Pavement management framework

Departmental Policy on pavement type selection

Direction générale des infrastructures et des technologies

Transports Québec

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Foreword

This policy deals with the selection of pavement types. It covers a five-year period and is a core component of our road system management policy. Comprehensive in approach rather than project-based, it set outs the most appropriate types of pavement for roads under the Department's jurisdiction.

The analysis methodology it stipulates is a thorough, proven approach based on consistent, verifiable parameters and a transparent development process throughout.

The new policy, which replaces the Policy on the Construction and Maintenance of Cement Concrete pavements in force since 1995, allows greater consideration of new technologies and road work requirements through its integrated approach under a comprehensive Québec pavement management framework.

Implementation of this policy must fit with road work planning strategies and the Department's financial capabilities.

In drawing up this new policy, the Department met with representatives of the concrete and asphalt industries as well as the Association des constructeurs de routes et grands travaux du Québec (Québec's road builders' association) in order to take their views into account.

Québec Minister of Transport

Objectives

Department authorities decided to replace the 1995 policy and assigned the task of drawing up a new policy to the Infrastructures and Technologies Directorate (Direction générale des infrastructures et des technologies). The Department's new position takes the form of a departmental policy covering a five-year period.

In particular, the new policy seeks to:

- Determine the kinds of pavements best suited to the road system under the Department's jurisdiction

- Take a system-wide rather than project-by-project approach

- Use a thorough and proven analysis methodology based on consistent, verifiable parameters

- Make the entire process a transparent one.

Issues

The main roadways under the jurisdiction of the Ministère des Transports were built more than thirty years ago. The Department must devote substantial sums to maintaining and improving the level of service provided.

The Department recognizes that all pavement types are viable options. The important thing is to choose the ones that offer the best return on investment.

From this perspective, we must determine what is necessary to maintain pavement construction know-how to ensure that all work done is long-lasting and of high quality.

Similarly, it is important to consider the maintenance and development of a high level of expertise within the industry to ensure the emergence of innovative and effective solutions.

Profile of the Road System

The road system under the Department's jurisdiction is 29,100 km in length. The portion built out of concrete, with or without a coating of asphalt, amounts to 1,239 km (two-lane equivalent), or 4% of the total.

About a quarter of Québec's major highways are concrete. Of these, some three-quarters are in the Montréal metropolitan area. This portion of the road system bears 35% of total automobile traffic in Québec.

Process

As originally planned, input was sought out from industry stakeholders. Meetings were held with the cement concrete and asphalt industries to gather their comments on the 1995 policy.

These consultations led to a consensus, notably on the following:

- Replace the existing policy with a general departmental pavement management policy to be reviewed every five years
- Establish a method for selecting different paving techniques, taking into account the cost of road works over the whole life cycle of the pavement and the cost to users as a result of maintenance and repair work
- Establish a multicriteria analysis method making it possible to assign weights to criteria whose cost is difficult to quantify
- Develop and maintain a high level of expertise in the industry
- Encourage the use of performance specifications.

Also as originally planned, the next step called for rigorous analysis using consistent parameters. The Department applied the Life Cycle Cost Analysis (LCCA) and multicriteria analysis methods.

The LCCA method seeks to compare return on investment over a given period for different types of pavement. A comparison is generally done for each road project. Analysis was based on typical conditions and costs for different traffic categories representative of Québec conditions. Sixteen standard cases of traffic on each pavement type were analyzed, for a total of thirty-two. These traffic conditions were then transposed to the corresponding sections on the road system, associating the analysis results in each case.

The parameters – for reconstructed concrete and asphalt pavement – were as follows:

- Analysis period of 50 year

- Pavement structures calculated according to traffic conditions, on the basis of
  - average annual daily traffic (AADT)
  - the proportion of heavy trucks
  - the average aggressivity factor associated with each of the trucks

- Typical intervention frequency

- Typical costs of road works and differential for the period analyzed

- Cost actualization.

The Department also evaluated a number of non-quantifiable criteria, the main ones for purposes of the study being road marking and winter maintenance. Paired with the costs to users, these criteria made it possible to assign weights to the LCCA results.

