Selection of Surface Type for Low Volume Roads

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ABSTRACT

Surface treatments, seal coats and chip seals are commons surface types on low volume roads in Canada. With changes in traffic volumes and business activities, transportation agencies face the challenge of deciding if and when surface-treated pavements should be upgraded to asphalt concrete pavements or, alternatively, when asphalt concrete pavements should be downgraded. Many agencies base the decision to upgrade a roadway based on traffic volumes, but most do not have a formal set of guidelines for deciding if the surface of a low volume road should be surface-treated or asphalt concrete. This paper describes a model, based on a numerical score, which facilitates systematic and judicious selection of pavement surface type for low volume roads.

Many factors may influence the selection of the pavement surface type for low volume roads. These factors fall into two broad categories – costs and benefits. Cost considerations include agency cost to build and maintain the pavement surface, agency experience with constructing and maintaining different pavement surfaces, and user costs. Benefit considerations include benefits to local and long distance road users, to individuals and businesses, and the impact on nearby residents. Not all costs and benefits can be readily quantified. To develop guidelines that capture quantifiable economic aspects as well as societal aspects, the engineering analysis of costs and benefits were supplemented by expert opinion using a Delphi technique. Using this technique, eight experts reached a consensus regarding the type of selection factors and their relative importance that form the guidelines for surface type selection.

The selection factors that were recommended for scoring the need to upgrade surface-treated pavement sections are listed below. The numbers in brackets following the factors are factor weights. The total factor weight is 100.

1. Traffic volumes adjusted for the presence of commercial vehicles (25).
2. Impact on nearby residents based on the number of residences close to the highway (10).
3. Impact on local business activities based on the presence of five different industries (10).
4. Impact on long-distance travel based on percentage of long-distance commercial vehicles (10).
5. Total agency costs of upgrading a surface-treated pavement (45).

Detailed instructions were prepared on how to score individual selection factors. For example, the instructions for scoring the impact on local business activities were prepared separately for the forestry industry, tourism industry, agricultural industry, mining and extraction of resources industries, and for all other industries. The paper also outlines the methods used to develop scoring guidelines and the results of their application to a 350 km long network of low volume roads.

For those surface treated roads that have been identified as candidates for upgrading to asphalt concrete pavement, a cost-benefit analysis was used to prioritize them using a cost-benefit ratio. The cost benefit analysis utilized the Ontario Ministry of Transportation's Priority Economic Analysis Tool (PEAT).

BACKGROUND

The main objective of the work described in this paper was the development of a model for surface type selection for low volume roads and the testing of the model by applying it to a network of low-volume roads. To facilitate the development of the model, a literature review and agency surveys were carried out regarding the factors used by agencies to decide between surface treatment and hot mix asphalt.

Based on the surveys results, most agencies do not have a formal set of guidelines for the selection asphalt concrete (AC) pavement versus a surface treatment (ST) pavement for low volume roads. The agencies used a variety of factors for deciding between ST and AC pavements. The selection factors typically used by agencies include AADT volumes, number of commercial vehicles, road classification, urban versus rural surroundings, and economic analysis.

Typically, agencies which have pavement surface type selection guidelines for low volume roads use one or two factors (such as traffic volume and road functional classification) with a provision that the outcome can be modified by other site-specific considerations. None of the agencies surveyed are currently using a scoring procedure that systematically combines several selection factors into a combined score for AC pavement versus ST pavement type selection.

The range of threshold traffic volume for ST pavements varies radically from AADT as low as 100 to as high as 30,000 with the majority of agencies selecting surface treatments for roads with traffic volumes of less than 2,500 AADT. Typically, roads classified as industrial, collector, and arterial would be considered for an AC surface. In addition, most agencies would consider an AC surface for roads directly serving high density residential developments.

Even though several agencies that responded to the survey indicated that they use an economic analysis to decide between AC and ST, none of the agencies was in the position to provide any further information beyond the statement that an economic analysis is used. It is possible that an economic analysis is carried out for site-specific applications only and that there is no standard analysis approach.

A supplemental consideration in the decision to use one surface type or the other has been categorized by many agencies as engineering judgment. Those that elaborated on engineering judgment generally advised that regardless of the surface type selected, the pavement must be structurally adequate to support the anticipated future traffic loading, and to protect the investment in the AC layer from premature damage. Other ancillary considerations included geometric issues such as slope gradient and vertical curves which appear to be more detrimental to ST pavements.

As the review of the material obtained from transportation agencies indicated, there are many diverse approaches to the pavement selection process. The approach chosen was to extract and evaluate, from the results of the literature review and agency surveys, those attributes that are relevant to the pavement type selection issues.

GUIDELINE MODEL

The procedure for the selection of the pavement surface type for low volume roads combines various factors and considerations that influence the selection of the pavement surface type in the form of a guideline model shown in Figure 1. The model consists of four components starting with preliminary screening of candidate sites and ending with prioritization analysis of selected sites based on the detailed evaluation of site-specific benefits and costs.

