% lane area	4.7	4.7
BC	% lane area	0.0	0
LC	m/km	13.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	526	0
Subgrade PI	%	0	
Subgrade P_{075}	%	9	
Subgrade P_{020}	%	5	
Annuel precipitation	mm	1217.0	0
Precipitation s.-d.	mm	20.3	0
Site factor	-	26.7	0
Calibration factor	-	0.52	

Final roughness (m/km)	With CE	Without CE
	3.10	2.44



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860603-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.4	9.9	0.33	0.29	0.04	**0.89**	**0.11**
Fa	%w.path area	**0.25**	45	7.4	7.5					
Ro	m/km	**0.25**	4	3.1	2.4					
LC	m	**0.125**	367.9	2.0	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	9.9	0.38	0.33	0.05	**0.86**	**0.14**
Fa	%w.path area	**0.2**	45	7.4	7.5					
Ro	m/km	**0.35**	4	3.1	2.4					
LC	m	**0.125**	367.9	2.0	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	9.9	0.29	0.26	0.03	**0.90**	**0.10**
Fa	%w.path area	**0.35**	45	7.4	7.5					
Ro	m/km	**0.2**	4	3.1	2.4					
LC	m	**0.1**	367.9	2.0	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 860603-3

Monitored traffic (kESAL): 97.66

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
1560	8.78	9.13	16	1950	2.23	2.29	20

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

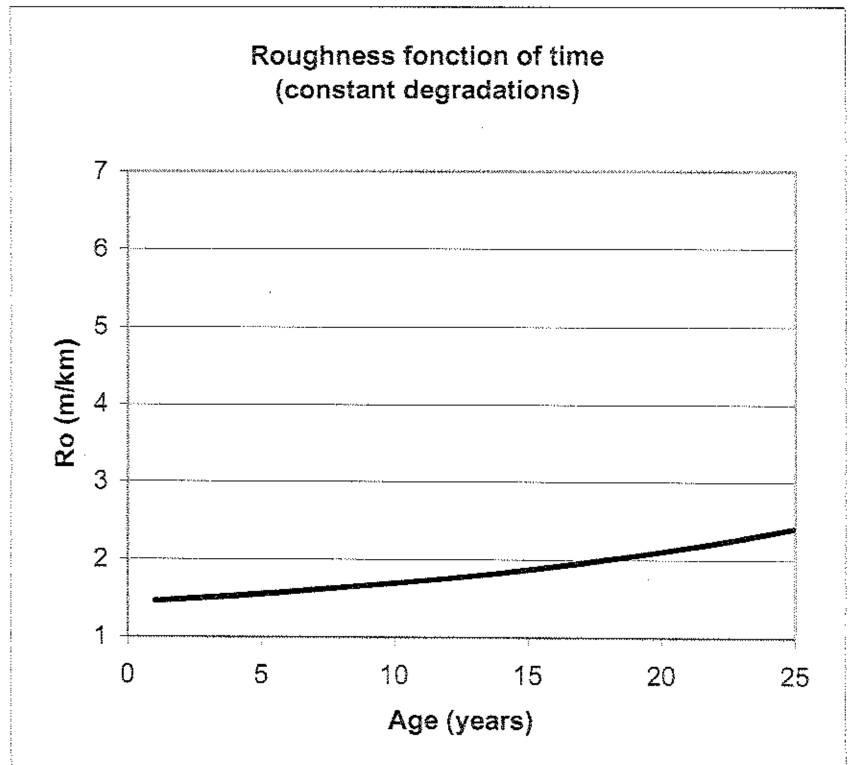
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 860603-3

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	14	
TC	m/km	0.0	0
Fa	% lane area	0.6	0.6
BC	% lane area	0.0	0
LC	m/km	0.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	526	0
Subgrade PI	%	0	
Subgrade P_{075}	%	9	
Subgrade P_{020}	%	5	
Annuel precipitation	mm	1217.0	0
Precipitation s.-d.	mm	20.3	0
Site factor	-	26.7	0
Calibration factor	-	0.31	

Final roughness (m/km)	With CE	Without CE
	1.84	1.45



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 860603-3

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	2.2	2.3	0.14	0.12	0.02	**0.84**	**0.16**
Fa	%w.path area	**0.25**	45	1.0	1.0					
Ro	m/km	**0.25**	4	1.8	1.4					
LC	m	**0.125**	367.9	0.0	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	2.2	2.3	0.18	0.15	0.03	**0.82**	**0.18**
Fa	%w.path area	**0.2**	45	1.0	1.0					
Ro	m/km	**0.35**	4	1.8	1.4					
LC	m	**0.125**	367.9	0.0	0					
TC	m	**0.125**	454.5	0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	2.2	2.3	0.12	0.10	0.02	**0.84**	**0.16**
Fa	%w.path area	**0.35**	45	1.0	1.0					
Ro	m/km	**0.2**	4	1.8	1.4					
LC	m	**0.1**	367.9	0.0	0					
TC	m	**0.15**	454.5	0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 870102-1

Monitored traffic (kESAL): 14

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
12950	88.86	78.25	925	113000	115.57	117.27	8071

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

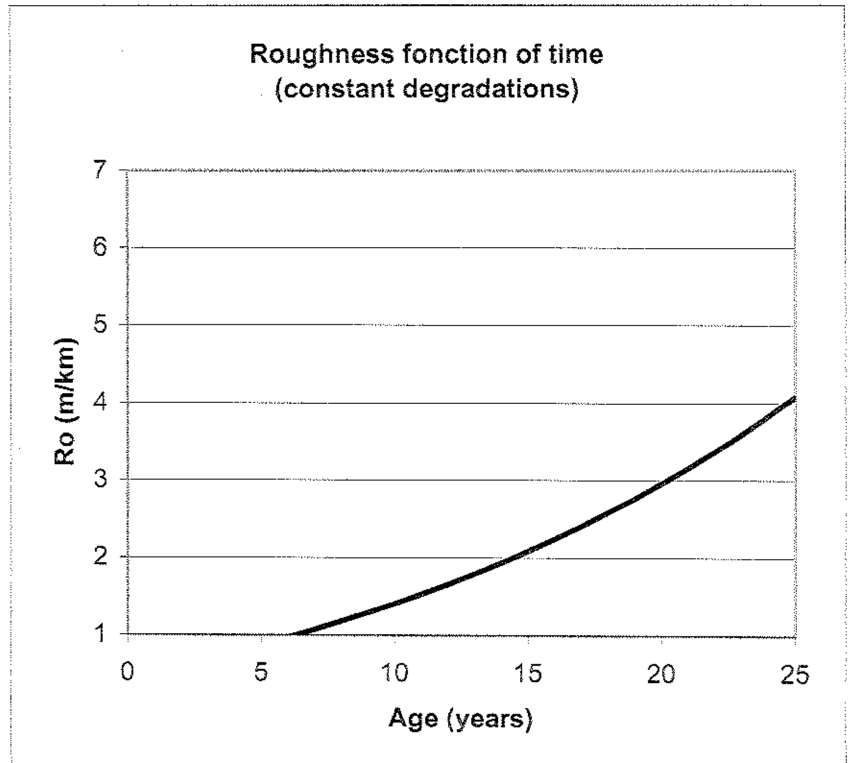
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 870102-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	22	
TC	m/km	792.7	0
Fa	% lane area	30.6	30.6
BC	% lane area	1.4	0
LC	m/km	66.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	875	0
Subgrade PI	%	34	
Subgrade P_{075}	%	94.6	
Subgrade P_{020}	%	86	
Annuel precipitation	mm	821.7	0
Precipitation s.-d.	mm	13.7	0
Site factor	-	397.9	0
Calibration factor	-	0.079	

Final roughness (m/km)	With CE	Without CE
	3.38	1.00



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 870102-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	22.2	19.6	0.76	0.55	0.21	**0.73**	**0.27**
Fa	%w.path area	**0.25**	45	52.0	52.8					
Ro	m/km	**0.25**	4	3.4	1.0					
LC	m	**0.125**	367.9	10.0	0					
TC	m	**0.125**	454.5	118.9	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	22.2	19.6	0.74	0.48	0.26	**0.65**	**0.35**
Fa	%w.path area	**0.2**	45	52.0	52.8					
Ro	m/km	**0.35**	4	3.4	1.0					
LC	m	**0.125**	367.9	10.0	0					
TC	m	**0.125**	454.5	118.9	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	22.2	19.6	0.79	0.62	0.18	**0.78**	**0.22**
Fa	%w.path area	**0.35**	45	52.0	52.8					
Ro	m/km	**0.2**	4	3.4	1.0					
LC	m	**0.1**	367.9	10.0	0					
TC	m	**0.15**	454.5	118.9	0					