It was thus possible to determine the parts of the road system where pavement types led to noticeably better returns on investment. The results guided the preparation of the following policy statement.

Policy

With regard to major rehabilitation work and the reconstruction of roads under its jurisdiction, the Department has established three zones where different types of pavement are to be used. These zones are shown on the maps in Appendix 1. Thus the Department recognizes that

- Concrete pavement is suited to that portion of the road system where analysis has shown it to be the most cost-effective option

- Asphalt pavement is suited to that portion of the road system where analysis has shown it to be the most cost-effective option

- A more detailed analysis based on LCCA and multicriteria methods must be done on those portions of the road system where no option is noticeably superior in terms of return on investment. In such cases,

  - Cost to users of traffic disruptions resulting from road works is an additional factor to consider
  - The scope of the analysis must be greater than the length of a given project. The Department first defines the segment to be analyzed, then selects a single pavement type in order to consolidate maintenance work and facilitate road system operation
  - Analysis is to be performed by the regional offices and validated by the Department's Pavements Branch (Service des chaussées), to ensure consistency in the study methodology
  - A description of how the detailed analysis is to be performed based on the LCCA and multicriteria analysis methods is provided in Appendix 2.

The performance specification concept can be used once the best-performing pavement option has been determined. This type of specification cannot be used to put two types of pavement in competition with each other. With regard to the construction of new roads, a description of how the policy is to be applied is provided in Appendix 3.

Conclusion

This five-year departmental policy replaces the 1995 policy, *Politique de construction et de conservation des chaussées en béton de ciment*. The Department recognizes that each type of pavement is suited to those portions of the road system where rigorous analysis has shown it to be the most cost-effective option. If major changes came about in regard to the factors used to carry out the studies, the Department could review its findings.

This policy must be integrated into the current road works planning strategy, the multiyear financial framework, and the new priorities of user safety and traffic flow. Its purpose is to extend the life cycle of existing pavements through recourse to any appropriate technique that will optimize the scheduling of major reconstruction or repairs work.

For the next five years, a minimum of work involving the different pavement types will be planned in order to ensure know-how is maintained.

In addition, the Department plans to continue the development of decision-making tools by encouraging the creation of discussion panels, groups, and forums whose role will be to maintain and develop a high level of expertise.