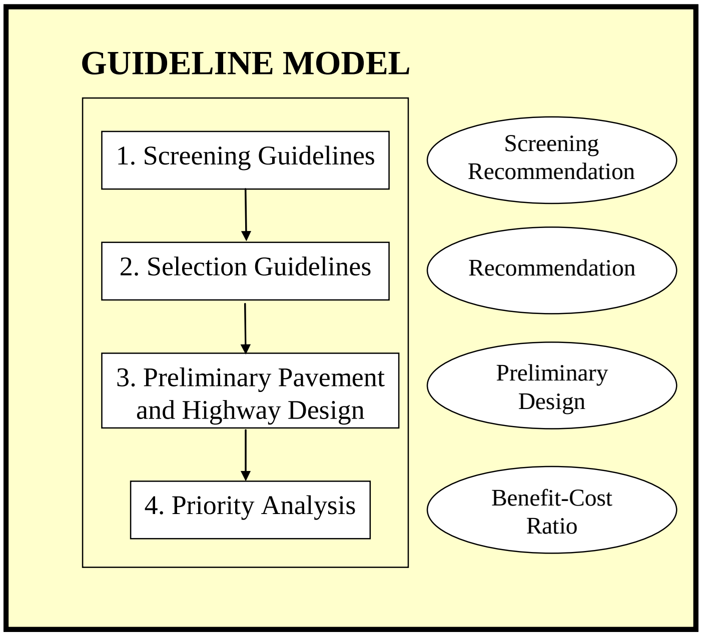


Figure 1. Guideline model and its components.

1. *Screening Guidelines* are used for a preliminary identification and ranking of candidate ST pavement sections for upgrading. Screening guidelines provide a preliminary indication of which pavement sections may warrant upgrading. Screening guidelines utilize selection factors characterized by routinely available data that can be obtained with minimum effort.

2. *Selection Guidelines* are used for the identification and ranking of candidate ST pavement sections that warrant upgrading. The selection guidelines use the same factors as the screening guidelines, but the factors are characterized by more detailed, more reliable, and more up-to-date information. The selection guidelines have the potential to be used as design guidelines. The selection guidelines can also be used without the need to carry out detailed site specific investigations. For example, it is possible to apply selection guidelines without the need to carry out a preliminary highway design.

3. *Preliminary Pavement and Highway Design* is used as part of the model to estimate the agency and road user costs associated with upgrading a ST pavement. The cost of upgrading to AC may include pavement strengthening to eliminate the need for spring load restrictions. The preliminary pavement design is based on site specific considerations, and considers life-cycle costs. The preliminary highway design identifies locations of all substandard highway

design features (e.g., pavement and shoulder widths, grades, sight and stopping distances, and horizontal, sag, and crest curves) and recommends specific remedial actions.

4. *Prioritization* is based on life-cycle costs to both the agency and the users. Prioritization is carried out using site-specific costs based on the preliminary pavement and highway design carried out in Step 3. Benefits of the proposed upgrading include savings in road user costs, and may include other benefits such as the impact on local business activities and impact on nearby residents.

   The road user costs are calculated using user cost functions developed for PEAT [1]. The subsequent prioritization process ranks the candidate sections for upgrading using cost benefit indicators, such as benefit-cost ratio and net present value. Prioritization analysis could also be used to compare the cost-effectiveness of different pavement upgrading projects, or to compare the cost effectiveness of pavement upgrading projects with that of other road infrastructure projects (e.g., intersection improvements, or bridge projects).

The screening and selection guidelines are intended to provide guidance for upgrading ST pavements to AC pavements. They are not expected to be used for the determination of the type of AC pavements in terms of the thickness of the AC layer, or in terms of the mix type. The determination of AC thickness and the mix type (e.g., HMA, CMA with or without surface seal) should be carried out using a site-specific detailed pavement design.

MAIN SELECTION FACTORS

Selection factors are defined as major considerations influencing the selection of pavement surface type for low volume roads. The following 12 selection factors were considered for inclusion in the screening and selection guidelines.

- <u>Agency costs.</u>
- Road user costs.
- Benefit-cost indicator.
- <u>Traffic.</u>
- Road functional class.
- <u>Impact of surface type on nearby residents.</u>
- <u>Impact of surface type on the local business community.</u>
- <u>Impact of surface type on long-distance travel.</u>
- Experience with pavement surface type construction and performance.
- Impact of surface type on the environment.
- Community expectations regarding the surface type.
- Miscellaneous factors.

Based on the review of all candidate factors and considerations for the selection of pavement surface type for low volume roads, and the need for simplicity, only five of the 12 selection factors listed above were selected for the screening and selection guidelines. The selected factors are underlined.

The selected factors directly or indirectly represent a large majority of the prominent factors and considerations. The five main selection factors, together with their associated or secondary factors and main reasons for their inclusion in the guidelines, are described in Table 1.