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 870102-2

Monitored traffic (kESAL): 14

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
16275	111.8	97.89	1163	48500	49.6	50.34	3464

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

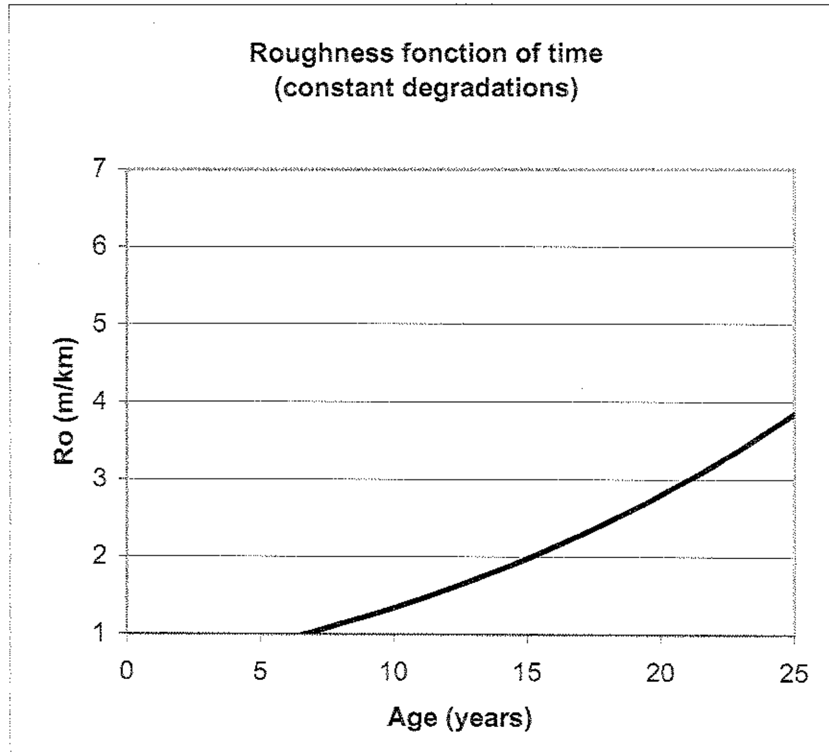
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 870102-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	22	
TC	m/km	788.0	0
Fa	% lane area	13.1	13.1
BC	% lane area	6.0	0
LC	m/km	391.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	875	0
Subgrade PI	%	34	
Subgrade P_{075}	%	94.6	
Subgrade P_{020}	%	86	
Annuel precipitation	mm	821.7	0
Precipitation s.-d.	mm	13.7	0
Site factor	-	397.9	0
Calibration factor	-	0.074	

Final roughness (m/km)	t+c	t
	3.19	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 870102-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	28.0	24.5	0.66	0.43	0.22	**0.66**	**0.34**
Fa	%w.path area	**0.25**	45	22.3	22.7					
Ro	m/km	**0.25**	4	3.2	1.0					
LC	m	**0.125**	367.9	58.7	0					
TC	m	**0.125**	454.5	118.2	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	28.0	24.5	0.65	0.38	0.27	**0.59**	**0.41**
Fa	%w.path area	**0.2**	45	22.3	22.7					
Ro	m/km	**0.35**	4	3.2	1.0					
LC	m	**0.125**	367.9	58.7	0					
TC	m	**0.125**	454.5	118.2	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	28.0	24.5	0.61	0.42	0.19	**0.69**	**0.31**
Fa	%w.path area	**0.35**	45	22.3	22.7					
Ro	m/km	**0.2**	4	3.2	1.0					
LC	m	**0.1**	367.9	58.7	0					
TC	m	**0.15**	454.5	118.2	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 900402-2

Monitored traffic (kESAL): 133

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
2190	42.4	33.63	16	4900	11.4	11.06	37

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

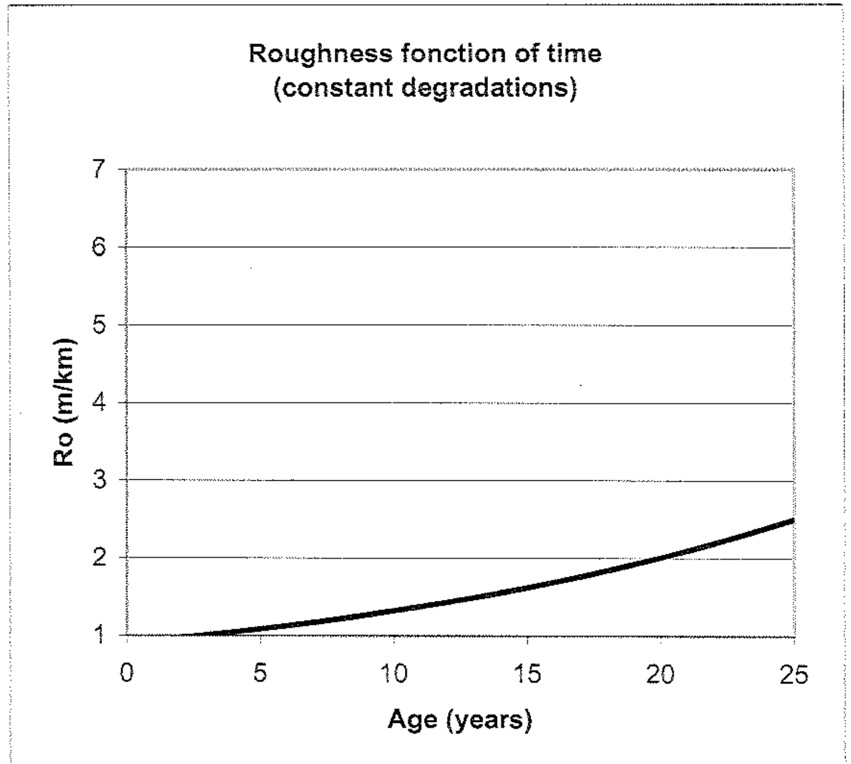
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 900402-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	26	
TC	m/km	1675.3	0
Fa	% lane area	3.0	3.0
BC	% lane area	0.0	0
LC	m/km	1682.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1775	0
Subgrade PI	%	10.2	
Subgrade P_{075}	%	67.5	
Subgrade P_{020}	%	29	
Annuel precipitation	mm	357.6	0
Precipitation s.-d.	mm	6.0	0
Site factor	-	132.2	0
Calibration factor	-	0.105	

Final roughness (m/km)	t+c	t
	2.62	1.00



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 900402-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	10.6	8.4					
Fa	%w.path area	**0.25**	45	5.1	5.0					
Ro	m/km	**0.25**	4	2.6	1.0	0.45	0.17	0.28	**0.38**	**0.62**
LC	m	**0.125**	367.9	252.4	0					
TC	m	**0.125**	454.5	251.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	10.6	8.4					
Fa	%w.path area	**0.2**	45	5.1	5.0					
Ro	m/km	**0.35**	4	2.6	1.0	0.49	0.18	0.31	**0.36**	**0.64**
LC	m	**0.125**	367.9	252.4	0					
TC	m	**0.125**	454.5	251.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	10.6	8.4					
Fa	%w.path area	**0.35**	45	5.1	5.0					
Ro	m/km	**0.2**	4	2.6	1.0	0.41	0.16	0.25	**0.38**	**0.62**
LC	m	**0.1**	367.9	252.4	0					
TC	m	**0.15**	454.5	251.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 900802-1

Monitored traffic (kESAL): 209

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
875	29.1	22.88	4.2	750	3.0	2.83	3.6

