Current and emerging challenges in road risk management in Québec

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"Abstract"

With an area of 1,700,000 km, Québec offers a climate with major temperature variations, given its geographic features. In addition, there are special conditions: the St. Lawrence River, which runs through marine clay deposits recognized as sensitive; many lakes, reservoirs and hydroelectric dams; several airports in isolated regions; a road network estimated at 320,000 km.

The Ministère des Transports du Québec (MTQ) manages and maintains 30,400 km of this network (highway system), including some 10,000 structures (bridges, overpasses and other). Most of the transportation infrastructures were built from 1960 to 1980 on the basis of knowledge which has evolved considerably since then; the transportation infrastructures were designed on the basis of climate scenarios, which today are being reconsidered or modified.

The main risks confronting Québec are: melting of the permafrost in northern Québec, shoreline erosion in coastal environments along the St. Lawrence and in the Gulf, forest fires, floods due to high-water levels and high tides, landslides, freezing rain and other extreme winter conditions, transport of heavy equipment and hazardous materials.

The MTQ has adopted some risk management tools and is pursuing research and development regarding roads and structures to implement solutions adapted to the Québec context. In a context of budget restrictions, the MTQ must target and prioritize its interventions wisely and prepare to deal with emerging challenges, generated by climate change or resulting from the interdependence of essential transportation systems. To this effect, integrated risk management, based on objective, reliable and verifiable multidisciplinary data and on rigorous and well-documented methodologies, is still the preferred approach.

1. QUÉBEC

With an area of about 1,700,000 km², Québec has close to 320,000 km of roads. Its area is 5 times the size of Japan or 3 times the size of France. It has only 7.7 million inhabitants, while Mexico City has nearly double that population.

The majority of the population resides in southern Québec, and 80% of Québec's population lives near the shores of the St. Lawrence River on clayey soil from postglacial seas. The inhabited areas are located in the south, with its temperate climate, mixed forest and four successive seasons.

In the north, the climate is more arid, especially north of the tree line, where the territory has the rigours of an Arctic climate and tundra vegetation. The northern regions are where permafrost (permanently frozen subsoil) is found. The Nord-du-Québec region is almost uninhabited, with a population of only 35,000.

2. THE MINISTÈRE DES TRANSPORTS DU QUÉBEC

The MTQ's mission is to "ensure, all across the territory (of Québec), the mobility of people and goods through efficient and safe transportation systems that contribute to the sustainable development of Québec".

For this purpose, the MTQ has about 4,000 permanent employees and 3,000 casual employees, distributed among 14 territorial divisions, 60 service centres, 1 Bureau for the coordination of Nord-du-Québec and 2 integrated traffic control centres.

Where the road network is nonexistent, in remote or isolated regions or in the absence of structures to span major watercourses, the MTQ performs its mission through other transportation modes and infrastructures, such as airports in Nord-du-Québec, ferries, marine and air services, and the Québec Central Railway, which are under its administration.

3. THE QUÉBEC ROAD NETWORK

Of the approximately 320,000 km of roads crisscrossing Québec, 30,400 km are under the MTQ's responsibility and 102,000 km are under municipal jurisdiction. The remainder is the responsibility of other administrations, such as: Hydro-Québec (3,300 km), the Ministère des Ressources naturelles (186,000 km), and the federal government (500 km). The Ministère des Transports du Québec also manages about 10,000 bridges and overpasses (including those of municipalities with populations under 100,000) and the 3 tunnels in the Montréal region, including the biggest tunnel under the St. Lawrence Seaway.

The road network extends from east to west along the shores of the St. Lawrence. To the north, the road network makes it possible to reach the major dams of James Bay, which are under the authority of the government corporation Hydro-Québec. Bypasses are often absent in the north and east. A major multimodal trade corridor runs through Québec, linking the Maritimes, Ontario and the United States.

4. STRUCTURES

The structures and infrastructures were built from 1960 to 1980, in accordance with Canadian design, construction and maintenance standards and departmental design standards for roads, structures and culverts. These criteria account for road safety standards, environmental standards and natural risks related to earth movements.

Prior to the work, geotechnical analyses are performed to verify whether the road theoretically may be at risk due to landslides. Some routes under study or existing routes have been modified to account for these risks.

The design of structures accounts for the risks according to their category and the risks of damage to the structures by seismic activity, according to the Canadian Highway Bridge Design Code (CAN/CSA-S6-06). Since 1987, data concerning the structures have been integrated into a management system, called the GSQ-6026 system, which contains a multitude of inventory, inspection and evaluation data. These data are used for various purposes, particularly within the context of work allowing analysis of the vulnerability of infrastructures to various risks.