Table 1. Description of the main selection factors

Main selection factor	Associated factors and considerations	Main reason for inclusion in guidelines
Traffic	AADT volume. Volume of commercial vehicles of different types. Expected growth in traffic volumes. Road user costs. Road functional classification.	To approximate road user costs
Impact on Local Residents	Increased sound levels associated with surface treatment. Number of dwelling units near roadway. Proximity of dwelling units to the roadway. Loose or flying aggregate, dust. Impact on the environment. Smoother and quieter ride on HMA. Community expectations regarding the surface type. Road functional classification.	To characterize benefits incurred by nearby residents
Impact on Local Business Activities	Presence of large truck trip generators such as forestry, mining and agricultural activities. Impact of spring load restrictions local business activities. Number of retail stores along the route. Presence of tourist related facilities and attractions.	To characterize benefits to local businesses
Impact on Long-Distance Travel	Proportion of trips that have both the origin and the destination outside the local business area. Impact of spring load restrictions on long-distance commerce. Road functional classification. The need for alternative transportation corridors.	To characterize benefits to long-distance travel
Agency Costs	Initial construction costs for pavements, and highway and bridge improvements. Future maintenance and rehabilitation costs. Routine maintenance and winter maintenance costs. Pavement performance and constructability issues. Road functional classification.	To characterize costs of providing and maintaining an upgraded road facility

The factors not included in the preliminary guidelines are outlined below, along with the rationale for their exclusion.

Road User Costs

Road User Costs (RUC) include operating costs of highway vehicles such as vehicle maintenance and fuel consumption costs (which increase with pavement roughness), travel delay costs caused by speed restrictions or by construction delays, and environmental costs. Operating costs are related to the traffic flow volume, composition, and speed.

The major factor influencing operating costs is traffic volume. For low-volume roads, there is only a small difference in RUC between the ST and AC pavements on highways with identical geometric design features. For the purposes of screening and design guidelines, it is sufficient to use traffic volumes as an approximate measure of vehicle operating costs. However, site-specific RUC were used for priority analysis.

Benefit-Cost Indicator

The benefit-cost indicator combines agency costs and user costs. The screening and selection guidelines did not use a benefit-cost indicator because of the excessive data and calculations that would be required. However, benefit cost indicators were used for selecting and ranking sections for upgrading as part of the prioritization process (Step 4 of the Guideline Model).

Functional Class

Road functional class is considered by some agencies as a deciding factor. However, functional classification is strongly related to several other selection factors that are easier to quantify, such as traffic volumes. Also, the use of functional classification as a selection factor has limited usefulness as the low volume roads typically belong to only one or two road functional classes.

Experience with Pavement Surface Type Construction and Performance

Based on the agency survey, several agencies reported that the ability to construct surface treatments of reliable quality using in-house forces is one of the considerations for selecting surface treatments. Pavement construction and pavement performance concerns are included indirectly as part of agency costs that include the life-cycle cost of AC and ST pavements.

Impact of Surface Type on the Environment

Impact of the pavement surface type on the environment may include different rates of winter sand and/or salt application, issues related to recycling construction materials and sustainability of construction activities, pavement noise, and dust associated with the construction of ST. In addition, in the case of an extensive upgrading of deficient road alignments, the changes in green house gas emissions and other emissions may need to be considered. Factors associated with noise and dust were included as part of the main selection factor <u>Impact of surface type on nearby residents</u>. Other environmental factors were considered to have only a marginal influence on low volume roads.

Community Expectations Regarding the Surface Type

Community expectations regarding the surface type were not considered within the guidelines which are intended to focus on technical and economic considerations only. Community expectations can be considered outside the model.

Miscellaneous Factors

Additional factors that can influence the surface type selection include the amount of pedestrian and bicycle traffic, the continuity of pavement surface type, and the presence of entrances to large traffic generators attracting heavy vehicles or cars pulling trailers. These factors have typically a minor influence. However, miscellaneous factors may need to be considered as part of the engineering judgement in specific situations.

SCREENING AND SELECTION GUIDELINES

Types of Guidelines

Using selection factors and their characteristics, it is possible to develop guidelines in two basic forms:

- *Guidelines based on individual selection factors*. This type of guideline considers a few main factors individually, or in combination. The advantage of this approach is the simplicity of its application and its flexibility to modify the outcome using engineering judgement and other considerations. The disadvantage of this approach is the inability to systematically and objectively determine which candidate sections should be upgraded if several additional selection factors need to be considered at the same time.
- *Guidelines based on combined selection factors*. All major selection factors are included using a pre-determined framework that takes into account the importance of the selection factors and their values. Guidelines are based on "a combined score". The scoring system may comprise many factors and their scores. The factors can be scored in terms of their importance, the reliability of the score, and the possible spread of the score [2]. While at the first glance this type of system seems to be logical and defendable, it can result in significant controversy with many of the factors, and their scoring, reliability, and spread values challenged by the industry and the public. It follows that the scoring procedure should be straightforward, transparent, and defendable.

Formulation of Screening and Selection Guidelines

Guidelines based on a combined score were chosen for their ability to capture systematically and objectively the combined importance of several factors for upgrading of ST pavement sections to AC pavement sections.

The five main selection factors listed in Table 1 were used for both screening and selection guidelines. The use of the same factors is justified because both guidelines serve the same underlying purpose and are based on the same reasoning. However, the screening guidelines utilize preliminary estimated data, whereas the selection guidelines utilize more detailed and reliable data.

WEIGHTS OF SELECTION FACTORS

The procedure used assign the weights to the individual selection factors utilized the Delphi technique [3]. One of the major premises underlying the Delphi approach is the assumption that a large number of "expert" judgments is required in order to "treat adequately" any issue. What distinguishes the Delphi from an ordinary polling procedure is the feedback of the information gathered from the group and the opportunity the individuals have to modify or refine their judgments based upon their reaction to the collective views of the group. Secondary characteristics are various degrees of anonymity imposed on the individual responses to avoid undesirable psychological effects.

