

Expansion of the Concrete Pavement Network in Quebec with the Update of the Departmental Policy on Pavement Selection Type

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Abstract

In 2001, the Quebec Ministry of Transportation (MTQ), in Canada, adopted a policy subdividing the existing pavement network into dedicated concrete and asphalt networks. Sixteen (16) different combinations yielded 32 pavement designs in asphalt and concrete that were compared in pairs over an analysis period of 50 years using a probabilistic Life Cycle Cost Analysis (LCCA) software. In parallel to the LCCA, a multiple criteria analysis was performed to account for a certain number of factors that are not easily quantifiable in monetary terms. The final selection criteria were applied to the Province's pavement network and the result was mapped. After minor adjustments to ensure continuity as much as possible, the respective networks ("white" for concrete, "black" for asphalt and "gray" for further analysis) were officially established. The policy making this network allocation official was scheduled for review every 5 years. In 2010, the policy on pavement selection type has been updated based on the new knowledge related to pavement materials and work costs, as well as the environment. Taking into account the environmental issue has been the subject of a special effort to meet the MTQ's requirements for the sustainable development. To take into account the environmental issue, a pavement Life Cycle Assessment (LCA) was also performed on the 16 cases: the results of the LCA were integrated as a factor in the multiple criteria analysis. The dedicated concrete network went from 799 km in 2001 to 1231 km in 2010.

Introduction

Until year 2001, the Quebec Ministry of Transportation (MTQ) policy for pavement type selection on existing roads was that concrete pavements remained in concrete and asphalt pavements remained in asphalt, unless a technical and economical analysis concluded otherwise. The nature and methodology of these analyses were not specified, so for almost all major rehabilitation projects, objections were raised either from the asphalt or concrete industry about the choice made by the MTQ: results of the analysis were disputed, hypotheses were challenged, costs and performance of future treatments were questioned, etc.

In 2001, a new policy was adopted which defined dedicated asphalt and concrete pavement networks after an extensive study, using a probabilistic Life Cycle Cost Analysis (LCCA) method, determining which conditions were best for each pavement type (Transport Québec, 2001). The main benefits of a dedicated networks approach compared to the previous policy are as follows: there are no disparities in the decision process between different territories in the Province, the cost-effectiveness and economic viability of both pavement types were demonstrated on a comparable basis in the study, according to the hypotheses that were used, a minimum market is granted to industries, giving them more stability and encouraging the preservation and development of their expertise and the controversy over specific projects is ended (Cormier and Thébeau, 2005). This paper presents the methodology used for determining the new 2010 dedicated networks using the three following

analysis: LCCA, LCA and multiple criteria analysis. It also presents the 2010 policy application. The significance of the work is mainly for practitioners.

Context

The road network under the responsibility of the MTQ is made up of approximately 30 400 kilometres, mainly of flexible pavements (out of asphalt mix or gravel) or rigid pavements (out of cement concrete). Each type of pavement reacts differently to the various conditions of traffic. The mechanical behaviour of the pavement types is characterized by a different response to the effects of the heavy loads. Thus, the loads distribution under a pavement will differ according to the type of riding surface. In Quebec, the thickness of the pavement structure, formed by the base and subbase, is a function of the desired frost resistance. The nature of the traffic, in addition, directly influences the choice of pavement and their thickness. The two types of pavement make it possible nevertheless to achieve the MTQ goals for performance and safety. In this context, the MTQ recognizes that each type of pavement represents a viable option and that it is important to privilege the product which offers the best long-term output according to economic, social, environmental and operational criteria.

At the time of the adoption of the departmental policy of 2001, the MTQ committed to carry out a revision of it after five years. The process¹ of revision however required additional time because of the trend of the cost of the essential components of the pavement and knowledge as regards to environment. The principal reasons of the modifications made to the present policy are as follows: evolution of the parameters of costs having effects on the output of the investment as the cost of materials and work; conditions of traffic influencing the long-term performance of the pavement types as the traffic flow and the increase in demand in transportation of heavy loads; improvement of knowledge and the expertise in regards of pavements because of the performance in time; taking into consideration the effect of the type of pavements on the environment by means of a Life Cycle Assessment (LCA).