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

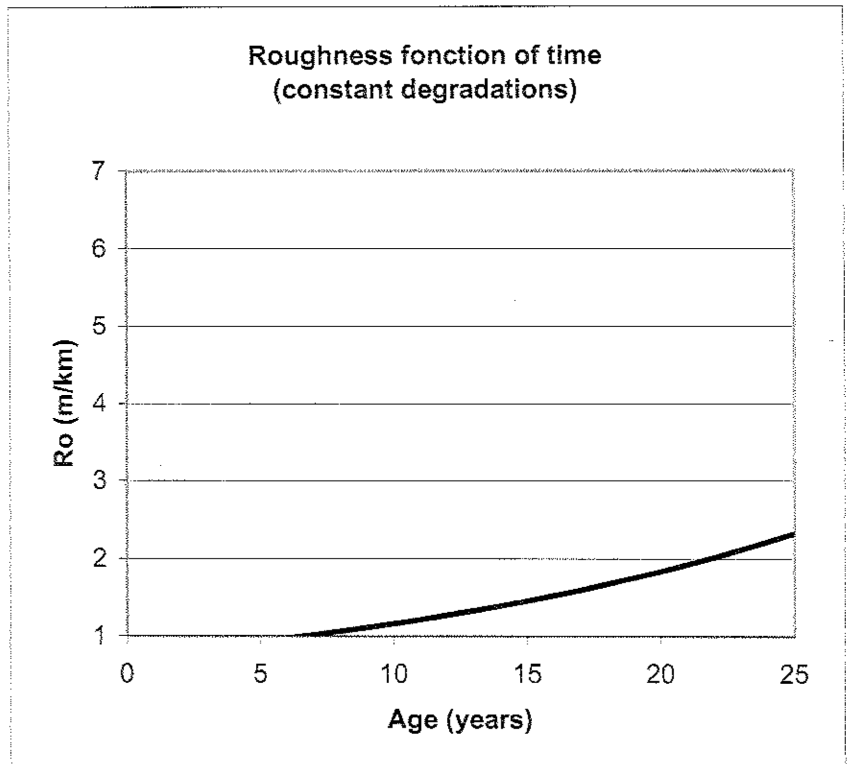
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 900802-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	22	
TC	m/km	1512.0	0
Fa	% lane area	0.7	0.7
BC	% lane area	0.0	0
LC	m/km	1024.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1950	0
Subgrade PI	%	10.2	
Subgrade P_{075}	%	67.5	
Subgrade P_{020}	%	29	
Annuel precipitation	mm	457.4	0
Precipitation s.-d.	mm	7.6	0
Site factor	-	139.5	0
Calibration factor	-	0.098	

	t+c	t
Final roughness (m/km)	2.02	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 900802-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	7.3	5.7	0.32	0.13	0.19	**0.39**	**0.61**
Fa	%w.path area	**0.25**	45	1.4	1.3					
Ro	m/km	**0.25**	4	2.0	1.0					
LC	m	**0.125**	367.9	153.7	0					
TC	m	**0.125**	454.5	226.8	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.3	5.7	0.36	0.14	0.22	**0.39**	**0.61**
Fa	%w.path area	**0.2**	45	1.4	1.3					
Ro	m/km	**0.35**	4	2.0	1.0					
LC	m	**0.125**	367.9	153.7	0					
TC	m	**0.125**	454.5	226.8	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.3	5.7	0.29	0.11	0.18	**0.37**	**0.63**
Fa	%w.path area	**0.35**	45	1.4	1.3					
Ro	m/km	**0.2**	4	2.0	1.0					
LC	m	**0.1**	367.9	153.7	0					
TC	m	**0.15**	454.5	226.8	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 900802-2

Monitored traffic (kESAL): 209

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
530	20.45	16.11	2.5	975	4.4	4.15	4.7

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

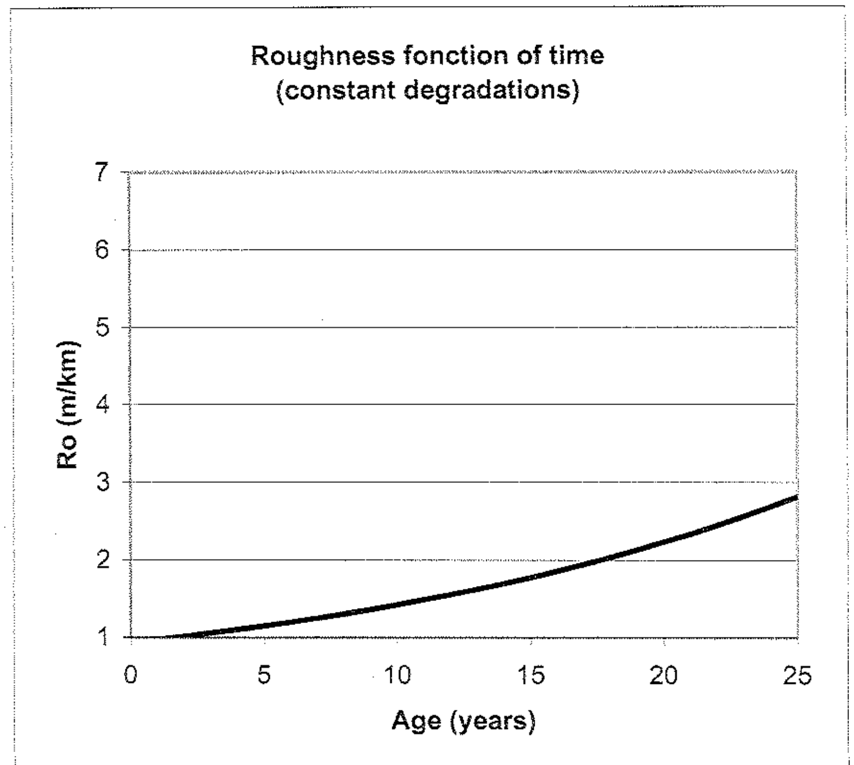
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 900802-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	21	
TC	m/km	1820.7	0
Fa	% lane area	1.1	1.1
BC	% lane area	0.0	0
LC	m/km	1000.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1950	0
Subgrade PI	%	10.2	
Subgrade P_{075}	%	67.5	
Subgrade P_{020}	%	29	
Annuel precipitation	mm	457.4	0
Precipitation s.-d.	mm	7.6	0
Site factor	-	139.5	0
Calibration factor	-	0.117	

Final roughness (m/km)	t+c	t
	2.34	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 900802-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	5.1	4.0	0.33	0.11	0.22	**0.34**	**0.66**
Fa	%w.path area	**0.25**	45	2.0	1.9					
Ro	m/km	**0.25**	4	2.3	1.0					
LC	m	**0.125**	367.9	150.0	0					
TC	m	**0.125**	454.5	273.1	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.1	4.0	0.38	0.13	0.25	**0.34**	**0.66**
Fa	%w.path area	**0.2**	45	2.0	1.9					
Ro	m/km	**0.35**	4	2.3	1.0					
LC	m	**0.125**	367.9	150.0	0					
TC	m	**0.125**	454.5	273.1	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	5.1	4.0	0.30	0.10	0.21	**0.32**	**0.68**
Fa	%w.path area	**0.35**	45	2.0	1.9					
Ro	m/km	**0.2**	4	2.3	1.0					
LC	m	**0.1**	367.9	150.0	0					
TC	m	**0.15**	454.5	273.1	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 900803-1

Monitored traffic (kESAL): 237.66

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
216.7	56.75	44.48	0.9	8625	102.26	96.59	36

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 900803-1

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	5	
TC	m/km	1935.1	0
Fa	% lane area	24.9	24.9
BC	% lane area	0.0	0
LC	m/km	719.3	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1800	0
Subgrade PI	%	19.1	
Subgrade P_{075}	%	30	
Subgrade P_{020}	%	48	
Annuel precipitation	mm	468.0	0
Precipitation s.-d.	mm	7.8	0
Site factor	-	226.1	0
Calibration factor	-	0.2	

Final roughness (m/km)	t+c	t
	2.17	1.00

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 900803-1

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	14.2	11.1	0.65	0.42	0.23	**0.64**	**0.36**
Fa	%w.path area	**0.25**	45	46.0	43.5					
Ro	m/km	**0.25**	4	2.2	1.0					
LC	m	**0.125**	367.9	107.9	0					
TC	m	**0.125**	454.5	290.27	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	14.2	11.1	0.62	0.37	0.26	**0.59**	**0.41**
Fa	%w.path area	**0.2**	45	46.0	43.5					
Ro	m/km	**0.35**	4	2.2	1.0					
LC	m	**0.125**	367.9	107.9	0					
TC	m	**0.125**	454.5	290	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	14.2	11.1	0.71	0.48	0.23	**0.68**	**0.32**
Fa	%w.path area	**0.35**	45	46.0	43.5					
Ro	m/km	**0.2**	4	2.2	1.0					
LC	m	**0.1**	367.9	107.9	0					
TC	m	**0.15**	454.5	290	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 900803-2