The initial step in the procedure involved the preparation of a background document and survey questionnaire outlining the meaning and importance of selection factors. The preliminary weights of selection factors provided in the initial survey questionnaire are given in Table 2, Column 2. For clarity, the sum of the weights assigned to the selection factors equals 100. Considering that in the context of asset management, highway decisions are increasingly made using priority analysis and that priority analysis typically utilize benefit-cost ratio, 50 percent of the factor weights were assigned to benefit-related factors and 50 percent of the factor weights to cost-related factors. The initial overall factor weights are shown in Table 2, Column 3.

Table 2. Selection factors and their relative weights

Selection factor	Relative factor weight		
	Original	Overall	Final
1	2	3	4
Traffic volumes	55	50	25
Impact on nearby residents	10		10
Impact on local business activities	10		10
Impact on long-distance travel	5		10
Agency costs	20	50	45
All factors	100	100	100

The survey questionnaire was distributed to six members of the project team (consultant team) and to two members of the client team (agency team). The eight survey responses were completed independently, and their results were given to all eight participants. The results, reported anonymously, included scores for both teams, overall average scores, and a summary of reasons for changing scores provided by the participants. The participants were then asked to reconsider their original scores, considering the feedback provided. The new survey responses were then analysed and the results given to the leader of each team. The team leaders were charged with reaching a consensus on the weighting scores. The results are presented in Table 2, Column 4.

The highest factor weight (45) was assigned to agency cost, the lowest weight (10) to the impact on nearby residents, the impact on local business activities, and to the impact on long-distance travel. The maximum score a factor can reach was set to equal its weight. Thus, the total maximum number of points that a section can achieve is 100.

SCORING OF SELECTION FACTORS

The score of a selection factor depends on the value of the selection factor, which in turn depends on the site specific characteristics. The total section score is obtained by adding the scores obtained for the individual selection factors. The procedure is illustrated using an example given in Table 3.

Table 3. Scoring procedure for screening and selection guidelines

Main selection factor	Relative factor weight	Selection factor value	Selection factor score
Traffic	25	430	10
Impact on Nearby Residents	10	10%	2
Impact on Local Business Activities	10	3	3
Impact on Long-Distance Travel	10	20%	4
Agency Costs	45	$200,000	40
All Factors	**100**		**59**

The selection factor score (or number of points) assigned to an individual factor depends on the site-specific characteristics of the factors. The more favourable a characteristic is for upgrading a ST section, the higher the factor score. The scores for the selection factors are calculated as an average score for the entire road section.

Scoring Traffic

The selection factor for traffic was included in the guidelines to approximate road user costs (RUC). Because RUC of cars and trucks significantly differ, traffic volumes are expressed in terms of combined AADT traffic volumes that take into account differences in RUC for cars and trucks. The maximum score for traffic is 25 out of 100.

The score for traffic is a function of a combined traffic volume. The combined traffic volume is AADT volume adjusted for the presence of trucks using Passenger Car Factors (PCF). The value of PCF was set to account for the effect of trucks on highway capacity and for higher travel time costs of drivers of commercial vehicles compared to the travel time costs of car drivers.

The conversion of the combined traffic volume to traffic scores is carried out using the function presented in Figure 2. According to Figure 2, the maximum scoring value for traffic (25) is reached when combined traffic volume equals or exceeds 1,200 vehicles. This value was selected by considering the existing MTO Pavement Structural Design Guidelines for Secondary Highways [4].

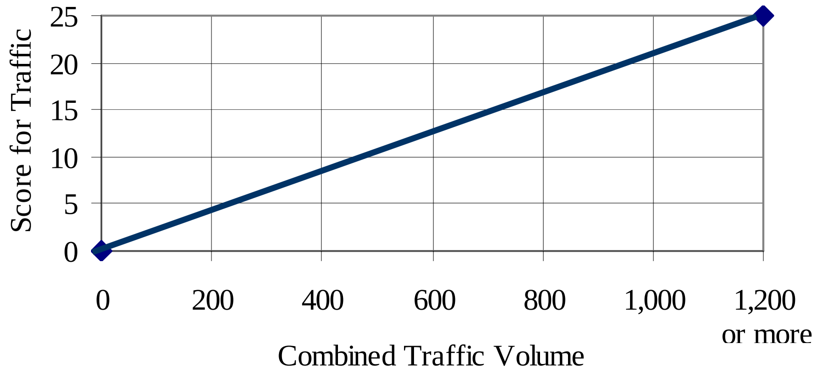


Figure 2. Function relating traffic score to traffic characteristics.

The pavement structural guidelines for secondary highways recommend a HMA surface for highways with AADT volumes exceeding 1,500, and cold mix asphalt for highways with AADT volumes exceeding 1,000. Assuming a ten percent of commercial vehicles, an AADT of 1,000, and assuming that one commercial vehicle equals three cars, the combined volume of 1,200 vehicles approximates AADT volume of 1,000 vehicles.

Screening Guidelines

Screening guidelines use only AADT volumes and the percentage of commercial vehicles. One commercial vehicle is converted to three cars. Traffic data used to calculate combined traffic volumes for screening guidelines should be the best available data.