Some of these parameters have a marked influence on the long-term output of the investments. It is recognized that the two types of pavement can constitute a profitable investment according to conditions of traffic. Consequently, the proportion of the network where the asphalt and concrete pavements involve better long-term investments is different from what was obtained during the analysis completed in 2001 for the development of the first policy.

Objectives and Methodology

By adopting the present policy, the MTQ pursues 4 goals: to determine the types of pavements which are best adapted to the conditions of use of the road network under its responsibility; to support and optimize the long-term planning of the interventions by using an approach centered on the network; to facilitate the development of the expertise of the pavement designers and the network owners; and finally, to clearly integrate the principles of sustainable development in the decision-making process.

In order to ensure the transparency of the revision process of the policy, the MTQ consulted the representatives of the concrete industry (Cement Association of Canada) and of the asphalt industry (Bitume Québec) like those of the association of the road contractors of Quebec (ACRGQT). MTQ was in charge of the project for the revision process, but consulted the representatives of the industries in order to receive

¹ Note: Some information about the review process of this policy could not be released in this paper.

their concerns and to hear their comments on the various analysis parameters selected. This collaboration made it possible to consider the demands of the industries and to renew the agreement established in 2001 as for methodology of analysis used and with the need for maintaining and developing a specialized expertise within the various groups concerned.

Before starting the policy review, the MTQ wanted to make sure to use a methodology that is objective, rigorous and supported by data and reports that are well demonstrated. In addition, this process of analysis should be applicable to all roads under its responsibility. The methodology relies on three tools for the decision-making process (Figure 1):

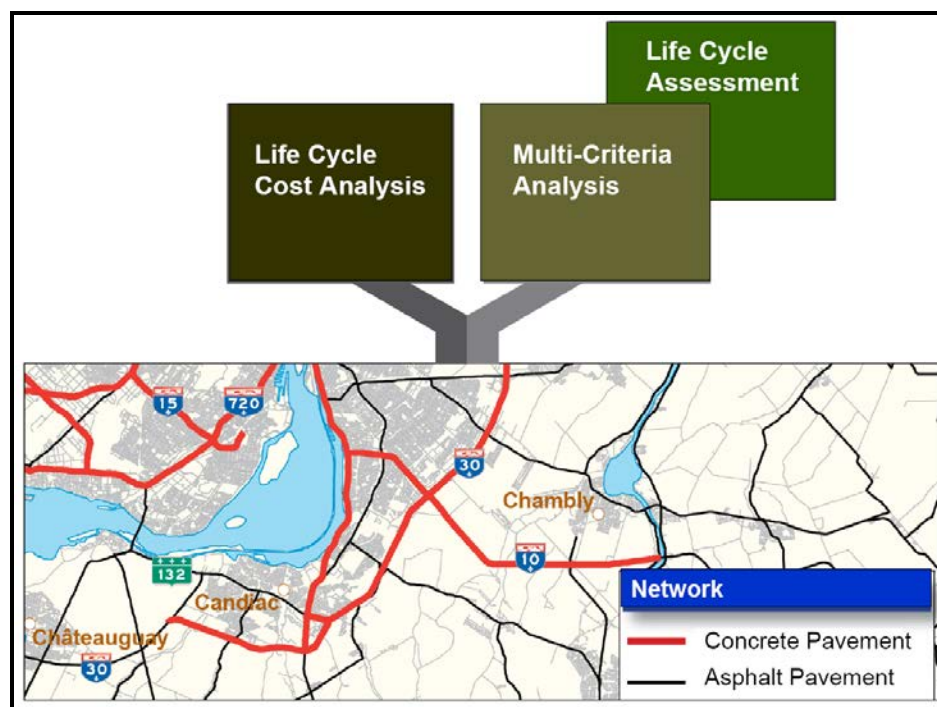


Figure 1 – Decision-Making Tools

- An economic analysis known as Life Cycle Cost Analysis over the life of the pavement (LCCA);
- A Life Cycle Assessment (LCA), which considers the environmental impacts of different types of roads;
- A multicriteria analysis that takes into account aspects difficult to quantify in monetary terms and that able us to integrate the results of the LCA.