5. VULNERABILITY OF TRANSPORTATION INFRASTRUCTURES

The infrastructures were built on the basis of information that has evolved since the 1960s: transportation has become heavier, with higher AADT (annual average daily traffic) and a greater percentage of trucks, particularly in the cross-border trade corridors with the United States and Ontario.

Furthermore, the transportation infrastructures were designed on the basis of climate scenarios which today are being reconsidered or modified. Thus, during the design and construction of the structures in Nunavik, no permafrost protection measures were taken, in view of the forecast of a stable climate context.

Faced with these new climate conditions, the infrastructures thus can exhibit new vulnerabilities, particularly attributable to the initial design, their age (life cycle) or the level of maintenance received. There is often little or no knowledge of these new technical and structural vulnerabilities and new environmental conditions, although studies are in progress to learn more.

Moreover, the infrastructures frequently may be affected by risks related to natural or man-made disasters (Figure 1) and also represent a choice target for malicious acts, according to the trends observed around the world.

	
Landslides Permafrost melting Floods, high-water levels and high tides Shoreline erosion Dam failures	Forest fires Earthquakes Extreme winter conditions Transport of hazardous materials Transport by heavy vehicles
	

Figure 1 – Main risks affecting Québec

6. RISK MANAGEMENT AT THE MTQ

The fundamental principles of risk management have long been applied to transportation infrastructures. However, the methods have evolved considerably in the past few years. This is explained by technological advances, globalization of trade, and information technology, which have combined to result in changes in road risk management techniques and methods.

The MTQ's actions increasingly are based on objective and verifiable criteria. The MTQ relies on the development of multidisciplinary and objective scientific knowledge and on up-to-date, reliable and verifiable data to manage its transportation infrastructure planning, construction, maintenance and monitoring activities.

The Gouvernement du Québec defines risk management as an approach aimed at risk reduction through constant and systematic consideration of the risks in administrative decisions, resource management and the way responsibilities are assumed. The purpose of the approach is to reconcile risk-taking with mastery of the dangers in order to render the risk acceptable, since zero risk is recognized as nonexistent.

7. APPLICATION OF RISK MANAGEMENT AT THE MTQ

The practical examples described below illustrate the engagement of the Ministère des Transports du Québec in the risk management field:

- Adaptation to climate change (7.1)
- Man-made risk reduction measures (7.2)
- Road projects and financial risks (7.3)
- Social perception of risks (7.4)
- Development and application of risk management methods (7.5)

7.1 Adaptation to climate change

7.1.1 New MTQ airport infrastructure planning and management approach in Nunavik in a context of climate change: towards an adaptation strategy

In Nunavik, the permafrost has high ice content. It was observed that it melts quickly with rising temperatures caused by climate change and the heat exchange attributable to water runoff and natural and mechanical accumulation of snow at the foot of embankments.

Between 1997 and 2000, the annual average atmospheric temperatures rose 3.5ºC. This increase is 5 to 7 times faster than the planetary temperature rise during the same period. It was also observed that precipitation increased from 16.8% to 29.4% in winter and from 3.0% to 12.1% in summer.

No protective measure against permafrost thawing was considered during the design and construction of the infrastructures, because a stable climate context was foreseen at that time. Major degradation is now observed on the infrastructures, such as cracking at the top of the embankments, subsidence over the entire width of the infrastructure and a disruption of the drainage system at the foot of the embankments of the roads and landing strips. The announced temperature increase will accentuate the scope and speed of degradation. The adoption of an adapted approach to design and maintenance of the structures is therefore necessary to account for climate change-related factors.

Since 2003, geophysical surveys, (seismic refraction and georadar) and deep drilling with recovery of samples have been performed. Since 2004, field inspections have allowed the MTQ to track the evolution of the existing depressions and inventory new ones, as well as pools and snow accumulations at the foot of embankments. Ground movement plates have been installed at locations with major depressions in order to track the evolution of subsidence, despite current maintenance work, which may camouflage the problem it remedies.

Thermistor cables have been placed by Université Laval since 2005 to document the evolution of the situation. Experiments have been conducted with new techniques, such as thermal drains, embankments with a mild slope, air convection embankments and reflective surfaces. An aerodynamic study will be performed on the Tasiujaq Airport site to validate the relevance of installing snow fences to minimize snow accumulation at the base of the embankments.

7.1.2 Shoreline erosion in Îles-de-la-Madeleine

Îles-de-la-Madeleine (also known as the Magdalen Islands) are located in the Gulf of St. Lawrence. The combined action of sea and wind has a very dynamic effect on the entire coast of the islands, causing shoreline erosion. This phenomenon is accentuated by climate change, which is causing higher magnitude storms. During the 2007 road inventory, the MTQ detected 20 sites vulnerable to erosion, distributed over 10.9 km, more than 12% of the road system in the coastal axis (84.7 km).