Monitored traffic (kESAL): 237.66

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
117.5	30.76	24.58	0.5	10600	125.68	118.71	45

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

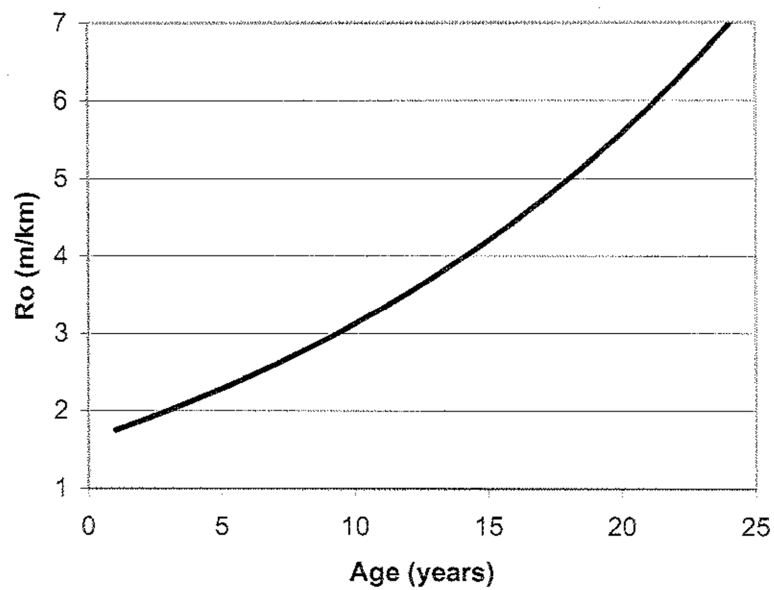
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 900803-2

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	5	
TC	m/km	1433.1	0
Fa	% lane area	30.5	30.5
BC	% lane area	0.0	0
LC	m/km	800.0	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1800	0
Subgrade PI	%	19.1	
Subgrade P_{075}	%	0	
Subgrade P_{020}	%	48	
Annuel precipitation	mm	468.0	0
Precipitation s.-d.	mm	7.8	0
Site factor	-	225.9	0
Calibration factor	-	0.22	

Final roughness (m/km)	t+c	t
	2.28	1.05



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 900803-2

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	7.7	6.1	0.63	0.42	0.21	**0.67**	**0.33**
Fa	%w.path area	**0.25**	45	56.6	53.4					
Ro	m/km	**0.25**	4	2.3	1.1					
LC	m	**0.125**	367.9	120.0	0					
TC	m	**0.125**	454.5	214.97	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.7	6.1	0.61	0.38	0.23	**0.62**	**0.38**
Fa	%w.path area	**0.2**	45	56.6	53.4					
Ro	m/km	**0.35**	4	2.3	1.1					
LC	m	**0.125**	367.9	120.0	0					
TC	m	**0.125**	454.5	215	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	7.7	6.1	0.72	0.52	0.20	**0.72**	**0.28**
Fa	%w.path area	**0.35**	45	56.6	53.4					
Ro	m/km	**0.2**	4	2.3	1.1					
LC	m	**0.1**	367.9	120.0	0					
TC	m	**0.15**	454.5	215	0					

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 34E98T

Monitored traffic (kESAL): 24.8

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
565	14.01	12.04	23	31575	113.61	106.26	1273

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

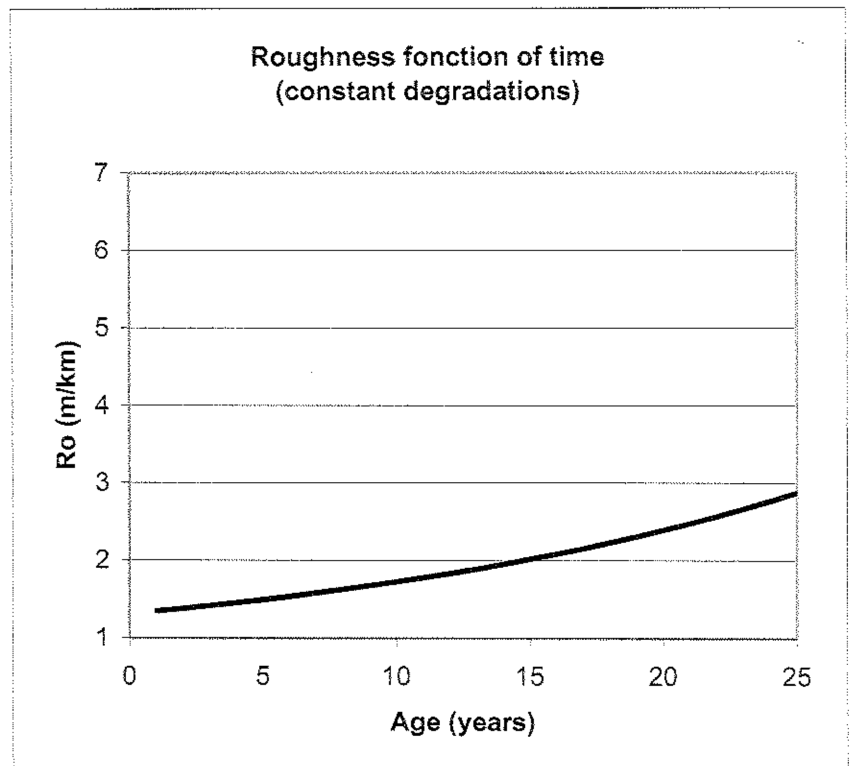
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 34E98T

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	5	
TC	m/km	481.8	0
Fa	% lane area	31.0	31.0
BC	% lane area	0.0	0
LC	m/km	435.6	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1260	0
Subgrade PI	%	5	
Subgrade P_{075}	%	39.6	
Subgrade P_{020}	%	11	
Annuel precipitation	mm	1066	0
Precipitation s.-d.	mm	18	0
Site factor	-	59.92	0
Calibration factor	-	0.225	

Final roughness (m/km)	t+c	t
	1.50	1.08



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 34E98T

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	3.5	3.0	0.45	0.36	0.09	**0.80**	**0.20**
Fa	%w.path area	**0.25**	45	51.1	47.8					
Ro	m/km	**0.25**	4	1.5	1.1					
LC	m	**0.125**	367.9	65.3	0					
TC	m	**0.125**	454.5	72.3	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	3.5	3.0	0.43	0.33	0.10	**0.77**	**0.23**
Fa	%w.path area	**0.2**	45	51.1	47.8					
Ro	m/km	**0.35**	4	1.5	1.1					
LC	m	**0.125**	367.9	65.3	0					
TC	m	**0.125**	454.5	72.3	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	3.5	3.0	0.54	0.45	0.09	**0.83**	**0.17**
Fa	%w.path area	**0.35**	45	51.1	47.8					
Ro	m/km	**0.2**	4	1.5	1.1					
LC	m	**0.1**	367.9	65.3	0					
TC	m	**0.15**	454.5	72.3	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 53E93M14

Monitored traffic (kESAL): 184

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
1900	38.01	36.88	10	38350	106.35	107.4	208

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

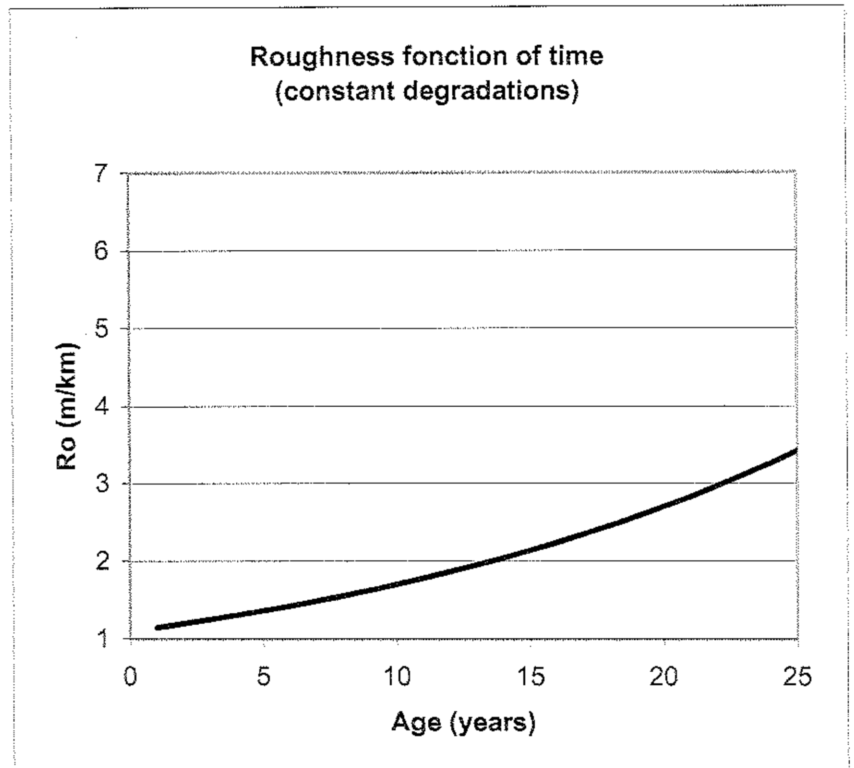
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 53E93M14