The factors defining these standard cases are the Annual Average Daily Traffic (AADT), the percentage of trucks, the number of lanes in each direction and the load spectrum type (local or transit) with the associated truck factor. Local traffic mainly consists of single-unit trucks with a lower truck factor than transit traffic, which mainly consists of semi-trailers (see Table 1, Cormier and Thébeau, 2005).

Table 1 - Standard Cases Numbering and Description

Type of Load Spectrum		Local	Local	Transit	Transit
% Trucks		5	10	10	25
Truck Factor*		1	1	2	3.2
Lanes per direction	AADT				
2	20 000	1	2	3	4
2	40 000	5	6	7	8
3	50 000	9	10	11	12
3	90 000	13	14	15	16

*: Flexible equivalent single axle load per truck

Life Cycle Cost Analysis

The purpose of the LCCA method is to establish, among several possible alternatives, the one for which the Net Present Value (NPV) – that is, the sum of all the discounted costs anticipated over the analysis period – is the lowest.

Thus, for each type of asphalt or concrete pavement, an investment scenario was developed to determine the cost of construction and rehabilitation of a section of 5 km over a period of 50 years with a discount rate of 5%. Since the estimation of LCCA parameters always entail some degree of uncertainty, a probabilistic method was employed to account for this uncertainty and measure its influence on the results.

Design criteria and sequence of intervention compliance practices recognized by the MTQ were validated by an outside firm (Applied Research and Associates). As for the cost of materials (concrete and asphalt), they were derived from the costs that the MTQ has obtained from contracts for the volume representative in the light of market developments between 2004 and 2008.

A sequence of intervention was developed for each of the 16 cases of asphalt and concrete alternatives. Figure 2 illustrates an example of a concrete pavement sequence of intervention.

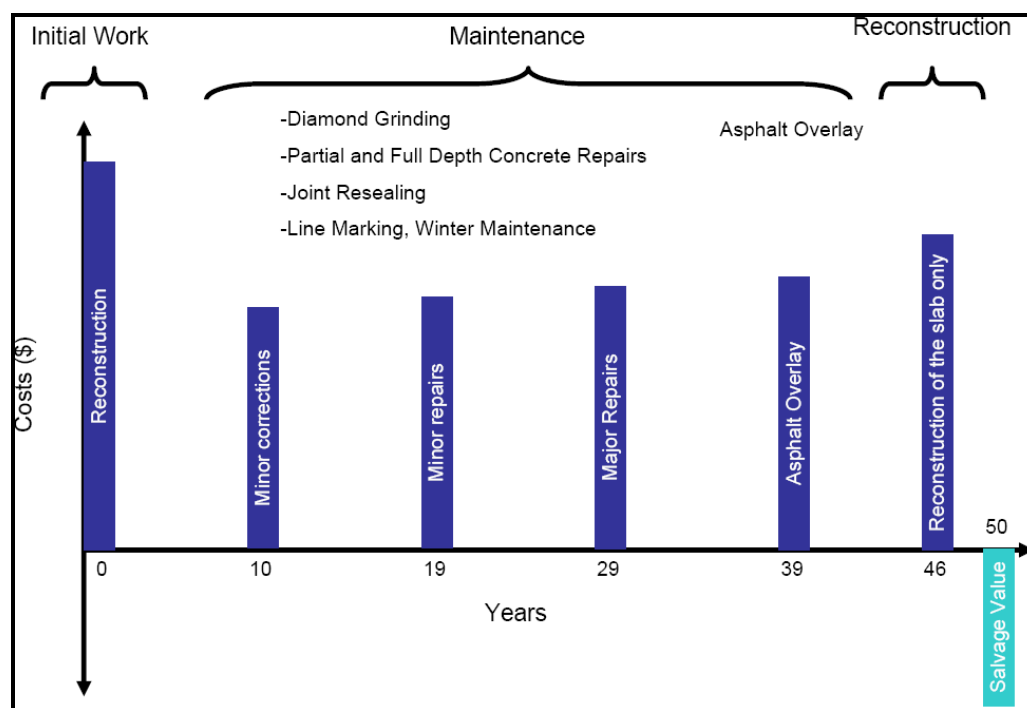


Figure 2 – Sequence of Intervention for the Concrete Pavement Alternative

The most economical alternative in the long term is the type of pavement that meets structural and functional design and has the lowest value.