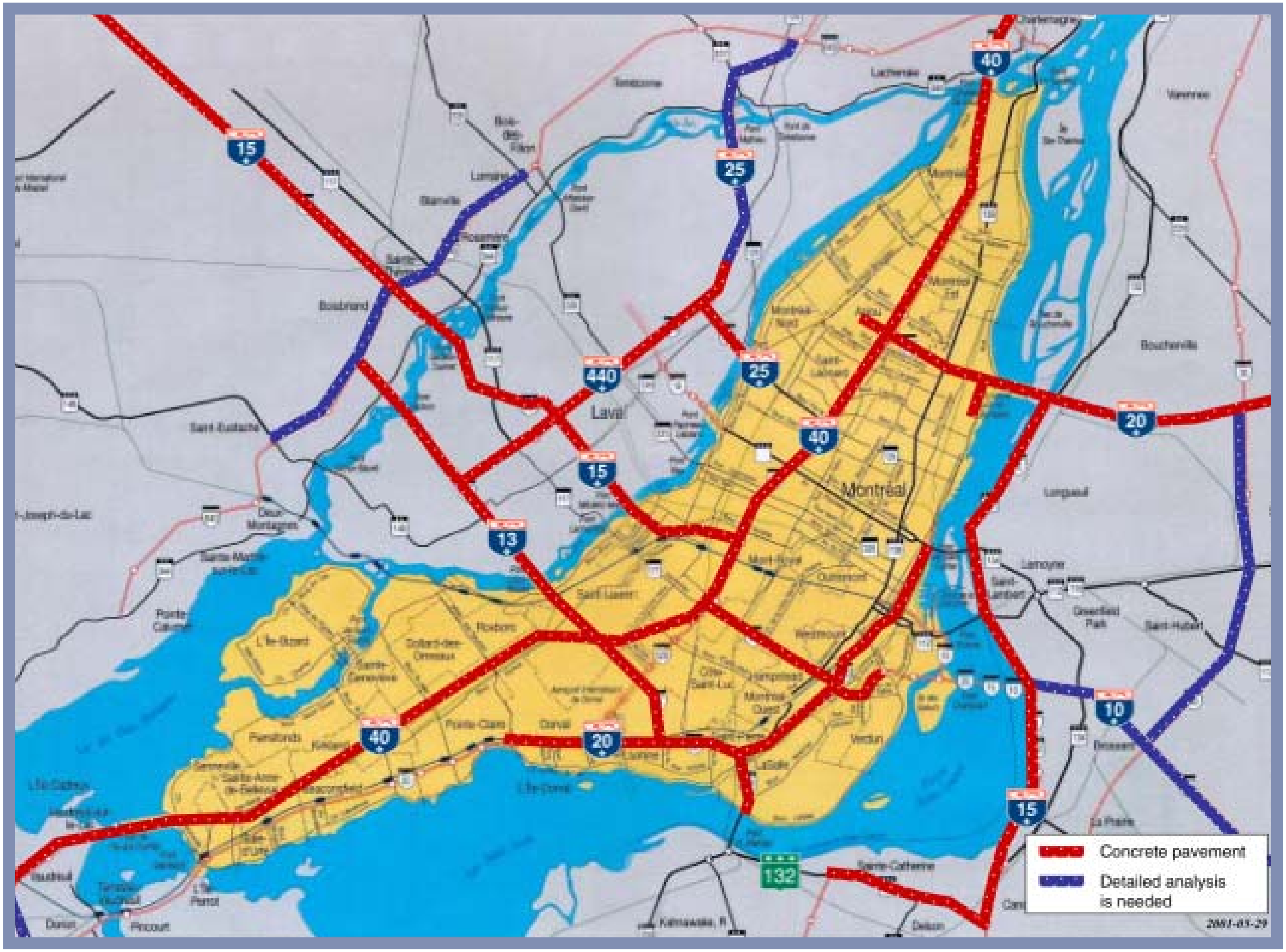
Appendix 1

- Map of Montréal and Québec City
- Map of the Québec City area
- Map of the Montréal area

Map of Montréal and Québec City

Map of the Québec City area

Map of the Montréal area



Appendix 2

Detailed Analysis Procedure (TBA)

This appendix describes how to perform a detailed analysis to determine the best investment pavement alternative in zones where neither cement concrete pavement nor bituminous pavement offers a clear advantage over the other. An analysis can only be carried out in project mode. In this appendix, lengths expressed in km are only valid for one direction in the case of highways and divided roads. For all other cases, they are valid for both directions.

1. Objective

Results of lifecycle cost analysis (LCCA) and multicriteria analysis (MCA) studies must be available to perform a detailed analysis. The purpose of the LCCA is to determine the best investment alternative for a given project by comparing the costs of the various options over the same analysis period in a formalized, fact-based process. The MCA complements the LCCA by introducing nonquantifiable factors that must be considered in the decision-making process. Detailed analysis calculations are based on the costs involved with each project and worksite conditions.

The result of the process weighs heavily in the final decision, but it does not automatically determine that decision. The choice of project timing and scope also depends on budgetary and operational considerations by MTQ managers.

2. Projects Affected and Road Segmentation for Analysis Purposes

Projects subject to detailed analysis are listed in Appendix 1. The road segments involved are listed in Table 1 on the next page.

The road segment list includes only expressways (main arteries) and therefore excludes interchanges, service roads, and any other secondary structure or road.

For analysis purposes only, the subdivision of these road segments into subsections is performed as follows:

- Each of the segments identified as requiring a detailed analysis can be subdivided into one or more analysis subsections depending on the project plan and the nature of the work to be carried out

- The length of each analysis subsection is based on the homogeneity of the work to be carried out, given traffic volume and pavement conditions. This analysis subsection must be at least equal to the length of a single construction project that lends itself to a contract without being shorter than 4.0 km

- Where more than one project or contract is earmarked for the same analysis subsection or where more than one type of work is planned for a given subsection, the pavement type selected as representative of the entire analysis subsection will be the one indicated for the longest cumulative stretch of the subsection in question.