For the past five years, these sites have necessitated constant maintenance and close supervision. Some sectors often require beach nourishment after a storm. The 2009-2012 action plan contains the main measures to be taken to counter shoreline erosion in Îles-de-la-Madeleine, based on the prioritized sectors. The criteria used to classify these sites are: storm exposure, source of storms, the storm surge risk, the annual recession rate, the nature of the coastal substrate, and the number of interventions in the past 20 years.

Several research studies have been conducted or are in progress on these sites to characterize their sedimentology and their geomorphology, evaluate their sensitivity to climate change, perform coastal surveys and analyze the feasibility of shoreline protection measures. One avenue considered in this regard is the use of dredging sands from the Mines Seleine salt mines for beach nourishment, due to the proximity of the resource and the large quantities available.

7.1.3 Dam failures and floods in Saguenay

The Saguenay–Lac-Saint-Jean region has several hydroelectric dams. Its watershed is the fifth biggest in Québec and the second to feed the St. Lawrence River, after the Ottawa River watershed. It offers a moist continental climate with cool summers and no dry season. The region’s geographic location predisposes it to precipitation.

In the summer of 1996, torrential rains poured down on the Saguenay region, causing dam failures and major floods. Many river shores, homes, villages and transportation infrastructures were damaged, swept away or destroyed. Following the recommendations of the Nicolet Report on watershed and dam management, the MTQ, in partnership with various agencies and other government departments, developed and went online with a geomatics tool (online atlas), which consolidates the data on the Saguenay–Lac-Saint-Jean region.

This tool, which bears the Web name SCORE, allows users to consult historical flood data and find out information regarding the road network, including the descriptive and location data for structures, bridges and culverts. It also allows simulation of the consequences of floods for infrastructures and the real time of the flood wave at strategic points, and assessment of all the collateral effects on the partners (e.g.: Hydro-Québec power transmission lines).

In addition, from the SCORE website, the user can access the emergency plans developed for each dam for which the level of consequence is considered medium to considerable, in order to protect human lives and property (structures). It also includes the inventory of situations that could cause a dam failure, the general description of the flooded territory, the alert procedures, and the flood maps.

7.1.4 Forest fires in Chibougamau

Nearly 130 forest fires are reported each year in Saguenay–Lac-Saint-Jean–Chibougamau. The heat and drought from May to September and snowless winters are increasing the number of forest fires. From 1991 to 2002, above-normal temperatures were recorded. The years 2002, 2009 and 2010 presented exceptional characteristics for causing forest fires. The year 2009 was characterized by a snowless spring and a windy month of May, with gusts up to 100 km/h.

Forest fires have a direct impact on the road infrastructures in the Chibougamau region, where the road network is surrounded by forest and has no bypasses. A forest fire, even far from the road, can have consequences for the mobility of people and goods, mainly due to visibility. Forest fires also have a major impact on the forest industry, which represents a major economic activity in Québec. The interruption of the road network also results in heavy economic impacts for the region.

The MTQ acts in coordination with Société de protection des forêts contre le feu (SOPFEU) and Hydro-Québec for lightning fires and location of all forest fires. It conducts helicopter overflights to find out the situation regarding the road network.

The MTQ intervenes by setting up roadblocks on its network and on forest roads. It interrupts traffic and organizes escorted convoys for road users and heavy transportation. After the fires have passed, the MTQ inspects the bridges and participates in the debriefing. As a result of the last events, the MTQ will clear a 75 m width along the road network of the Réserve faunique des Laurentides wildlife reserve (firewall) and will prepare response plans to deal with the situations caused by forest fires.

SOPFEU, which monitors the territory to protect the forest, has lightning strike point software that brings together observations and weather forecasts from 159 weather stations and allows real-time assessment of the location of the fire in relation to the MTQ's road network. The software used by SOPFEU for geoconferencing will soon be accessible online to all civil protection partners and the Ministère des Transports du Québec.

7.2 Man-made risk reduction measures

7.2.1 Transport of aluminium products by barge for Aluminerie Alouette

Aluminerie Alouette is a major aluminium producer, located in Sept-Îles on the Lower North Shore, which sells its production in Canada, the United States and overseas. Before 2005, Aluminerie Alouette shipped its production to the continental market by truck, by rail and occasionally by ship.

The adoption of a multimodal transportation solution (truck-barge-truck or rail) by Aluminerie Alouette to ship its aluminium products allowed a 10% annual reduction in the number of movements (14,000/140,000 movements/year) on a segment of Route 138 on the Upper North Shore, identified as having a high risk of serious or fatal accidents, given that heavy trucks are often involved.