The REALCOST software from the Federal Highway Administration (FHWA) was used to perform the analyses. This software calculates the NPV of several alternatives, including the work zone user costs if desired. It can perform sensitivity analyses of the main variables and allows consideration of the uncertainty for the following 4 parameters: reconstruction and rehabilitation treatment costs, treatment life, traffic growth rate and discount rate. The variability of the basic parameters was taken into account by means of a triangular probability distribution, based on the minimum, maximum and most likely values usually observed. This type of distribution is more concrete and easier to use than a normal distribution. For example, the minimum and maximum values for the treatment life of a repair can be estimated fairly easily based on expert opinion, but the determination of a standard deviation for that same parameter is a concept much less tangible unless sufficient hard data are available. The Monte Carlo sampling simulation technique is used by the software to compute the NPV distribution resulting from the variability of the parameters.

Life Cycle Assessment

The environmental aspect and the wish to take into account the sustainable development were addressed through a life cycle assessment analysis (LCA). This type of analysis is increasingly used in the field of transport infrastructure to assess the potential environmental impacts of a product throughout its life.

The MTQ commissioned the “Centre interuniversitaire de recherche sur le cycle de vie des produits, procédés et services (CIRAIG)” from the Ecole Polytechnique of the University of Montreal to produce the LCA. The CIRAIG is an independent firm, recognized for its expertise in the field.

In the context of this policy, the LCA evaluates all of the resources used and emissions produced during the first 50 years of use of a pavement. The life cycle of a pavement includes raw material extraction, production and transportation of materials, construction activities, maintenance, operation and waste disposal at the end of their useful life. The inventory thus generated is then translated into potential impacts on the environment (Figure 3).