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	9	
TC	m/km	158.4	0
Fa	% lane area	26.6	26.6
BC	% lane area	0.0	0
LC	m/km	25.2	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1100	0
Subgrade PI	%	5	
Subgrade P_{075}	%	69	
Subgrade P_{020}	%	18	
Annuel precipitation	mm	954.3	0
Precipitation s.-d.	mm	16	0
Site factor	-	91.60	0
Calibration factor	-	0.22	

Final roughness (m/km)	t+c	t
	1.63	1.05



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 53E93M14

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.5	9.2	0.47	0.43	0.04	**0.91**	**0.09**
Fa	%w.path area	**0.25**	45	47.9	48.3					
Ro	m/km	**0.25**	4	1.6	1.0					
LC	m	**0.125**	367.9	3.8	0					
TC	m	**0.125**	454.5	23.8	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.5	9.2	0.44	0.38	0.06	**0.87**	**0.13**
Fa	%w.path area	**0.2**	45	47.9	48.3					
Ro	m/km	**0.35**	4	1.6	1.0					
LC	m	**0.125**	367.9	3.8	0					
TC	m	**0.125**	454.5	23.8	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.5	9.2	0.54	0.50	0.04	**0.93**	**0.07**
Fa	%w.path area	**0.35**	45	47.9	48.3					
Ro	m/km	**0.2**	4	1.6	1.0					
LC	m	**0.1**	367.9	3.8	0					
TC	m	**0.15**	454.5	23.8	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 53V96D11

Monitored traffic (kESAL): 693.5

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
11700	36.45	39.49	17	13800	9.14	9.44	20

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

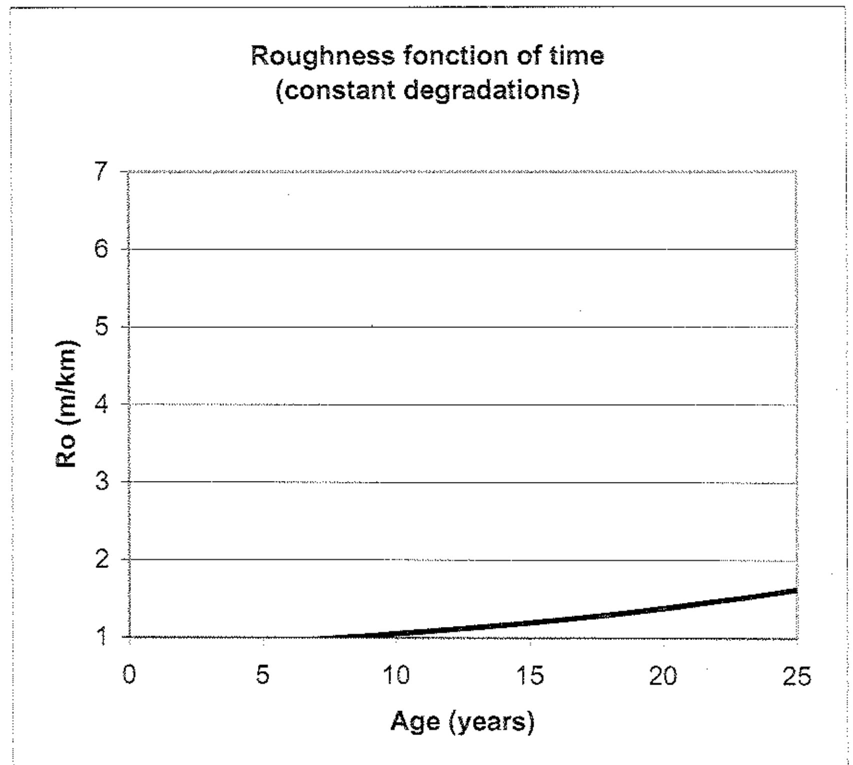
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 53V96D11

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	8	
TC	m/km	0.0	0
Fa	% lane area	2.3	2.3
BC	% lane area	0.0	0
LC	m/km	13.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	974	0
Subgrade PI	%	5	
Subgrade P_{075}	%	25	
Subgrade P_{020}	%	7	
Annuel precipitation	mm	902.9	0
Precipitation s.-d.	mm	15	0
Site factor	-	37.58	0
Calibration factor	-	0.18	

	t+c	t
Final roughness (m/km)	1.00	1.00



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Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 53V96D11

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.1	9.9	0.18	0.18	-0.01	**1.04**	**-0.04**
Fa	%w.path area	**0.25**	45	4.1	4.2					
Ro	m/km	**0.25**	4	1.0	1.0					
LC	m	**0.125**	367.9	2.1	0					
TC	m	**0.125**	454.5	0.0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.1	9.9	0.18	0.19	-0.01	**1.03**	**-0.03**
Fa	%w.path area	**0.2**	45	4.1	4.2					
Ro	m/km	**0.35**	4	1.0	1.0					
LC	m	**0.125**	367.9	2.1	0					
TC	m	**0.125**	454.5	0.0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.1	9.9	0.16	0.16	-0.01	**1.04**	**-0.04**
Fa	%w.path area	**0.35**	45	4.1	4.2					
Ro	m/km	**0.2**	4	1.0	1.0					
LC	m	**0.1**	367.9	2.1	0					
TC	m	**0.15**	454.5	0.0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 54V96D11

Monitored traffic (kESAL): 673.4

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
10250	18.37	20.57	15	179500	67.98	72.39	267

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

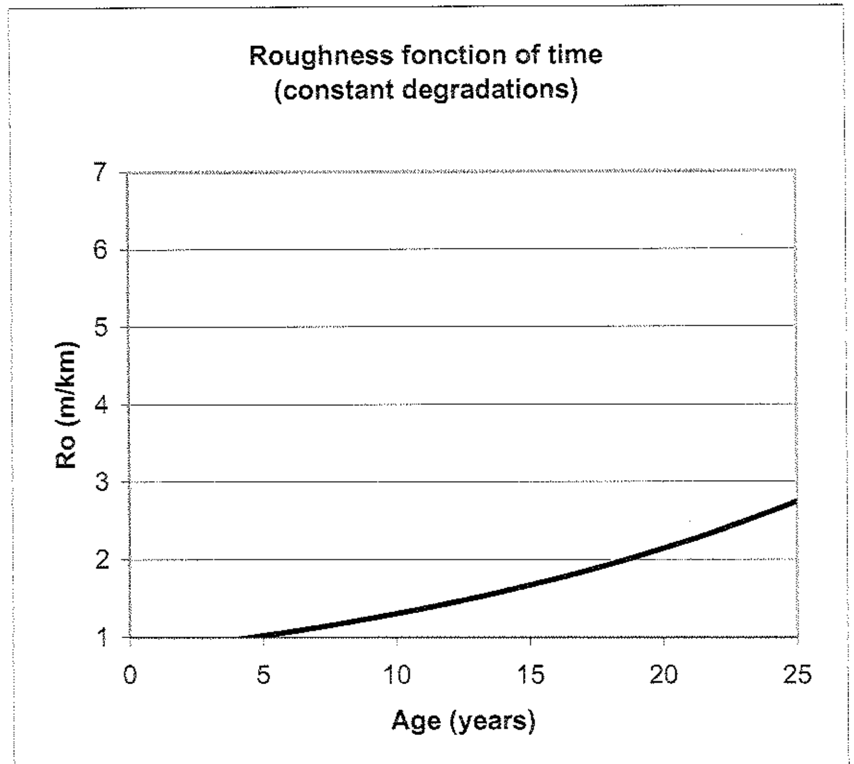
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 54V96D11