Transportation by barge has allowed clear reductions in greenhouse gas emissions estimated at a total of 38,000 tons per year. The road network maintenance cost has been reduced by about $600,000 per year. The reduction in the number of trucks on the road has decongested the ferry service linking the east and west shores of the Saguenay River at the edge of the St. Lawrence River.

7.2.2 Regulatory requirements for electronically assisted driving for tank trucks of hazardous materials

In Canada, transport of hazardous materials by road accounts for the biggest share of hazardous materials transported (50.8% by road). On the average annually in Québec, there are 178 accidents involving transport of hazardous materials. Tank trucks are involved in sixty-three percent (63%) of accidents involving vehicles transporting hazardous materials (from 1995 to 2007).

The accident risks are multiplied by the development of transportation infrastructures, high vehicle speeds, the increased capacity of tank trucks and the increase in the quantities transported related to traffic growth. In Québec, tank truck fleet transporting hazardous materials is estimated at about 8,000. A risk analysis was performed to determine the effects of speed and centrifugal force on the vehicles.

Following the results of the study, the Minister added the following obligations to the Transportation of Dangerous Substances Regulation (TDSR): “As of 15 August 2006, tank trucks transporting dangerous substances must be equipped with a driver monitoring system that records significant speed variations and relevant data on the date, time and speed, or an electronic system for dynamic stabilization of the vehicle to assist the driver during a critical manoeuvre.” In the case of a motorized road vehicle assembled before 15 August 2006, “either system mentioned in the first paragraph may be replaced by a speed limiter that limits speed to 100 km/h”.

The installation of a speed recording system (SRS) on trucks has had a positive effect on driver behaviour. The electronic stabilization system, equipped with different sensors (gyroscope, accelerometer, etc.), is particularly effective, because it systematically takes control of the ABS (antilock braking system) of a rig (tractor-trailer) when the sensors detect the slightest loss of control.

7.2.3 The departmental process for monitoring structures

For the past ten years, the Ministère des Transports du Québec has emphasized monitoring of the road network. Monitoring concerns all the activities necessary to obtain adequate knowledge of the condition and use of the road network continuously, in order to intervene rapidly and implement the necessary measures to ensure the users' safety, provide them with assistance and maintain this network's functionality and traffic fluidity.

The MTQ manages road network monitoring according to a departmental management framework. The network monitoring frequencies are modulated according to the road's functional classification and annual average daily traffic (AADT). The risks associated with operation of the road network are considered in the establishment of patrol frequencies. For example, we should mention the failure risks associated with faulty culverts; the risks of detachment of concrete from tunnel and overpass surfaces; the risks of incidents and traffic obstructions on high-traffic roads (monitored by a camera network and field visits).

The highway bridges are the nerve centres of the road network. The collapse of an overpass on September 30, 2006, causing the deaths of 5 people and injuring 6 others, led the MTQ to implement several actions. The relative short-term demolition of 135 bridges built during the same years (including some of the same design) was undertaken immediately and unprecedented investments of $5.4 billion were committed to repair the structures by 2013. The MTQ produced an action plan, one of the measures of which is to implement a risk management approach by monitoring structures (in preparation).

The network monitoring process was completed in 2008 with the addition of monitoring of the structures (a total of about 10,000 structures erected between 1960 and 1980). It allows reporting of structural anomalies and rapid intervention according to the potential safety risks for road users or neighbouring occupants. Between two general or annual inspections, a methodical patrol is conducted by personnel trained for this purpose, to ensure structural soundness and the safety of overpasses for the users.

7.3 Road projects and financial risks

7.3.1 Risk management for the Route 73/175 highway axis widening project

Route 175 is the main link between Ville de Saguenay and Ville de Québec. This two-lane highway extends over 174 kilometres and passes through a hilly forest environment. It offers no bypass within the Réserve faunique des Laurentides wildlife reserve. Several major accidents have been reported on this highway. A redevelopment project, announced in 2002, provides for a 4-lane divided highway with a median. The two levels of government — Canada and Québec — which are sharing the costs, have agreed that the project will be carried out according to a process integrating risk management for the major issues implicit in the project.

For the Ministère des Transports du Québec, this involves managing the risks of a highway project according to a rigorous method, concerning the financial aspect, safety of workers and users, protection of the environment, and maintenance of traffic and fluidity.