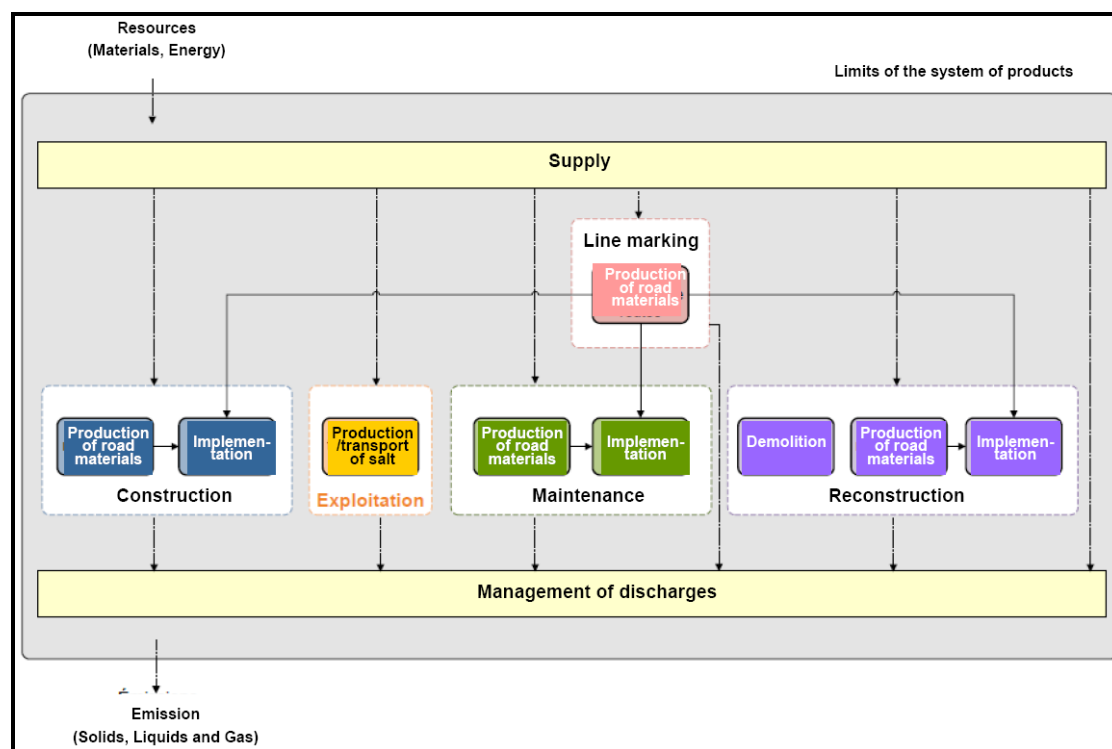


Figure 3 – Life Cycle of a Pavement

The 16 standard cases have been the object of the LCA. These cases were used to compare the environmental performance of pavement types for 15 impact categories grouped into 4 indicators of damage:

- Human health;
- Quality of ecosystems;
- Climate Change (global warming);
- Sustainability of the resource.

MTQ used the LCA to account in the decision making process, the energy and the environmental impacts. The LCA results were incorporated into the multicriteria analysis.

Multi Criteria Analysis

The multicriteria analysis allows considering several criteria difficult to quantify in monetary terms and to appreciate and weigh the criteria by comparing them to each other.

To this end, an expert committee including members of the MTQ and outside consultants was formed to determine the criteria and their relative importance in the process of selecting the pavement type. The mandate of this committee was also to determine how concrete and asphalt pavements can meet these criteria. Among the hundreds of criteria examined, the committee has selected 17 that meet the following conditions:

- Significant: Members should agree on the definition and the relative importance of the criterion. The criterion should be used in a network-based approach. Too specific cases have not been retained.
- Discrimination: The criterion has to establish a sufficient difference to favour one option over another.
- Proven: The criteria must be sufficiently demonstrated in practice.

The criteria were then grouped into five categories, after which it was assigned a weighting to each category according to its relative importance in the selection process:

- Environmental impact (32%):
 - o LCA: Implications for human health, quality of ecosystem and global warming;
 - o LCA: Resource depletion;
- Impact on road users (25%);
- Maintenance interventions (18%);
- Construction interventions (15%);
- Planning and management (10%).

The multicriteria analysis was used to compare the two types of pavement on various aspects. The results indicate an overall score of 6.1 out of 10 for asphalt pavement and 4.1 out of 10 for concrete pavement. This analysis is a supplement to the LCCA and sheds new light on the results of the latter.

Determination of Respective Concrete and Asphalt Networks

The combination of the results of the LCCA with those of the multicriteria analysis was used to determine what portion of the road network each pavement offers the best long-term performance.

We first translated the results of the LCCA in number of trucks in order to generalize the entire road network according to actual conditions of traffic. To achieve this, the 16 standard cases were grouped into 4 categories depending on the type of traffic (local traffic or in transit) and the number of lanes (highway of 4 or 6 lanes and above). Then, for each category of traffic, we have drawn a regression of the net present values supplied by the LCCA. These curves were thus determined the thresholds of number of trucks from which the concrete pavement becomes more profitable.

Finally, to reflect the outcome in the multicriteria analysis, we evaluated several scenarios based on a difference in the net present value between concrete and asphalt pavements. Because the multicriteria analysis result was in favour of the asphalt pavement, the MTQ has finally raised the threshold for the number of trucks, corresponding to a difference of 8%, from which the concrete pavement becomes more profitable (Figure 4). This is the gap that best meets the principles of the distribution of the pavement types on the road network that has been set the MTQ which takes into consideration:

- The existing networks of concrete and asphalt pavements;
- The continuity of networks with the same type of pavement;
- The effects of the proposed networks on maintenance on the road.