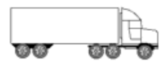
Selection Guidelines

Selection guidelines use the five vehicle types shown in Table 4. Traffic data used to calculate combined volumes for selection guidelines should be the best available traffic data estimated for 10 years after the expected project implementation. The use of a future year captures the influence of the expected traffic growth. The use of the same future year for all projects provides a common timeline for comparison purposes.

Scoring the Impact on Nearby Residents

The impact of pavement surface type on nearby residents is related to the number and proximity of residential dwelling units. The maximum score for the impact on nearby residents is 10 out of 100.

Table 4. Conversion factors for selection guidelines

Vehicle Class	Description	Graphic	Passenger Car Factor (PCF)
1	Passenger cars		1
2	Two and three-axle trucks		2.5
3	Four-axle trucks		3
4	Five-axle trucks		3.5
5	Six-or-more axle trucks		4

Screening Guidelines

Screening guidelines are based on the extent of residential area, adjacent to the section, which has dwelling units located less than 50 m from the edge of pavement. The scoring function for the impact on nearby residents is shown in Figure 3. The maximum weight of 10 points is assigned when the specified residential area adjacent to the section reaches 50 percent of the section length on any one side. Thus, if the residential area (with dwelling units closer than 50 m from the edge of pavement) is adjacent to both sides of the section, the maximum weight of 10 points is reached when the residential area on the both sides of the road reaches 25 percent of the section length.

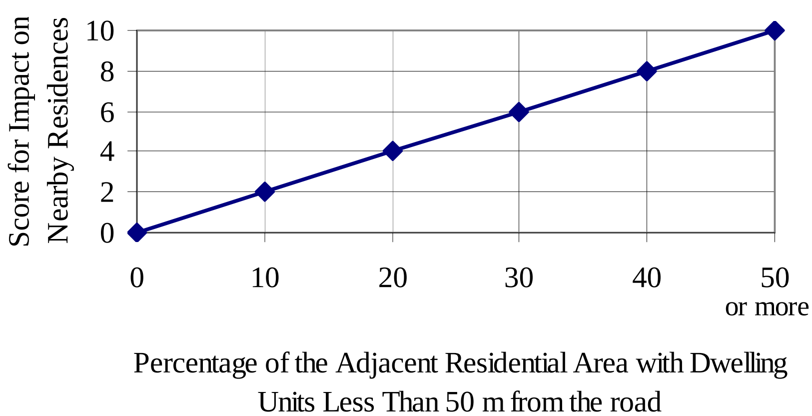


Figure 3. Scoring the Impact on Nearby Residences for screening guidelines.

Selection Guidelines

Selection guidelines are based on the number of residential dwelling units that are located near the section. Dwelling units that are located 50 m or less from the edge of pavement are counted as one equivalent unit, dwelling units located 50 to 100 m from the edge of pavement are counted as 0.25 equivalent dwelling units, and dwelling units more than 100 m from the edge of pavement are not included. The scoring function for selection guidelines for the Impact on Nearby Residents is shown in Figure 4.

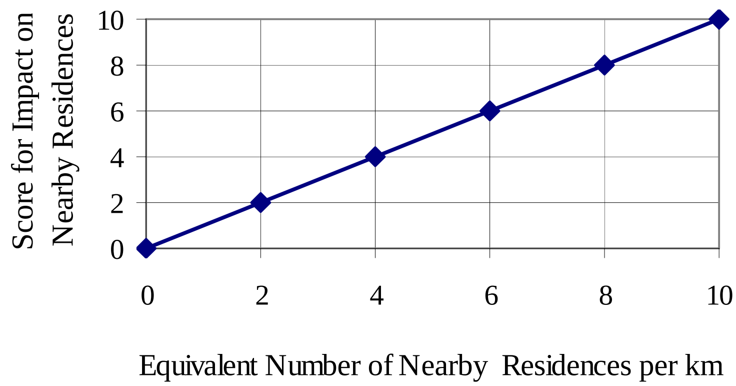


Figure 4. Scoring the Impact on Nearby Residences for design guidelines.

The maximum weight of 10 points is assigned when the number of equivalent dwelling units reaches ten units per one km of the section length. The dwelling units can be located on either side.

Scoring the Impact on Local Business Activities

The assessment of the impact on local business activities is similar for both screening and selection guidelines. It is based on business impact assessment carried out separately for five industries: forest, tourism, agriculture, mining and extraction of resources, and other industry.

Screening and Selection Guidelines

The scoring of the impact on local business activities is given in Table 5. The recommended scores are not additive. The highest score obtained for any individual business activity is the total score for the impact, with some exceptions. For example, if the forestry industry is rated as high (10), and the mining and extraction of resources industry is rated as medium (6), the total score is 10. If there are at least three low scores, and no other higher scores, the total score is medium. If there are at least two medium scores and no other higher scores, the total score is high.

Detailed scoring guidelines were developed for scoring the local business activities for all five industries. An example of the scoring guidelines developed for the forest industry is given in Table 6.