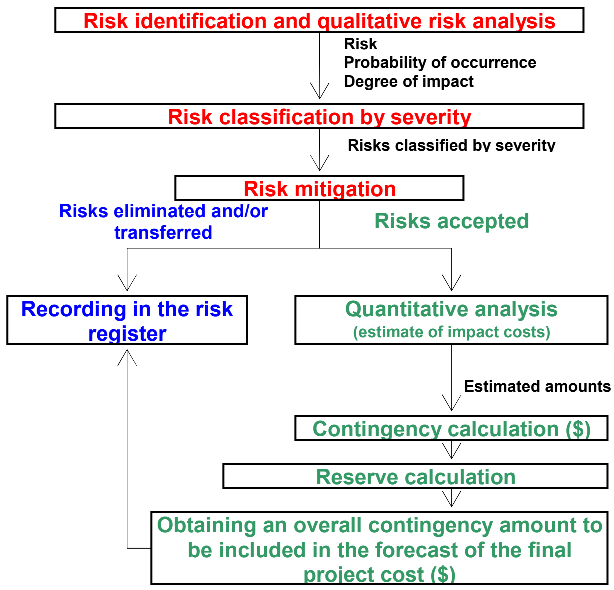
A Project Office was established to support the territorial divisions concerned in the planning, coordination, management and monitoring of the Route 73/175 highway axis project, in addition to assuming project management responsibilities for health and safety. An initial risk analysis was performed in 2003. Subsequently, updates have been produced each year, and will continue up to the end of the work.

Table 1 – The method used for the Route 73/175 highway axis

The methodology used is adapted from PMBOK *:

i. Risk identification
ii. Quantitative risk analysis
iii. Risk classification
iv. Risk quantification
v. Contingency and reserve calculation
vi. Risk register

* PMBOK: *A Guide to the Project Management Body of Knowledge* (PMBOK), Project Management Institute, 2000.



i. Each risk was identified with the following formulation: “In view of <causes>, <risk> could occur, which would have as consequences the following <impacts>.”

ii. The degree of impact of each risk was determined for different aspects of the project (generally costs and deadlines) and their probability of occurrence.

iii. The risks were classified in descending order of severity, calculated averaging the degree of impact and multiplying the result by the probability of occurrence of the risk.

iv. The risks were quantified by determining a more precise impact cost, i.e. “how much would it cost if the risk occurred”.

v. For each risk, a contingency amount and a reserve amount were calculated to establish an overall budget forecast. The contingency was calculated by multiplying the impact cost by the (percentage) probability of occurrence of the risk. The reserve, a fund allocated to cover the uncertainty of the unknown elements of the project (i.e. the unidentified risk that could occur) was assessed at about 10% of the total contingences. The sum of the contingences of each risk and the reserve represents the total amount to be added to the project budget, as a provision, to estimate the anticipated final cost.

vi. The results are recorded in a project risk register. This register is updated each year. All the risks are reassessed (impact and probability of occurrence) and, if necessary, new risks are added. A new contingency forecast amount is then calculated.

Initially envisioned as an overall project, it was subsequently subdivided into road sections and subsections corresponding to an equivalent number of separate contracts, for which a specific risk analysis was performed. This had the effect of increasing the precision of the analyses. The application of the method establishes that at the beginning of the project, in 2003, its total cost was estimated at $711 million, including a $60 million contingency and reserve provision. In 2010, when over half of the project was completed, its overall cost was evaluated at $1100 million. The update for 2010 is a better reflection of the reality regarding the impact costs of contingent claims by contractors, an aspect which had been underestimated at the beginning of the project.

7.3.2 Completion of Autoroute 25

The Autoroute 25 completion project was analyzed by a group of specialists to identify and quantify the risks, and to produce a risk matrix. For each phase of the project (design, construction, operation and rehabilitation), the identified risks were classified in 4 categories and studied by 4 subcommittees: financial and economic risks, technical risks, legal, judicial and regulatory risks, and sociopolitical risks. The same rigorous approach was followed by the 4 subcommittees. This exercise also made it possible to determine the most appropriate performance mode, either conventional or PPP (public-private partnership).

The MTQ's method, for quantification of the risks transferred to the partner, is inspired by the Partnerships British Columbia multipoint method. This consists of estimating the probability of occurrence of each risk. Assuming that the risk occurs, the probability of low, medium or high impact is assessed. Then the cost associated with this probability is estimated. The data obtained are integrated into the risk matrix, which automatically calculates the average value of the impact cost, if the risk occurs, and the hoped-for average value, which accounts for the probability of occurrence of the risk and the corresponding standard deviations.

The approach is completed by a validation of risk quantification and allocation, as well as mitigation measures by the group of specialists. The conventional mode is evaluated by accounting for these same risks in the calculation of the public comparator. The risks are included in the partnership agreement.

7.3.3 Financial risk management – Snow removal contracts

The Ministère des Transports du Québec ensures winter maintenance of the roadways under its responsibility. Eighty-two percent (82%) of roadway winter maintenance activities are contracted to local contractors, which corresponds to 66% of the snow removal and deicing contracts per year.