Table 1 – Projects Subject to a Detailed Analysis

Projects Requiring a Detailed Analysis	Location
Highway 10	From the Champlain bridge to the Rivière Richelieu bridge in Chambly
Highway 20	From Highway 540 in the Vaudreuil-Dorion municipality to the Ontario border
Highway 20	From the bridge over Rivière Richelieu (intersection with Route 133) to the junction with Route 116 (Exit 141)
Highway 20	From Exit 305 (Saint-Nicolas, intersection with Route 171) to Exit 330 (Lévis)
Highway 25	From Montée Saint-François in Laval to Highway 640
Highway 30	From Highway 10 to Highway 20
Highway 40	From Boulevard Brien in Repentigny to Route 343 (Montée Saint-Sulpice)
Highway 73	From Highway 20 (including A-20 access roads leading to the bridge) to the Pierre-Laporte bridge
Highway 540	From Highway 20 to Highway 40 in the municipality of Vaudreuil-Dorion
Highway 640	From the intersection with Route 148 in Saint-Eustache to the intersection with Route 335 in Lorraine

3. Work Covered by the Departmental Policy

A detailed analysis is only performed for projects that involve major reconstruction or rehabilitation work. Only the following types of work are included:

- Total reconstruction of the entire pavement structure right up to the infrastructure line

- Partial reconstruction of the pavement right up to the level of the unbound subgrade or subbase

- Major rehabilitation of an existing pavement that has reached the end of its useful life, i.e.,
  - Removal of 50% or more off the top of the existing bound layer followed either by its replacement with new bound material or its complete or partial recycling, then resurfacing with new bound material (the total thickness of the new bonded layers after the work, including the recycled ones, must be greater than that of the existing bonded layer left in place)
  - Resurfacing of an existing pavement with one or more layers, with the bound overlays having the same thickness as a new pavement – granular resurfacing followed by coating with plant mix or concrete, surfacing with concrete nonbonded concrete on asphalt or slabs.

Any expansion or geometric improvement work in direct contact with the subgrade of the existing pavement must be performed using the same type of pavement as the main pavement. Such expansion or geometric improvement work is subject to detailed analysis only if the detailed analysis is required for the main existing pavement in accordance with the criteria listed above.

4. Prerequisites for Detailed Analysis

Prior to performing a detailed analysis, a technical study must be conducted to identify the project options that are realistic, feasible, and competitive in terms of investment quality. The options must also resolve pavement behavior problems over a long term period. One or more options per pavement type can be part of the analysis process. The options must be sufficiently detailed to allow for a reliable estimate of costs.

The options must be adapted to reflect project conditions. All options selected must be roughly equal in their potential to deliver expected performance. The safety factors used in the design and the cost estimates must be as option-neutral as possible, i.e., they must be equally realistic for all options and not optimistic for one and pessimistic for another. The analysis must reflect reality to the greatest extent possible given the probabilities involved.

The LCCA can be performed by the regional office or one of its agents or by the Pavement Department. Given the nonquantifiable factors in the decision-making process, the MCA is the responsibility of the regional office. In all cases, the analysis must comply with the framework outlined in this Appendix. The complete methodology and the values obtained must be validated by the Pavement Department to ensure their consistency.

5. Scope of Analysis Methods Used

For the LCCA, activity costs and user costs must as far as possible reflect project conditions, i.e., worksite conditions as well as those expected to prevail in the future. Estimated activity costs must be based on the realistic costs of each project alternative. User costs resulting from delays are to be estimated on the basis of traffic management scenarios. All costs that differ from one option to another must be accounted, but only if actually encountered in the project.

All nonquantifiable factors that will affect the decision are addressed in the MCA, which complements the LCCA. The scores assigned to each criterion selected must also differ from one option to another.