Table 5. Scoring the impact on local business activities for screening and selection guidelines

Local business activity	Business activity level			
	None to very low	Low	Medium	High
Forest industry	0	3	5	10
Tourism industry	0	1	3	6
Agricultural industry	0	1	3	6
Mining and extraction of resources industry	0	3	5	10
Other industry	0	1	3	6

Table 6. Scoring of business activity levels for forest industry

Business activity level	Size of the catchment area	Number of loaded logging trucks and trucks carrying heavy processed forest products[1] per average day
None to very low	Road does not connect woodlots that are commercially harvested with processing mills or the total catchment area is less than about 200 square kilometres.	0
Low	Road serves a total catchment area of 200 to 3,000 square kilometres.	0.2 to 3
Medium	Road serves a total catchment area of over 3,000 to 8,000 square kilometres.	4 to 8
High	Road serves a total catchment area of 8,000 square kilometres or more.	8 or more

[1] Heavy processed forest products include composite solids and panels, and wood chips and other biomass

Scoring the Impact on Long-Distance Travel

The impact of the surface type on long-distance travel includes costs incurred by long-distance truck traffic because of seasonal load restrictions, and reduced attractiveness of the road to through traffic resulting in the reduction in local business activities that serve long-distance traffic. The maximum score for the impact on long-distance travel is 10 out of 100.

The impact on long-distance travel also includes the benefits of providing alternative long-distance routes for the trucking industry and the general public, particularly in emergency situations.

Screening and Selection Guidelines

The impact on long-distance travel is probably one of the most difficult selection factors to quantify. For both guidelines, it has been chosen to rate this factor using the expected percentage of long-distance commercial traffic defined as the traffic that has the origin and destination outside the local business area. The commercial traffic which has the origin or destination within the local business area is considered to be part of the selection factor *impact on local business activities*. For the conditions in the study area, the long distance commercial traffic was defined as trucks trips with trip lengths exceeding about 200 km.

The estimation of the amount of long-distance commercial traffic was based on the results obtained by MTO's Commercial Vehicle Surveys (CVS) [5]. For a truck to be captured by the CVS, it has to be "intercepted" during the CVS. Specifically, a representative truck must pass through at least one CVS location and be included in the origin-destination survey. In addition, the survey results need to be strong enough to influence the truck flow model. The percentage of trucks captured by the CVS indicates the proportion of long-distance truck trips with the trip length of approximately 200 km or more.

The scoring function for the impact of long-distance travel is shown in Figure 5.

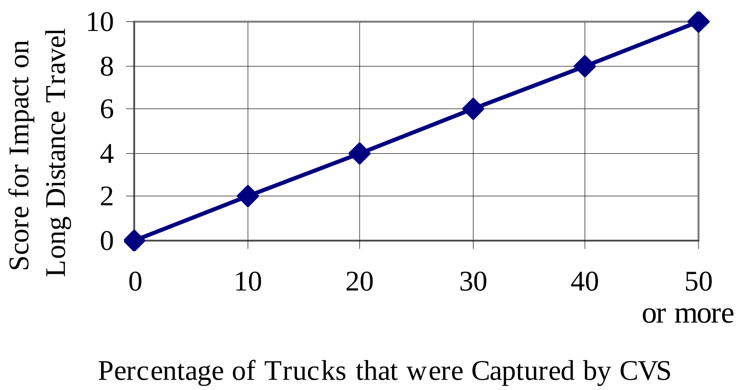


Figure 5. Scoring the Impact on Long-Distance Travel for screening and selection guidelines.

Scoring of Agency Costs

Agency costs include initial pavement construction costs and future pavement preservation costs for both highways and bridges (if bridge improvement is required as part of upgrading the highway geometry). The maximum score for agency costs is 45.

If the consequences of the decision to upgrade a ST pavement included only the construction of an HMA layer, the inclusion of agency costs in the screening and selection guidelines would probably be unnecessary. The unit cost of adding the HMA layer would be approximately similar for all sections. Thus, the inclusion of fairly constant costs would not change the relative scores. It may be also argued that the inclusion of pavement surfacing costs could unfairly treat users in more remote locations where the cost of HMA may be higher. However, agency costs of upgrading ST roads to AC roads may be substantial (if the upgrading includes pavement strengthening and improvements in roadway geometry) and need to be included in the guidelines.

Screening and Selection Guidelines

Both the screening and design guidelines use the scoring function shown in Figure 6. The estimated agency costs are defined as average estimated costs for upgrading of one-km long section. The average cost per km is calculated by dividing the total estimated cost of upgrading the section by the section length in km.

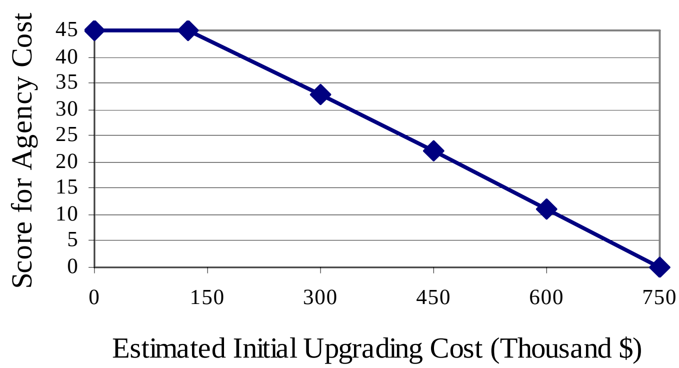


Figure 6. Scoring of Agency Costs for screening and design guidelines.