Over the past 10 years, the MTQ has been faced with two major problems related to the contracts for its winter maintenance operations. The first is competitiveness in awarding contracts in certain regions, and the second is the generalized increase in the cost of these contracts.

In 2005-2006, the cost of snow removal, including materials and equipment management, amounted to $204.6 million, which constituted a 19% increase since the 2002-2003 fiscal year. Between 1998 and 2006, expenditures related to winter maintenance increased 68% for eastern Québec. This rise in expenditures represents a major budget risk for the organization.

The Ministère des Transports du Québec thus established a pilot project based on an approach allowing the establishment of a win-win relationship with its contractors by reducing: 1) the contractual risk transferred to them; 2) the financial risk incurred by the MTQ; and 3) the MTQ's vulnerability to the lack of competitiveness in certain regions.

The proposed solution is based on the number of operations or the spreading rate of melting agents, and on snowfall. Moreover, a new contract clause offers the contractors the possibility of resorting to subcontracting of up to 50% of the amount of the contract.

This clause makes it possible to open the market to small contractors and increase competition when contracts are awarded.

The number of hours is estimated by averaging the number of hours of annual operation for the past three years. To ensure adequate tracking of the number of hours (of winter maintenance operations) performed during the contract period, the MTQ required the installation of a global positioning system (GPS) in each vehicle. The number of hours of operation during a season is therefore calculated from the data collected by this tool.

The contract amount is adjusted upward or downward by the MTQ if the quantity of snowfall during the winter season is less than 260 cm or greater than 300 cm. The amount of the adjustment is limited to 15% of the value of the contract and covers only the activities specific to snow removal, deicing, snow transport and route patrols.

The first two years of the pilot project showed: 1) the resurgence of interest by the contractors in the snow removal and deicing contracts offered by the MTQ; 2) the increased attendance at information sessions; 3) the arrival of new contractors who submitted offers of services, which may allow reduction of the risks related to the lack of competition in certain regions.

The risk sharing clauses combining the adjustment based on the quantity of melting agents and the adjustment based on the number of hours of operation seem particularly effective in limiting the growth of expenditures associated with the contracts, and even reducing them, which can limit the financial risk for the MTQ.

Under this pilot project, the costs associated with this technological deployment were paid for by Ministère des Transports du Québec. These costs may be greater or smaller according to the type of equipment present on the contractors' vehicles.

7.4 Social perception of risks

7.4.1 Quebecers' perception of road safety

In Québec, an average of 48,000 victims are killed or injured each year in road accidents; 80% of these accidents are related to user behaviour and not to fate. The MTQ mainly studies the visual impact of route routes, road work sites, signage, pavement marking and the environment of road corridors. However, various efforts are made in conjunction with Société de l'assurance automobile du Québec and the Sûreté du Québec to promote road safety through costly public awareness campaigns.

Surveys were conducted in 2007 to: 1) target the right audiences and the right messages during campaigns; 2) prioritize subjects that concern the public and those with an erroneous social perception; 3) measure the changes in perception and behaviour, after a risk communication campaign.

The results show that 53% of Quebecers say they feel safe on Québec roads, mainly people who use them extensively. The majority of Quebecers, 95%, underestimate the number of road accident victims. Almost all people perceive that most accidents could be avoided. More than half the people perceive that other drivers are the source of the problem; all, or almost all, of the population perceive themselves as careful. Seniors are the most fearful of road accidents. The role of the police in road safety is generally well perceived by the public. Two thirds of young people feel safe on the road; however, more than other age groups, they fear being intercepted by the police.

The main problem perceived, after drunk driving and speeding, is the distraction caused by cell phones and other objects not related to driving. In 2008, cell phones were banned while driving on Québec roads. The blood alcohol level must not exceed 0.8%. Driving courses were made compulsory again in 2010. Since 2009, photo radar has been installed at strategic points to reduce speeding by road users.

The social perceptions are very subjective and vary according to the users' experience and age. It is very important to measure them in order to develop awareness programs and determine the risk mitigation measures.

7.5 Development and application of risk management methods

7.5.1 Risk management of landslides on clayey soils in Québec

Over 85% of the population is settled on clayey soils conducive to the development of landslides. Forty percent (40%) of the landslides studied were triggered by man-made activities; 60% were of natural origin. Every year, there are a few hundred surface and rotational landslides covering tens of metres. Rotational landslides sometimes represent the beginning of a highly retrogressive movement that, in a few minutes, results in gigantic scars called "clay flows", which can grow to several hundred metres. They can occur in the most densely populated regions and thus cause losses of life and considerable damage to property and infrastructures.