6. Applying the LCCA Method

The LCCA method is used to determine the best investment strategy for a given project by comparing a number of options over the same analysis period. To do so, all anticipated costs over the lifetime of each of the pavement project alternatives are discounted in today's dollars for comparison purposes. The option that has the lowest net discounted cost and still meets all structural and operating requirements is considered the most cost-effective in the long term.

The February 24, 2000 version of the MTQ guide to applying the Net Present Value (NPV) in the LCCA of pavement construction and preservation projects[1] is a basic reference tool for this type of analysis. Generally, the recommendations set forth in this guide can be applied wholesale in implementing the Departmental Policy on Pavement Type Selection. The TRDI Visual LCCA™ software currently used in the Department is also an important tool for making these calculations. The analysis method used in the program is similar to the one outlined in the guide.

Project LCCA should be performed in a structured manner and properly documented at each of the following steps: definition of the analysis framework, definition of the analysis model, calculation of the net discounted cost of each option, and analysis of the results. Before nonquantifiable factors, the option considered the most cost-effective in the long term is the one with the lowest net discounted cost as determined by the LCCA.

1. Application de la valeur actualisée nette à l'analyse des coûts globaux de projets de construction et de conservation des chaussées à Transports Québec

6.1 Defining the Analysis Framework

For our purposes, the various project options will be identified following an assessment of the rehabilitation work. The options must be feasible and consistent with the project budget. All costs must be estimated from a sufficiently detailed description of each option and all technical or other constraints likely to have a significant impact on the decision must be known.

6.2 Presentation of the Analysis Model and Baseline Data

Projects that fall under the departmental policy will be analyzed using the following model and baseline data:

- The analysis period must be at least 40 years
- The discount rate is 5% with a standard deviation of 0.5%
- The analysis must be probabilistic and should take into account uncertainties affecting the following parameters: the discount rate, activity lifetime, activity costs, and traffic growth rate
- The lifecycle and frequency of each option's maintenance and rehabilitation work must be determined, along with related uncertainties (minimum and maximum lifetimes, standard deviation). The work sequence can be selected from among the alternatives listed in the guide or be specific to the project
- LCCA expenditure streams include all the differential costs of the various project options. These include the following agency and user costs:
  - The cost of construction based on the actual market costs at the time work is carried out
  - Engineering costs for project preparation and supervision if a differential exists
  - The costs of future maintenance and rehabilitation if deemed representative for the entire duration of the analysis period (historical costs, current costs, and the most realistic of market forecasts possible are used as benchmarks to determine analysis values)
  - The differential costs of measures designed to mitigate the impact of work on traffic (administration costs) – an implicit value of 17% of the construction is attributed to these measures
  - The uncertainty associated with each cost considered the most probable (minimum and maximum costs, standard deviation)

- The cost to road users of traffic delays during construction and rehabilitation work. However, no uncertainty is associated with the value of unit costs due to delays. It is important to note that user costs due to delays generally represent a far greater uncertainty than that associated with the actual work. The following factors should be taken into account in determining the user costs due to delays for each of the project options:
    - For each activity, the number of days traffic will be affected
    - The direction(s) affected
    - The proportion of traffic affected in a given direction
    - Roadway capacity
    - Hours of work (0 to 24 hrs)
    - Speed reduction at the work zone (in hours)
    - The presence or absence of a detour
    - The inflation factor (see NCHRP Report #133, 1972) applicable to user costs due to delays (this factor should be updated annually).

6.3 Calculating the Net Discounted Cost of Each Option

The TRDI Visual LCCA™ program is used to simultaneously calculate the net discounted costs of several options while also taking into account uncertainties related to the parameters listed above, including user costs resulting from delays. The following general steps should be used to calculate NPV:

- Calculate the unit cost ($\$/m^2$) and the administration cost of the various activities in each option, as well as the residual value, by combining the appropriate cost inputs. These costs must be determined in constant dollars and discounted to the base year even if they will only be incurred in the future. Next, calculate the minimum cost, the maximum cost, and the standard deviation [(maximum cost – minimum cost)/4] for each separate piece of work

- Calculate user costs due to construction and rehabilitation work delays

- Calculate the present cost of each option over the analysis period using a 5% discount rate

- For activity costs, determine the net discounted cost by adding up each option's discounted costs per year. Classify the options by ascending order of net discounted cost, assigning to each one the uncertainty level determined from the calculations

- Calculate the residual value of the pavement at the end of the analysis period
- For user costs due to delays, also calculate the net discounted cost by adding up the discounted annual costs for each option. Next, classify the options by ascending order of net discounted cost.