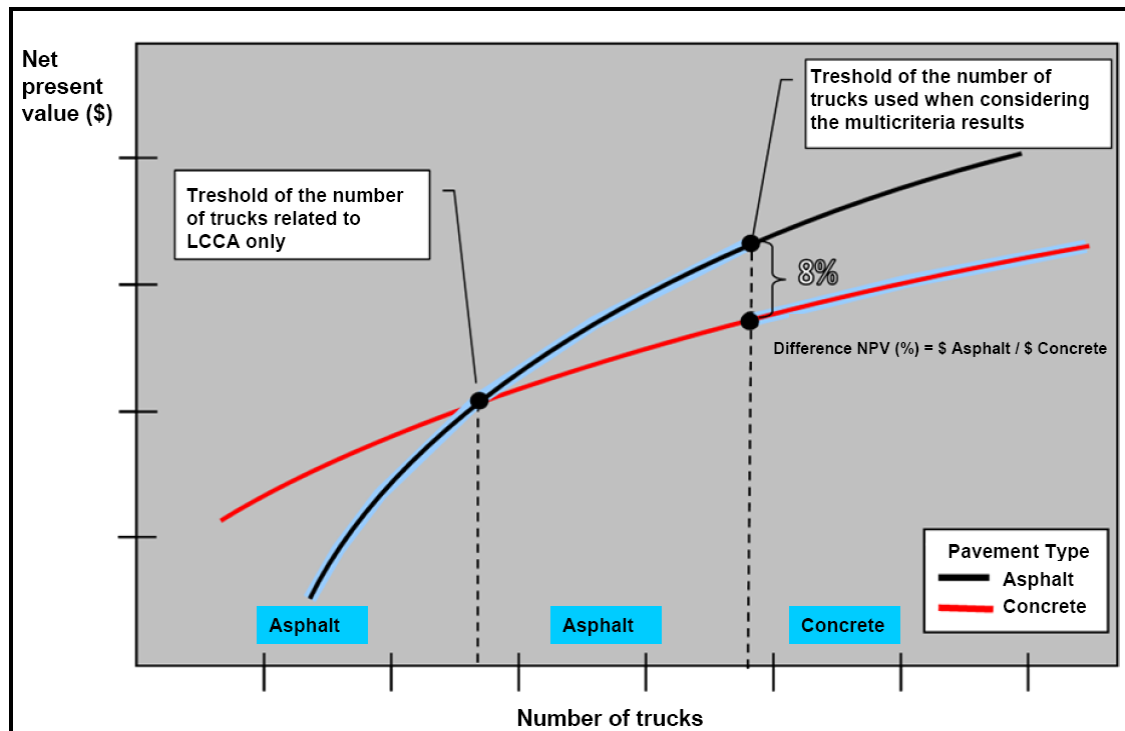


Figure 4 - Determination of the threshold of the number of trucks from which the concrete pavement becomes more profitable

In the context of the rehabilitation interventions of roads under its responsibility, the MTQ identified two networks specifying the types of pavement to use:

- A network of concrete pavements (1 231 km) where the analysis showed that this option offers the best return on investment. The red sections of road identified on Figures 5 and 6 are concrete pavements;
- A network of asphalt pavements (26 869 km) where the analysis showed that this option offers the best return on investment. The black section of roads identified on Figures 5 and 6 are asphalt pavements.