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	7	
TC	m/km	108.0	0
Fa	% lane area	17.0	17.0
BC	% lane area	0.0	0
LC	m/km	104.4	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	810	0
Subgrade PI	%	10	
Subgrade P_{075}	%	83.2	
Subgrade P_{020}	%	22	
Annuel precipitation	mm	902.9	0
Precipitation s.-d.	mm	15	0
Site factor	-	105.50	0
Calibration factor	-	0.16	

	t+c	t
Final roughness (m/km)	1.12	1.00



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 54V96D11

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	4.6	5.1	0.30	0.29	0.00	**1.00**	**0.00**
Fa	%w.path area	**0.25**	45	30.6	32.6					
Ro	m/km	**0.25**	4	1.1	1.0					
LC	m	**0.125**	367.9	15.7	0					
TC	m	**0.125**	454.5	16.2	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	4.6	5.1	0.28	0.27	0.01	**0.97**	**0.03**
Fa	%w.path area	**0.2**	45	30.6	32.6					
Ro	m/km	**0.35**	4	1.1	1.0					
LC	m	**0.125**	367.9	15.7	0					
TC	m	**0.125**	454.5	16.2	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	4.6	5.1	0.34	0.34	0.00	**1.01**	**-0.01**
Fa	%w.path area	**0.35**	45	30.6	32.6					
Ro	m/km	**0.2**	4	1.1	1.0					
LC	m	**0.1**	367.9	15.7	0					
TC	m	**0.15**	454.5	16.2	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 63E98D11

Monitored traffic (kESAL): 621.6

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
8500	26.73	23.63	14	3600	2.04	2.06	5.8

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

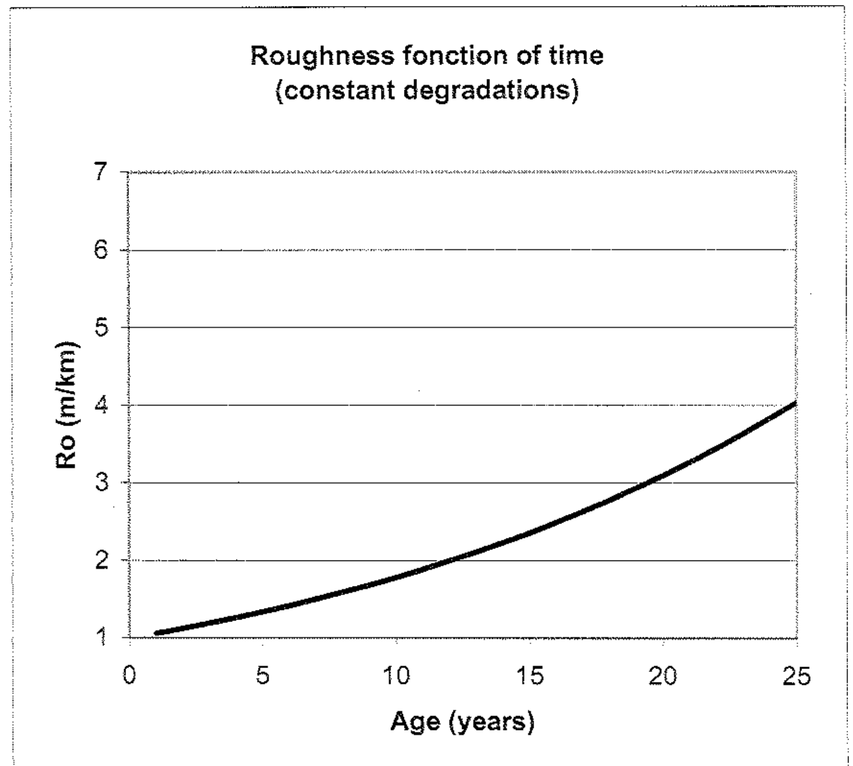
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 63E98D11

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	6	
TC	m/km	25.9	0
Fa	% lane area	0.5	0.5
BC	% lane area	0.0	0
LC	m/km	11.1	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1131	0
Subgrade PI	%	10	
Subgrade P_{075}	%	92.5	
Subgrade P_{020}	%	25	
Annuel precipitation	mm	936.3	0
Precipitation s.-d.	mm	16	0
Site factor	-	125.84	0
Calibration factor	-	0.21	

Final roughness (m/km)	t+c	t
	1.42	1.00



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 63E98D11

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.7	5.9	0.16	0.13	0.04	**0.78**	**0.22**
Fa	%w.path area	**0.25**	45	0.9	0.9					
Ro	m/km	**0.25**	4	1.4	1.0					
LC	m	**0.125**	367.9	1.7	0					
TC	m	**0.125**	454.5	3.9	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.7	5.9	0.18	0.14	0.04	**0.76**	**0.24**
Fa	%w.path area	**0.2**	45	0.9	0.9					
Ro	m/km	**0.35**	4	1.4	1.0					
LC	m	**0.125**	367.9	1.7	0					
TC	m	**0.125**	454.5	3.9	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.7	5.9	0.13	0.10	0.03	**0.78**	**0.22**
Fa	%w.path area	**0.35**	45	0.9	0.9					
Ro	m/km	**0.2**	4	1.4	1.0					
LC	m	**0.1**	367.9	1.7	0					
TC	m	**0.15**	454.5	3.9	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 89090

Monitored traffic (kESAL): 432.9

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3575	37.25	40.31	8.3	4100	7.79	8.02	9.5

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

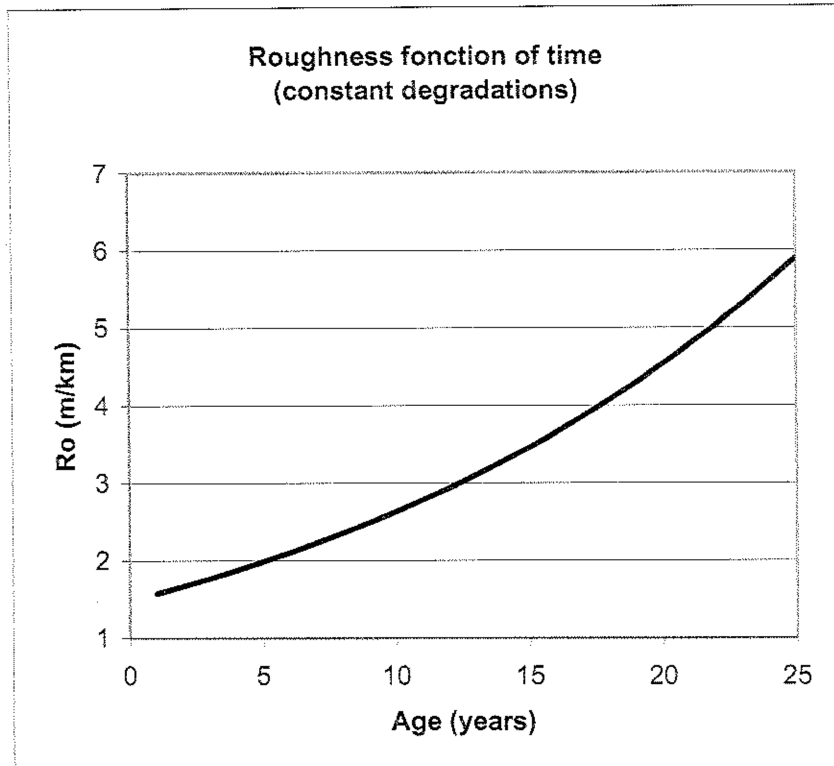
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 89090

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	6	
TC	m/km	51.2	0
Fa	% lane area	1.9	1.9
BC	% lane area	0.0	0
LC	m/km	186.7	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1648	0
Subgrade PI	%	10	
Subgrade P_{075}	%	90	
Subgrade P_{020}	%	24	
Annuel precipitation	mm	929.7	0
Precipitation s.-d.	mm	15	0
Site factor	-	127.31	0
Calibration factor	-	0.3	

Final roughness (m/km)	t+c	t
	2.10	1.40



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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 89090