7. Multicriteria Analysis (MCA)

MCA is used to study various project-relevant parameters that have not been taken into account in the LCCA. An analysis grid is completed by listing quantifiable and nonquantifiable criteria whose importance varies depending on the option. This grid is used to compare the advantages and disadvantages of a number of project options relative to the criteria. An uncertainty factor is added to the assessment of whether an option can meet a stated criterion.

The result is an overall rating to which a probabilistic distribution is added for each option. The various project options are then classified according to their potential to satisfy all the criteria selected for a given project.

7.1 Assessment Team Setup

For each project analyzed, the MTQ sets up a team to define and evaluate the criteria to be used in the analysis process. The team is made up of at least three (3) persons, including at least one (1) who has no direct responsibilities in the planning, design, and supervision of the project.

7.2 Criteria Definition

The assessment team defines which criteria it deems relevant for the project. The following four criteria must always be included in the assessment grid and must be applied to any comparison of an asphalt pavement to a concrete pavement:

- Minimize the net discounted activity costs (obtained from the LCCA) over the life of the project
- Minimize user costs due to delays
- Reduce the use of de-icing salt
- Reduce the cost and impact of pavement markings.

However, if the last two criteria can be assigned a dollar value, they are included in the LCCA instead.

7.3 Criteria Weighting and Scoring

Next, the criteria are weighted according to their relative importance. The sum of the weighting factors for all criteria is 1.0 or 100% and weighting must take into account the following requirements:

- The net discounted activity cost (from the LCCA) must be assigned a weight of at least 50% relative to all the other criteria

- The net discounted amount of user costs must be assigned a weight of at least 10% relative to all the other criteria. This criterion only applies if measures to ease the impact of the work on traffic flow have already been designed into the project and its cost. Only the residual impact after application of these measures is considered a separate criterion

- It is recommended that the de-icing salt reduction criterion be assigned a relatively higher weight than the pavement marking criterion. The relative importance of these criteria may be adjusted for a specific project.

Once the criteria are weighted, the project options are then assigned a score ranging from 0.0 to 10.0 for each criterion. The score is a measure of the option's potential to meet the criterion. The higher the score, the greater the likelihood that the project option will satisfy the criterion in question.

Generally, if the assessment team considers that one option is more likely to satisfy a given criterion than another option, the difference between their scores for that criterion will be at least 1.0. However, if the team wishes to increase the level of discrimination between the options, this difference must be at least 2.0. Conversely, if two options have virtually the same potential to satisfy a criterion, they must be assigned the same score. The table below should be used as a guide for assigning scores.

Score	Meaning
0.0	The option cannot satisfy the criterion
1.0 or 2.0	All indications are that the option will not satisfy the criterion
3.0 or 4.0	Little potential that the option will meet the criterion
5.0	There is a 50/50 chance that the criterion will be satisfied
6.0 or 7.0	High potential that the criterion will be met
8.0 or 9.0	All indications are that the option will fully satisfy the criterion
10.0	The criterion is fully satisfied

The assessment team must then evaluate the level of uncertainty (the "S" factor) for each score. This factor ranges from 0 to 4.0 and measures the level of optimism or pessimism about the likelihood – as indicated by the score – that an option will meet a criterion, given the various factors that may affect the project during its lifetime. Uncertainty regarding a score is expressed as follows:

Score + "S" = Optimistic Score   Score – "S" = Pessimistic Score

For illustrative purposes, the "S" factor can be applied as follows:

Factor "S"	Meaning
0.0	The score assigned will not be affected at all by conditions prevailing during work on the project
1.0	Little affected by conditions prevailing during work on the project
2.0	Slightly unaffected to slightly affected by conditions prevailing during work on the project
3.0	Rather affected by conditions prevailing during work on the project
4.0	The score will be greatly affected by conditions prevailing during work on the project

The scores and their deviations are assigned to the net discounted amounts from the LCCA. User cost values must reflect the fact that they are subject to a far higher level of uncertainty than activity costs.