The Gouvernement du Québec has established a landslide risk management system based on 4 aspects: 1) a new 1:5000 mapping program for the zones subject to landslides, accompanied by a normative framework defining intervention standards adapted to the stresses identified; 2) a risk management methodology applicable to the built and mapped zones; 3) technical support from the MTQ's Service de la géotechnique (Geotechnical Service) and financial support from the government, particularly in emergencies or for prevention work; 4) training and awareness sessions aimed at better integration of all these efforts in the community. The experience of the past 30 years in Québec shows that each of these aspects is essential to effective landslide risk management.

7.5.2 The strategic sites of an autoroute network, a civil protection planning and operations tool

The MTQ Emergency Preparedness and Civil Protection Plan defines 20 natural or man-made risks. The transportation infrastructures, particularly those in the road sector, would be affected in case these risks were realized. Some infrastructures are said to be "sensitive", because they can be affected by several types of risks. Others are qualified as "strategic", because their unavailability results in major socioeconomic impacts for Québec.

The MTQ has adopted a method to identify the strategic infrastructures and provide them with a specific response plan, which will be deployed in the event of the infrastructure's unavailability. This methodology has been applied to the autoroute network of the Montréal region. It is inspired by the methodology used by insurance companies to calculate the premiums payable by the client, equivalent to the product of the costs associated with the repair of damage multiplied by the probability of occurrence of the damage.

The principles of the method are based on the calculation of a score for each potentially critical site. The score awarded to each site is a qualitative assessment of the probability that the projected risks will occur, the alert level affecting the duration of the response (road closing) and the impact on the MTQ's socioeconomic mission. The assessment of the probability of occurrence of a risk was obtained by a survey of the stakeholders, based on their personal perception of the danger.

Four alert levels, according to the ability to respond and restore, were considered: less than 4 hours, 4 to 24 hours, 24 to 72 hours and over 3 days. The impact on the MTQ's socioeconomic mission is calculated according to 6 criteria: 1) AADT (annual average daily traffic); 2) trucking network density; 3) nature of the bypass alternative, 4) daily average congestion period; 5) seismic vulnerability; 6) complexity and geometry of the infrastructures (bridges, overpasses, tunnels and interchanges).

7.5.3 Risk management applied to structures

The Ministère des Transports du Québec manages over 10 000 structures. Technical vulnerability to risks first depends on a number of factors, such as the type of structure, the maintenance performed, and daily car and heavy vehicle traffic. However, it also depends on the type of risks to which the structures are exposed, including the constant increase in heavy traffic, overloaded truck traffic, spills of transported hazardous materials, high-water levels, erosion and scour, landslides and earthquakes.

Regardless of whether an incident results from a technical failure or whether it is caused by a natural or man-made event, the consequences are just as important. The deterioration or loss of a structure can cause loss of life or trigger a major economic impact. Moreover, the interdependencies of life support systems (water, electricity, gas/fuel, communications) and transportation infrastructures are often underestimated, while the domino effects resulting from the failure or dysfunction of any of these systems can acquire surprising and even catastrophic scope.

The MTQ has developed a rigorous methodology to determine the socioeconomic index (SEI) of structures and their level of vulnerability to various risks with high destructive potential. The purpose of this initiative is to target and prioritize the establishment of measures to reduce a structure's vulnerability, in order to prevent its unavailability.

The initiative developed is the result of the adaptation of two recognized approaches in this matter, *Standard AS/NZ 4360* on risk management, developed by Australia and New Zealand, and *A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection,* produced in 2002 by the American Association of State Highway and Transportation Officials (AASHTO) to assess the risks related to terrorist acts. *Standard AS/NZ 4360* was used to determine the risk with high destructive potential, while the AASHTO method was used to assess the SEI and the level of vulnerability of the structures.

The SEI refers to the assessment of the structure as a good and service in society. It corresponds to a value that is neither positive nor negative. This is a funding that does not depend on the risks. Thus, an SEI is determined for each structure, according to a weighting grid developed by the group of experts. It is based on the experience and inventory data accumulated in the Québec structure management system. Consideration of the SEI is integrated into the stage of prioritization of the structures, the fifth stage of the risk management process related to the structures under the responsibility of the Ministère des Transports du Québec.

7.5.4 Natural and man-made risk management in Québec

Transportation infrastructures are essential to the population. They are affected regularly by various emergencies. Over the past few decades, an increase has been observed in the types of risks, as well as a growing frequency and intensity of emergency incidents.

The Ministère des Transports du Québec has developed a methodology allowing better knowledge and better management of the risks that can generate impacts on road infrastructures. Following the application of the method to the 15 territories under the MTQ's responsibility, 7 natural risks and 13 man-made risks were counted for all regions (Table 2).