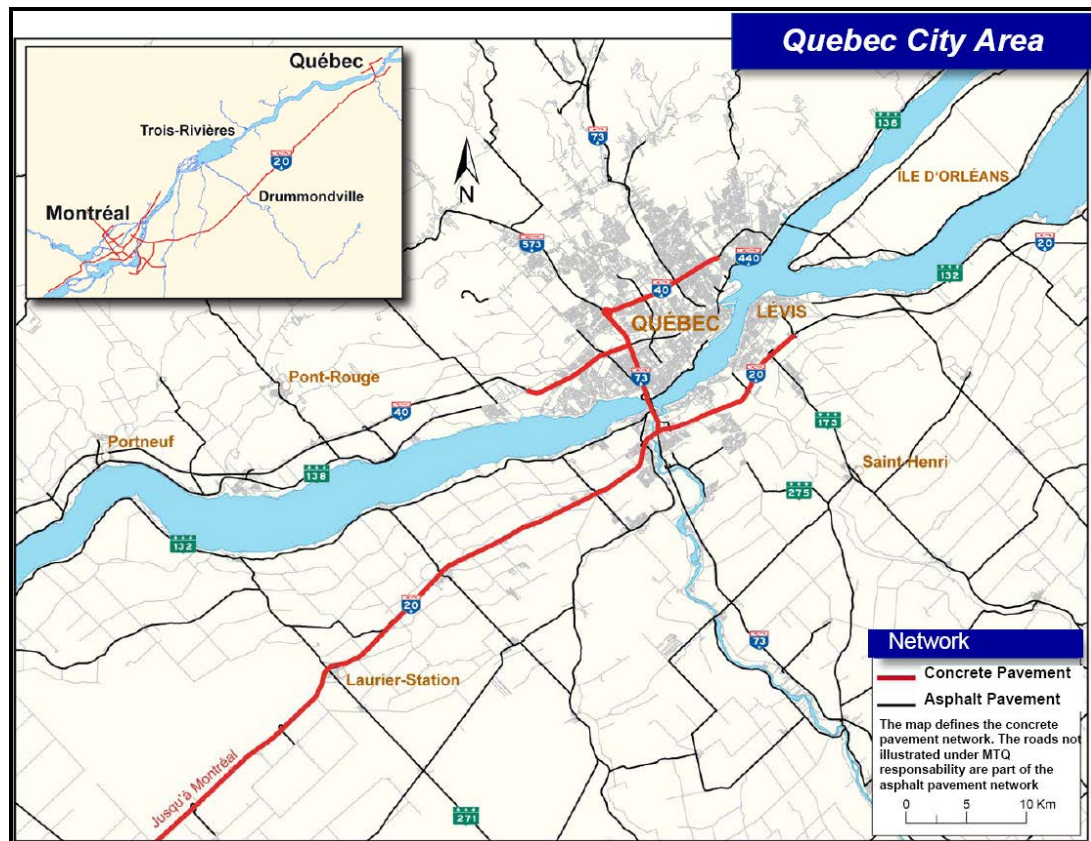


Figure 5 – Mapping of the types of pavement – Quebec City Area

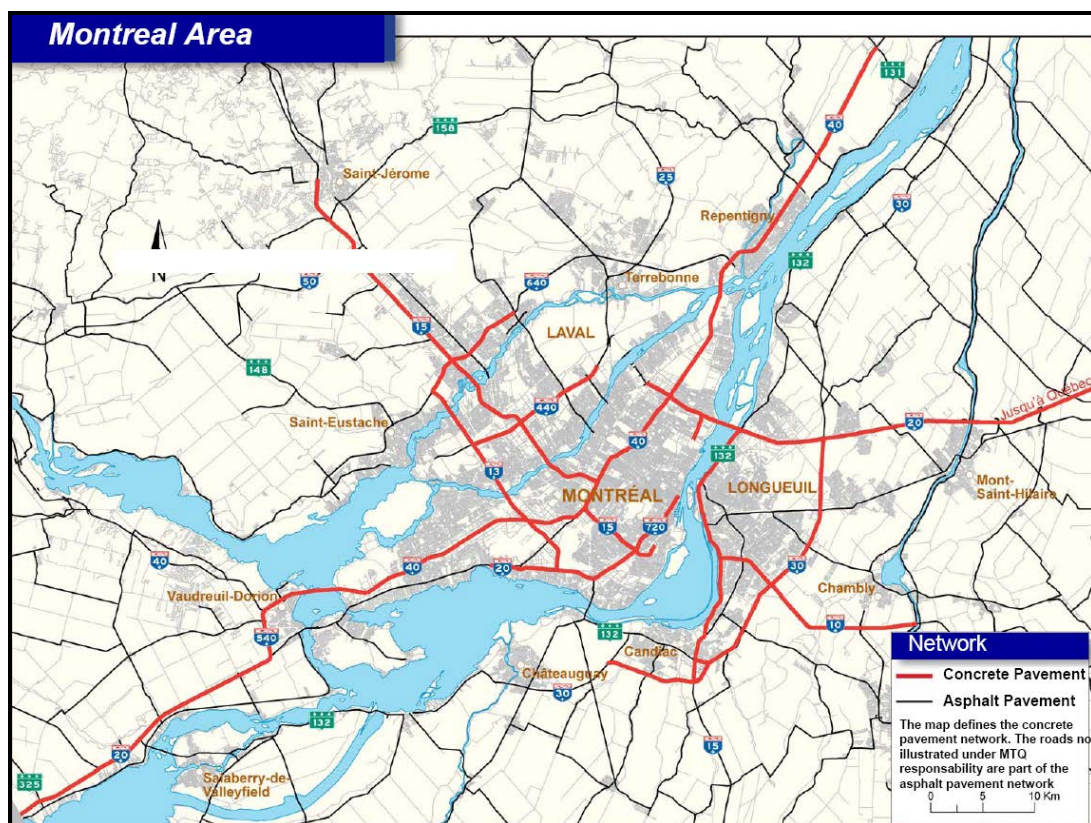


Figure 6 – Mapping of the types of pavement – Montreal Area

Policy Application

The policy on Pavement Selection Type becomes a reference; departmental managers and designers have to refer to it to choose the type of pavement when rehabilitation work is planned on the network.

For the purposes of the application of this policy, the various interventions are grouped into 3 categories:

- **The maintenance operations**, which include preventive, curative, palliative or emergency operations, whose size is limited and whose implementation can be decided quickly to ensure user safety or integrity of the road.
- **The surface rehabilitation interventions**, which include preventive, curative and palliative interventions whose scope, is broader than maintenance operations, which affect the upper part of the pavement. These include hot or cold recycling techniques, repairs with a correction and an hot mix asphalt (HMA) layer, mechanized patching and resurfacing with or without milling.

Milling 80 mm and less and recycling operations (hot or cold) that affect the first 100 mm from the surface are considered as surface rehabilitation interventions. As for milling and recycling interventions whose depth is greater than these values, they are considered full-depth rehabilitation interventions.

- **The in-depth rehabilitation interventions** are interventions for the rehabilitation of a pavement, that is to say they aim to correct, in a sustainable manner, all the distresses of the pavement. These interventions are generally heavier and more durable than the maintenance operations and surface rehabilitation interventions. They include the structural resurfacing with HMA, the concrete overlay of a concrete pavement or flexible pavement, the complete or partial replacement of the pavement (a depth exceeding values reported for the surface rehabilitation interventions), full-depth reclaiming and the partial and total reconstruction of the pavement.

For existing roads. The measures vary by category of intervention.

- **In-depth Rehabilitation Interventions**

When a pavement has reached the end of its useful life, in-depth rehabilitation interventions should be carried out in accordance with the types of roads shown on the maps in Figure 5 and 6.