According to Figure 6, if the average cost of upgrading does not exceed $150,000, the score remains 45. It was expected that the cost of paving one 50 mm thick layer of HMA, together with a limited restoration of the granular base, would not exceed about $150,000 per 2-lane km. Limited restoration means pulverizing the existing surface treatment and adding about 50 mm of Granular A where required.

The site-specific costs may vary considerably. Table 7 was prepared to provide guidance for the estimation of average costs for upgrading an existing ST pavement to a HMA pavement without the need to carry out a preliminary highway design. Table 7 can be used for both screening and selection guidelines. It is based on the premise that the cost of upgrading depends primarily on the width of widening and the terrain type, and that the total width of widening and the terrain type are also good indicators of the probable frequency of occurrence of other highway design deficiencies such substandard horizontal and vertical curves.

Table 7. Estimated agency costs for widening and paving with 50 mm of HMA

Total width of widening, m	Agency cost by terrain type, $ per km of roadway length		
	Flat	Rolling	Mountainous
None	$125,000	$125,000	$125,000
0.1 to less than 0.3 m	$150,000	$200,000	$300,000
0.3 to less than 0.6 m	$200,000	$250,000	$400,000
0.6 to less than 1.0 m	$275,000	$350,000	$500,000
1.0 to less than 2.0 m	S350,000	$450,000	$600,000
More than 2.0 m	$450,000	$500,000	$750,000

PRIORITY ANALYSIS

Prioritization represents the last step in the guideline model. The prioritization is based on life-cycle cost analysis that includes total costs to both the agency and the user. The product of this analysis, a benefit-cost ratio or net present value, is then used for prioritization.

Prioritization provides the opportunity to assess fully and systematically life-cycle cost and benefits associated with proposed upgrading of pavement sections. Prioritization analysis can utilize several analytical programs and can be carried out during different stages of project development. For this project, the selected analytical tool was PEAT [1] and the analysis was carried out during the preliminary design stage. Example results of prioritization analysis obtained by PEAT are shown in Table 8.

PEAT calculation of road user benefits can properly assess the benefits due to lower transportation costs. The PEAT analysis can use the section-specific pavement performance curves, or average agency-wide pavement performance curves, to estimate the benefits associated with upgrading of pavement sections.

The secondary benefits associated with lower transportation costs, such increased property values and growth in business activities, are already included in road user benefits calculated by PEAT because they are only a reflection of reduced road user costs (reduced travel time and vehicle operating costs). However, the assessment of road user benefits by PEAT does not include the impact on nearby residences and the benefits due to the removal of seasonal road restrictions. The removal of a reduced load period can provide the following benefits:

- Increased transportation productivity by allowing the transportation of regular payloads throughout the year.
- Achieving just-in-time delivery without the need to stockpile goods and raw materials to compensate for reduced load periods.
- Savings due to the elimination of the need to use longer alternative routes during reduced load periods.

Table 8. Example result obtained by PEAT

	Section 12 by 2033		Section 12 by 2008	
AGENCY COSTS				
Initial Capital Cost	$	-	$	1,736
All Other Agency Costs	$	1,298	$	232
Total	**$**	**1,298**	**$**	**1,968**
ROAD USER COSTS				
Workzone Delays	$	43	$	51
Other Travel Time Costs	$	9,360	$	8,853
Vehicle Operating Costs	$	10,679	$	10,148
Collision Costs	$	-	$	-
Total	**$**	**20,081**	**$**	**19,051**
NET BENEFITS				
Agency			$	1,067
Road Users			$	1,030
Total			**$**	**2,097**
NET COST				
Initial Capital Cost			**$**	**1,736**
NET PRESENT VALUE			**$**	**361**
BENEFIT-COST RATIO				**1.21**

Is this project a good investment? Yes

APPLICATION OF THE GUIDELINE MODEL ON NETWORK LEVEL

As part of the model development, the model was applied to 27 pavement sections. The 27 sections comprise about 350 km of low volume roads and represent a wide variety of the conditions typical to one specific geographical area. AADT volumes ranged from 160 to 1,050 vehicles, and truck percentage ranged from 7 to 28 percent. The roads serve a variety of purposes including providing a direct access to residences, facilitating transportation of forest products, supporting agricultural activities, and supporting tourism and recreation.

All 27 sections were systematically evaluated using the screening and selection guidelines. The necessary data to apply the screening and selection guidelines were obtained from field surveys.

In order to carry prioritization of the 27 sections using PEAT, a preliminary pavement and highway design was carried out to obtain preliminary construction costs for upgrading individual sections and to estimate improvements in the average operating speed. The sections were ranked in terms of the benefit-cost ratio obtained by considering costs and benefits of (a) upgrading the sections in 2008 versus (b) upgrading the sections in 2033.

To allow for a comparison of the PEAT results, which are on a cost-benefit scale, and those of the screening and selection guidelines, the PEAT results were normalized to a maximum value of 100 based on the maximum calculated benefit-cost ratio. The results of the screening guidelines, the selection guidelines, and the prioritization analysis are summarized in Figure 7.