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.3	10.1	0.26	0.21	0.05	**0.82**	**0.18**
Fa	%w.path area	**0.25**	45	3.5	3.6					
Ro	m/km	**0.25**	4	2.1	1.4					
LC	m	**0.125**	367.9	28.0	0					
TC	m	**0.125**	454.5	7.7	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.3	10.1	0.29	0.22	0.07	**0.77**	**0.23**
Fa	%w.path area	**0.2**	45	3.5	3.6					
Ro	m/km	**0.35**	4	2.1	1.4					
LC	m	**0.125**	367.9	28.0	0					
TC	m	**0.125**	454.5	7.7	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.3	10.1	0.22	0.18	0.04	**0.82**	**0.18**
Fa	%w.path area	**0.35**	45	3.5	3.6					
Ro	m/km	**0.2**	4	2.1	1.4					
LC	m	**0.1**	367.9	28.0	0					
TC	m	**0.15**	454.5	7.7	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 891021

Monitored traffic (kESAL): 488.4

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
2500	36.72	34.24	5.1	46000	94.38	96.24	94

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

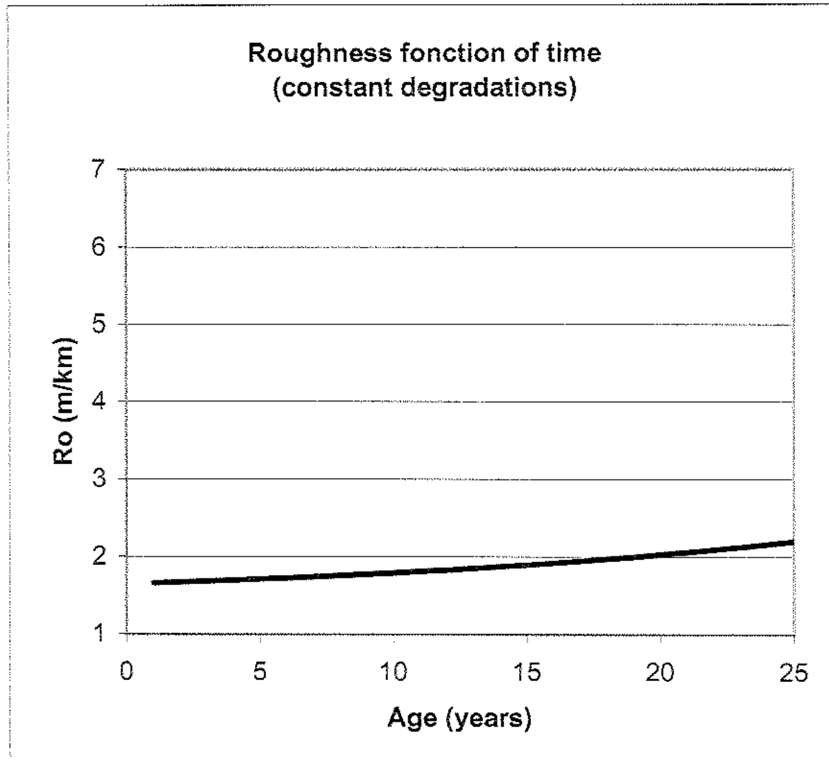
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 891021

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	9	
TC	m/km	744.6	0
Fa	% lane area	23.3	23.3
BC	% lane area	0.0	0
LC	m/km	1062.2	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1252	0
Subgrade PI	%	0	
Subgrade P_{075}	%	10.3	
Subgrade P_{020}	%	3	
Annuel precipitation	mm	1075.5	0
Precipitation s.-d.	mm	18	0
Site factor	-	19.92	0
Calibration factor	-	0.24	

	t+c	t
Final roughness (m/km)	1.77	1.14



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 891021

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.2	8.6	0.52	0.40	0.13	**0.76**	**0.24**
Fa	%w.path area	**0.25**	45	42.5	43.3					
Ro	m/km	**0.25**	4	1.8	1.1					
LC	m	**0.125**	367.9	161.9	0					
TC	m	**0.125**	454.5	113.5	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.2	8.6	0.50	0.36	0.14	**0.72**	**0.28**
Fa	%w.path area	**0.2**	45	42.5	43.3					
Ro	m/km	**0.35**	4	1.8	1.1					
LC	m	**0.125**	367.9	161.9	0					
TC	m	**0.125**	454.5	113.5	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.2	8.6	0.57	0.46	0.11	**0.81**	**0.19**
Fa	%w.path area	**0.35**	45	42.5	43.3					
Ro	m/km	**0.2**	4	1.8	1.1					
LC	m	**0.1**	367.9	161.9	0					
TC	m	**0.15**	454.5	113.5	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 892011

Monitored traffic (kESAL): 52.2

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
6435	37.68	33.22	123	148900	160.19	153.83	2852

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

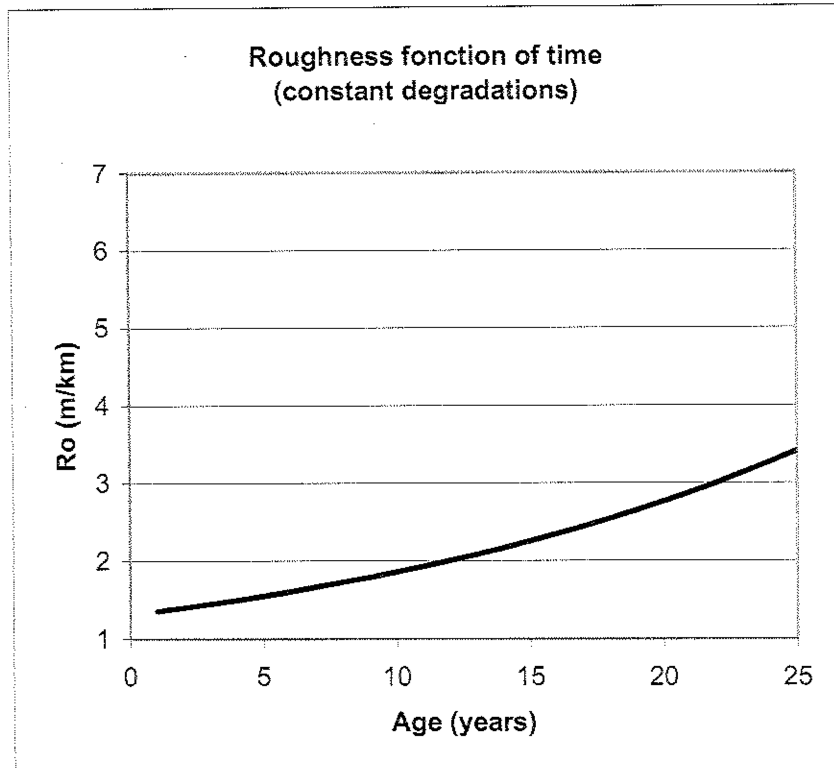
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 892011

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	24	
TC	m/km	1148.4	0
Fa	% lane area	43.7	43.7
BC	% lane area	0.0	0
LC	m/km	39.6	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1200	0
Subgrade PI	%	5	
Subgrade P_{075}	%	60.5	
Subgrade P_{020}	%	16	
Annuel precipitation	mm	1297.1	0
Precipitation s.-d.	mm	22	0
Site factor	-	86.75	0
Calibration factor	-	0.21	

Final roughness (m/km)	t+c	t
	3.27	1.02



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 892011

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	9.4	8.3	0.75	0.53	0.22	**0.71**	**0.29**
Fa	%w.path area	**0.25**	45	72.1	69.2					
Ro	m/km	**0.25**	4	3.3	1.0					
LC	m	**0.125**	367.9	6.0	0					
TC	m	**0.125**	454.5	175.0	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	8.3	0.73	0.46	0.27	**0.63**	**0.37**
Fa	%w.path area	**0.2**	45	72.1	69.2					
Ro	m/km	**0.35**	4	3.3	1.0					
LC	m	**0.125**	367.9	6.0	0					
TC	m	**0.125**	454.5	175.0	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	9.4	8.3	0.86	0.66	0.20	**0.76**	**0.24**
Fa	%w.path area	**0.35**	45	72.1	69.2					
Ro	m/km	**0.2**	4	3.3	1.0					
LC	m	**0.1**	367.9	6.0	0					
TC	m	**0.15**	454.5	175.0	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: 89A340

Monitored traffic (kESAL): 488.4

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
3950	58.03	54.09	8.1	50000	102.59	104.6	102

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Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