Rehabilitation projects that are adjacent to the concrete pavement network and where it is expected that the average volume of trucks exceed 5,000 vehicles per day during the five years following the road work must be performed by the procedure set for new roads.

- **Other interventions**

Interventions for maintenance or surface rehabilitation, the pavement type selected must be the same as the existing pavement.

The widening or geometric improvements that directly affect the platform of the existing pavement must be executed with the same type of pavement than the main pavement, unless the condition of the road requires an in-depth rehabilitation intervention.

For new roads. For the construction of new roads, a detailed study based on LCCA and multicriteria analysis should be performed to determine the type of pavement offering the best return on investment.

Conclusion

The Departmental Policy on Pavement Selection Type will harmonize practices within the MTQ and support road managers in the design and planning of the work. The implementation of this new policy involves the adoption of an intervention strategy that promotes the extension of the life of existing pavements using different interventions of maintenance, surface and in-depth rehabilitation, according to the annual budget.

This policy must be integrated with the planning strategy, the multiannual financial framework and the emergence of new priorities related to sustainable development and security of road users. It promotes the growth of the life of existing roadways through the use of appropriate techniques to optimize the programming of the surface and in-depth rehabilitation interventions.

These choices must also create the necessary conditions for the maintenance and development of expertise in the field of pavement to ensure the sustainability of the infrastructure and innovative and efficient solutions. To this end, the MTQ plans to promote the acquisition and maintenance of specialized expertise for each type of pavement by the creation of work tables, focus groups and discussion forums.

The policy also provides the monitoring of key parameters that can affect the performance of pavement types. It reserves the right to review the conclusions of the policy following a significant change in costs of materials, traffic conditions, and the life of the interventions or other circumstances beyond its control.

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