Table 2 – Natural and man-made risks for all regions

Natural risks	Man-made risks
▪ Difficult climate conditions (snowstorm, violent winds, freezing rain) ▪ Rock fall or avalanche ▪ Erosion or landslide ▪ Earthquake ▪ Ice jam or breakup ▪ Water accumulation or flood ▪ Forest fire	• Dam failure • Falling high-voltage lines • Failure of natural gas supply equipment • Interruption of marine traffic • Nuclear accident • Airport accident or incident • Fire or explosion • Railway accident • Road accident • Blocking of a road • Presence of a suspicious object • Hazardous materials spill • Subsidence

The application of a common methodology to all of the 14 territorial divisions and to Nord-du-Québec will have allowed harmonization of the MTQ's risk management approach. The results obtained and the findings resulting from the application of the method will have allowed the territorial divisions to position themselves regarding the risks to be given priority in their territory and to consider these risks in the network's everyday management. Following this exercise, the territorial divisions adopted action plans to reduce or eliminate the vulnerability of their infrastructures to a given risk.

8. EMERGING RISKS AND NEW CHALLENGES

As described above, the current risks are fairly well known, while the emerging risks are more difficult to circumscribe in the absence of real knowledge of the future impacts: however, certain sources of these risks are known.

- The risks related to climate change, which may result in major impacts on transportation network infrastructures, due to:
  - ✓ erosion riparian and coastal zones of the St. Lawrence River where the main road network runs and part of the railway system;
  - ✓ lowering of the average water levels of the St. Lawrence River upstream from Ville de Québec, which may affect Seaway traffic;
  - ✓ permafrost melting in Québec northern and mid-northern regions, affecting access roads and landing strips;
  - ✓ accentuation of extreme climate events (i.e. warming, high tides and increased torrential rains, resulting in increased episodes of freezing rain, erosion, flooding and landslides).
- CBRN-EX terrorist risks (chemical / biological / radiological / nuclear / explosive) related to the structural vulnerabilities of the road transportation infrastructures;
- The environmental risks related to transport of dangerous materials (road, rail and marine).
- The risks related to the interdependencies and resiliencies of the essential infrastructure networks and the transportation networks (road in particular).
- The risks related to the interdependencies and resiliencies of the essential transportation networks (road, air, marine and rail).

The Ministère des Transports du Québec is particularly concerned about two of these emerging issues: 1) the risks and vulnerabilities related to the effects of climate change; 2) the risks and vulnerabilities related to the interdependencies of essential infrastructures and transportation infrastructures.

The first issue is already better known than the second, and actions are already foreseeable. Adaptation strategies giving priority to the essential infrastructures are indispensable if one wishes to limit the scope of the apprehended impacts, particularly in the Québec Arctic and coastal zones.

The second issue, which has recently become part of the MTQ's concerns, is more complex; it concerns essential infrastructure <u>systems</u>, including their resilience and the domino effects after a dysfunction of any of them.

In 2008, with the aim of reducing these risks and increasing the resilience of the essential systems, the Organisation de la sécurité civile du Québec took an initiative based on an operational methodology of assessment of the interdependencies and resiliencies of essential infrastructure systems. In particular, it seeks to maintain or restore the operation of essential systems to an acceptable level of operation, despite the failures that may occur in one or more infrastructure systems.

The MTQ has already agreed to support the Ministère de la Sécurité publique for identification of the vulnerabilities related to the interdependencies and resilience factors. Nonetheless, this identification remains difficult to accomplish, despite the presence of increasingly sophisticated and high-performance modelling tools.

9. CONCLUSION

Québec covers a large territory that requires major transportation infrastructures. The problems vary from one region to another. Québec counts on a small population to defray the costs of these infrastructures and on more and more limited resources, which will oblige actions to be oriented to priorities. The pressure is accentuating on the managers of public funds, who are increasingly relying on the application of rigorous methodologies to make and justify their decisions.

In a context of limited resources, the “acceptability of risks” concept acquires its full meaning. This concept, introduced by the Civil Protection Act in 2001, nonetheless will have to harmonize with the new sustainable development principles introduced in 2006, which govern the departmental planning activities for integrated risk management. These are:

1) the prevention principle: in the presence of a known risk, prevention, mitigating and corrective actions must be put in place, with priority to the source;
2) the precautionary principle: when there is a risk of serious and irreversible damage, the absence of complete scientific certainty must not serve as a pretext to postpone the adoption of effective measures aimed at preventing environmental degradation.

The integration and harmonization of the concepts and principles is a challenge in itself for the Ministère des Transports du Québec, which will call on multidisciplinary teams of experts to pursue the research, studies and development of integrated risk management methodologies, based on reliable, verifiable and well-documented data and criteria.

References

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