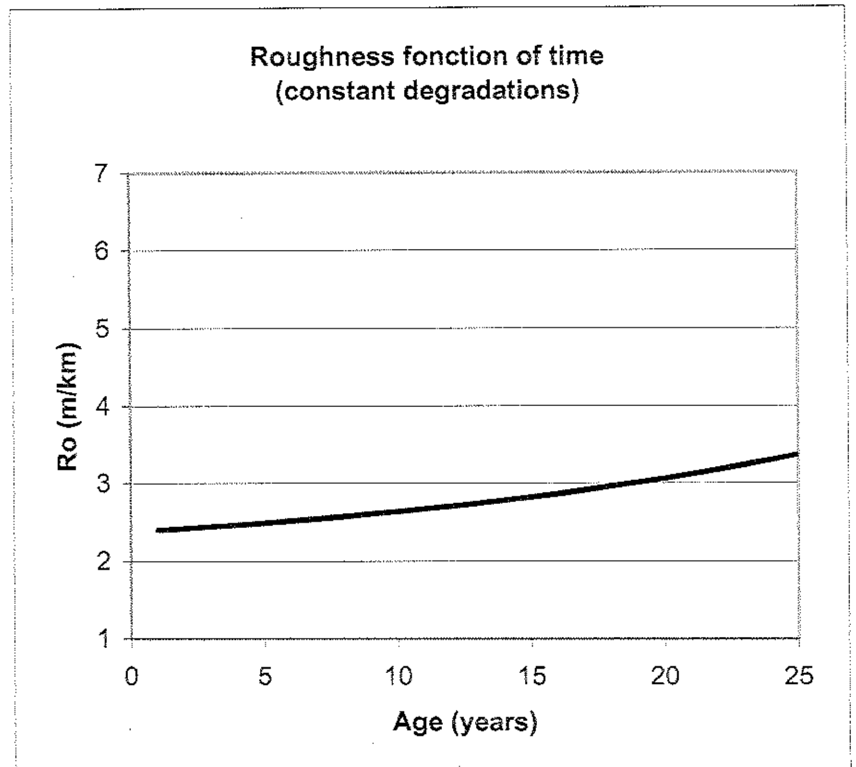
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: 89A340

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	12	
TC	m/km	317.6	0
Fa	% lane area	25.3	25.3
BC	% lane area	0.0	0
LC	m/km	339.8	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1252	0
Subgrade PI	%	0	
Subgrade P_{075}	%	10.3	
Subgrade P_{020}	%	3	
Annuel precipitation	mm	1075.5	0
Precipitation s.-d.	mm	18	0
Site factor	-	19.92	0
Calibration factor	-	0.43	

Final roughness (m/km)	t+c	t
	2.71	2.05



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: 89A340

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	14.5	13.5	0.60	0.52	0.08	**0.87**	**0.13**
Fa	%w.path area	**0.25**	45	46.2	47.1					
Ro	m/km	**0.25**	4	2.7	2.0					
LC	m	**0.125**	367.9	51.8	0					
TC	m	**0.125**	454.5	48.4	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	14.5	13.5	0.59	0.50	0.09	**0.84**	**0.16**
Fa	%w.path area	**0.2**	45	46.2	47.1					
Ro	m/km	**0.35**	4	2.7	2.0					
LC	m	**0.125**	367.9	51.8	0					
TC	m	**0.125**	454.5	48.4	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	14.5	13.5	0.64	0.58	0.06	**0.90**	**0.10**
Fa	%w.path area	**0.35**	45	46.2	47.1					
Ro	m/km	**0.2**	4	2.7	2.0					
LC	m	**0.1**	367.9	51.8	0					
TC	m	**0.15**	454.5	48.4	0					

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Results of rutting and fatigue damages computed with AKFPD software

Site number: SPE5423

Monitored traffic (kESAL): 404.1

Ru damage computation				Fa damage computation			
Traffic (kESAL)	damage (%)		Calibration factor	Traffic (kESAL)	damage (%)		Calibration factor
	t + c	t			t + c	t	
1725	25.17	27.38	4.3	47300	116.96	119.91	117

Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

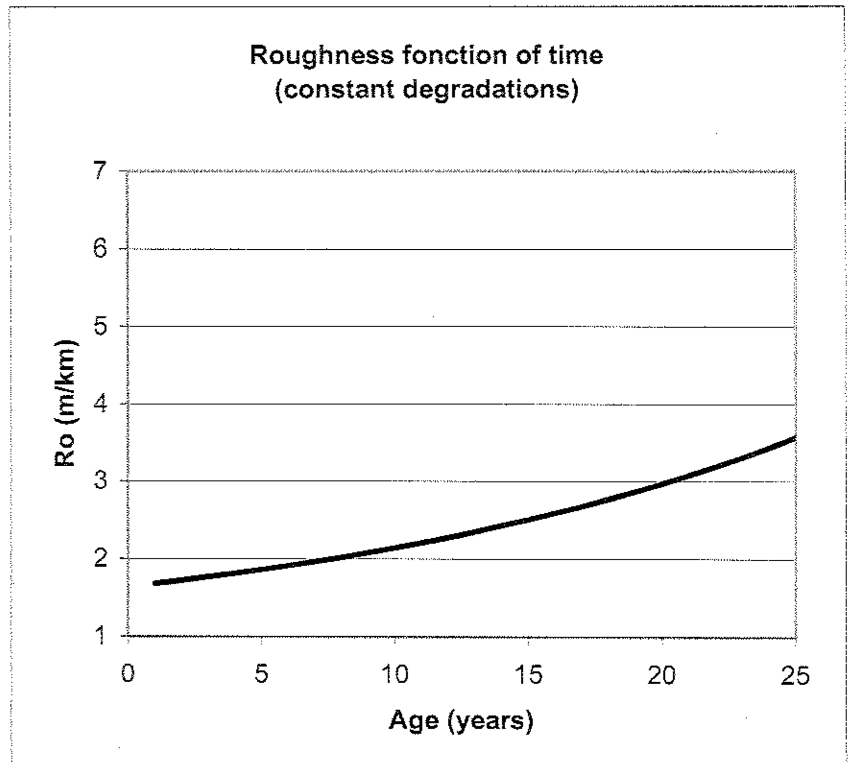
NCHRP-2002 roughness model for flexible pavement on granular base

Site number: SPE5423

Degradations			
Data	units	t + c	t
Ro_0	m/km	1	
Age	years	11	
TC	m/km	529.3	0
Fa	% lane area	28.8	28.8
BC	% lane area	0.0	0
LC	m/km	1226.4	0

Site characteristics			
Data	units	t + c	t
Freezing index	°C*d	1200	0
Subgrade PI	%	5	
Subgrade P_{075}	%	48.3	
Subgrade P_{020}	%	13	
Annuel precipitation	mm	1108.9	0
Precipitation s.-d.	mm	18	0
Site factor	-	69.84	0
Calibration factor	-	0.24	

Final roughness (m/km)	t+c	t
	2.21	1.15



Transport Canada

Estimation of the Relationships of road Deterioration to Traffic and Weather in Canada

BBR project number: M61-04-07

Calculation of traffic and climatic damages

Site number: SPE5423

Weighting factor repartition 1

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.25**	25	6.3	6.8	0.66	0.44	0.22	**0.66**	**0.34**
Fa	%w.path area	**0.25**	45	52.6	54.0					
Ro	m/km	**0.25**	4	2.2	1.1					
LC	m	**0.125**	367.9	367.9	0					
TC	m	**0.125**	454.5	158.8	0					

Weighting factor repartition 2

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.3	6.8	0.65	0.39	0.25	**0.61**	**0.39**
Fa	%w.path area	**0.2**	45	52.6	54.0					
Ro	m/km	**0.35**	4	2.2	1.1					
LC	m	**0.125**	367.9	367.9	0					
TC	m	**0.125**	454.5	158.8	0					

Weighting factor repartition 3

Degradation type	Unit	ωi	Degradation values			PI_{t+c}	PI_t	PI_c	Traffic damage	Climate damage
			Terminal	t + c	t					
Ru	mm	**0.2**	25	6.3	6.8	0.72	0.53	0.19	**0.74**	**0.26**
Fa	%w.path area	**0.35**	45	52.6	54.0					
Ro	m/km	**0.2**	4	2.2	1.1					
LC	m	**0.1**	367.9	367.9	0					
TC	m	**0.15**	454.5	158.8	0					