7.4 Calculating Overall Scores

Once the grid is completed, the designer performs the calculations required for an overall rating of each project option. Assigning minimum and maximum scores allows the designer to have an overall vision of the option that offers the best "guarantee" that all the criteria will be satisfied. This is done using the MTQ's multicriteria decision-making support system[2] that can be accessed through the Department intranet.

The overall scores and their dispersions are all taken into account in classifying the options. The option with the highest overall score and the lowest dispersion is the one that is less likely to fail to satisfy all the criteria.

2. Système d'aide à la décision multicritères – Transports Québec

8. Overall Analysis of the Results Taking Uncertainties into Account

It is first important to ensure that no score or dispersion for one of the criteria is so poor that the option must be rejected. For analysis purposes, the results are presented in the form of a graph showing the relative probability that the options will satisfy assessment criteria. If an analysis reveals that a particular option best satisfies the criteria in general but entails more uncertaintly, the final decision must be based on the level of risk the organization is prepared to accept in terms of uncertainty and the consequences of making the wrong choice.

The options are then ranked by level of performance. The option with the best performance level is selected as the most desirable. The options may be considered equivalent if the ranking is very sensitive to the assumptions used or if the probability distribution curves overlap and no option is markedly dominant.

The final step is to reconcile the results for all the subsections of the road segment analyzed – i.e., the pavement options selected for the subsections – to make sure of the following:

- The road segment analyzed must contain no more than two subsections with different pavement types

- A concrete subsection must not fall between two asphalt subsections and vice versa.

Appendix 3

Analysis Procedures for New Highway Construction Projects

Note: Many sections of this appendix refer to Appendix 2.

This appendix outlines analysis procedures to be used in selecting pavement types for new highway construction projects. In this appendix, lengths expressed in km are only valid for one direction in the case of divided highways and roads. For all other cases, they are valid for both directions.

1. Objectives of Project Mode LCCA and MCA

The objectives of LCCA and MCA studies for new highway construction projects are the same as those in section 1 of Appendix 2.

2. Projects Covered and Road Segmentation for Analysis Purposes

The pavement selection analysis process for new highway construction projects is only applied to expressways or main arteries of trunk roads. It is not applied to interchanges, service roads, and other secondary structures or roads. LCCA and MCA studies are carried out when the total length of the segments to be constructed is at least 4 km and only on the following types of projects:

- New expressways with 3 or more lanes in each direction
- New expressways with 1 or 2 lanes in each direction and new trunk roads, provided the average truck traffic volume expected for the ten (10) years following construction is at least 3,500 trucks per day and more for both directions.

When the new road is shorter than 4.0 km, it is considered an integral part of the existing segment. The asphalt type selected must be the same as that of the adjacent segment. The bituminous pavement type will be selected for any new road segment that does not fit into any of the project categories listed above.

For analysis purposes only, the dividing up of road segments into subsections is performed as follows:

- Each segment to be analyzed may be divided into one or more analysis subsections depending on the project plan and the nature of the work to be carried out
- The length of each analysis subsection must be at least equal to the length of a single construction project that lends itself to a contract, without being shorter than 4.0 km
- Where more than one project or contract is earmarked for the same analysis subsection or where more than one type of work is planned for a given subsection, the pavement type selected as representative of the entire analysis subsection will be the one indicated for the longest cumulative stretch of the subsection in question.

3. Prerequisites for a Detailed Analysis

The prerequisites for a detailed analysis for new highway construction projects are the same as those outlined in section 4 of Appendix 2.

4. Scope and Application of Analysis Methods

The lifecycle cost analysis (LCCA) and multicriteria analysis (MCA) methods are applied following the same procedures described in sections 5, 6, and 7 of Appendix 2.

5. Overall Analysis of the Results Taking Uncertainties into Account

Interpretation of all the detailed analysis results for new highway construction projects is performed in the same way described in section 8 of Appendix 2.