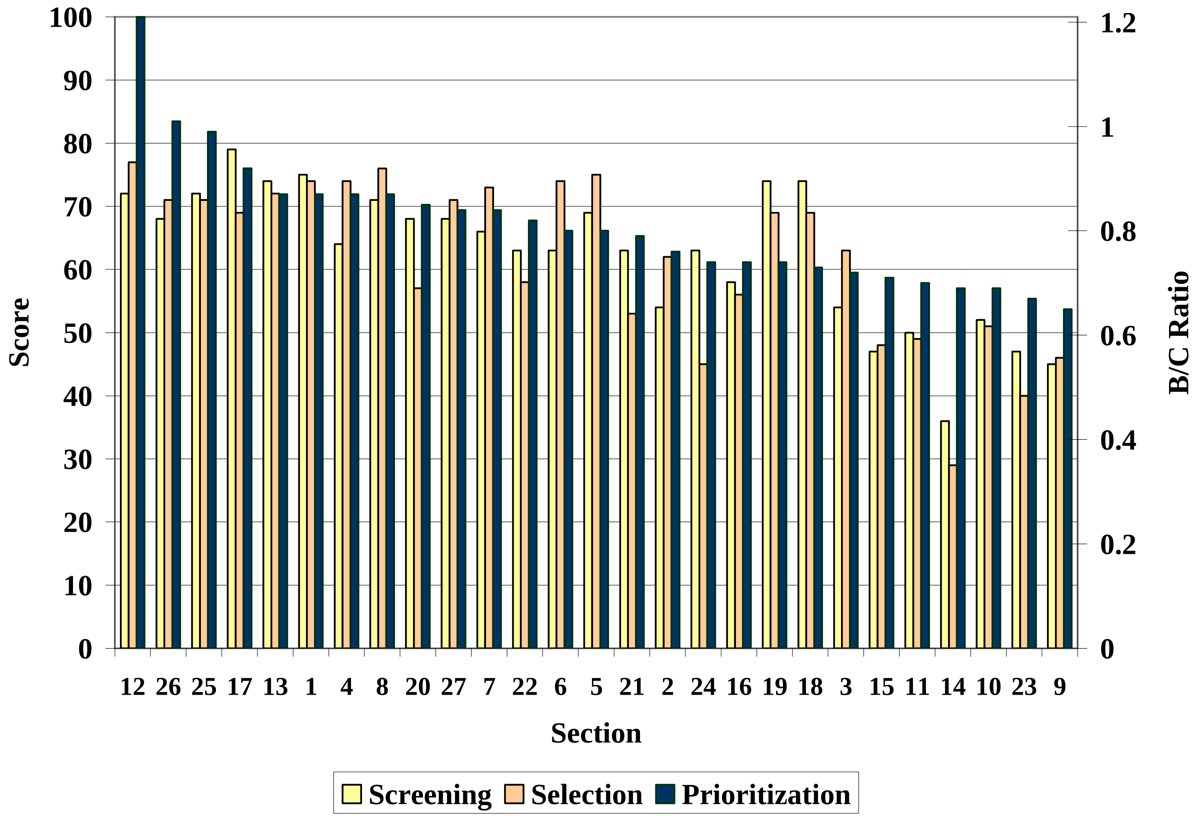


Figure 7. Comparison of Screening, Selection, and Prioritization Results.

As expected, there is a correspondence between the scoring results obtained by screening and selection guidelines presented in Figure 7. Any difference is due to more detailed and reliable data used for the selection guidelines. The scoring results based on prioritization analysis obtained by (PEAT) generally follow results obtained the application of the guidelines. The differences between the scores obtained by the guidelines and the PEAT are caused by differences in agency cost estimates and in the way the benefits are assessed.

USE AND FUTURE DEVELOPMENT OF THE MODEL

The guideline model for pavement surface type selection for low volume roads described in this paper was evaluated and tested on a limited number of sections. Selection factors and their weights recommended in this paper are considered appropriate for use, particularly for highways in a northern environment. However, other selection factors and different factor weights may need to be considered when applying the model to other geographical areas.

To improve and further verify the performance of the model, it should be evaluated by applying it to a wider variety of roadway sections. The assignment of priority rankings using the guideline model should consider all candidate sections located within an area. Preferably, the area where the model is applied should have well-defined political or geographical boundaries.

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REFERENCES

1. Cambridge Systematics, Inc., *PEAT User Manual – Priority Economic Analysis Tool*, Final Manual prepared for Ontario Ministry of Transportation, Cambridge, Massachusetts, November 2004.

2. Ohio Department of Transportation, *Pavement Selection the ODOT Way*, Columbus, Ohio, April 2003.

3. Linstone, H. A., and Turoff, M., *The Delphi Method: Techniques and Applications*, New Jersey Institute of Technology, University Heights, Newark, New Jersey, 1982, http://www.is.njit.edu/pubs/delphibook/.

4. Ontario Ministry of Transportation, *Pavement Design and Rehabilitation Manual*, SDO-90-01.ISBN: 0-7729-6379-7, Downsview, Ontario, January 1990.

5. Tardiff, Rob and GFR Consulting, *Province of Ontario 1995 Commercial Vehicle Survey – Station Summary Report*, ISBN 0-7778-7201-3, Ontario Ministry of Transportation, revised February 1999.