AN ORIGINAL APPROACH FOR CHOOSING AND DEVELOPING DECISION-MAKING SUPPORT TOOLS FOR WINTER MAINTENANCE

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1. Summary

Three years ago, the ministère des Transports du Québec decided to set up a network of road weather information systems throughout its provincial road network of 30,000 km. The associated problems were many: choice of technology, geographic realities, industrial support, implication of snow removal entrepreneurs, accompanying efforts to provide. With the help of an expert from France, the Infrastructure Operations Support Division of the ministère des Transports developed an original approach.

Beginning with a real needs analysis of the operational decision-makers, this approach is directed at optimising the ensemble of decision-making support tools. Five activities have been put together and proposed to the operational personnel of two pilot districts. An instrument for measuring the improvements made was developed, which was based on the perception of the operational decision-makers' confidence.

Following the one-year pilot project, numerous lessons can be drawn from each of the five activities:

- **with regards to the organisation**: the pressure felt by the operational decision-makers is considerable and it is useless to hope for significant benefits if the major irritants are not dealt with;
- **with regards to training**: a road weather information approach drastically changes the pragmatic road culture of the operational decision-makers. Substantial training efforts are necessary and should extend to the operators of winter maintenance materials;
- **with regards to weather forecasting**: efforts to join together these two very different cultures (meteorology and winter maintenance) are truly beneficial. New concepts (climate zoning, representative point, weather types and reliability index) greatly improve the confidence that the operational decision-makers have in weather forecasting;
- **with regards to mobile road weather information systems**: the decision to develop measuring technologies that would be installed on patrol vehicles (air temperature, relative humidity and dew-point temperature, road surface temperature and a search for measuring adherence and residual salinity) was shown to be excellent. This decision enables appropriation of new concepts and new reading of the road by the patrols;
- **with regards to stationary road weather information systems:** no decision to use stationary systems in the pilot district has yet been made. The operational personnel do not feel ready to integrate these technologies in their decision-making process. Their spatial limits curb their desire to use them.

The project will continue in 2001/2002 and we estimate that it could constitute an interesting methodological approach for those countries with only networks of stationary road weather information systems.

2. Introduction

Wanting to implement a road weather information system network throughout the vast territory that is affected by very difficult winter conditions such as Quebec is almost an impossible task. Beyond the technological, financial and human challenges, there is a kind of "logical" challenge. All countries that have accomplished this type of implementation have asked themselves the standard questions: which sensors to install, where to put them, how many systems to set up for a good coverage of risks, which communication network to use, how to optimise information processing from the systems?

Quebec has confronted a more fundamental question: can a network of road weather information systems meet all of the needs in an optimal manner? The ministère des Transports of Quebec has undertaken a methodological and scientific process for a more global approach to the problem of gauging decision-making support for winter maintenance. In this approach, the ministère was assisted by a French expert who was provided by the French ministère de l'Équipement, des Transports et du Logement.

The often-delicate winter conditions and the volume of traffic have lead France to develop a great expertise in winter road weather conditions. It is the only country to have a complete standardised procedure for road weather information systems. It has a solid foundation in winter road weather conditions training.

Quebec on the other hand has acquired an organisational integrity that measures up to the harshness of its winters. Today it is an ideal terrain open to the decision-making support technologies even though the technical and industrial support structures are still not very developed.

The innovative approach that we are about to present to you is a result of this complimentarity.

This approach may interest other countries that have not yet taken the big leap to a widespread road weather information systems network.

3. The extent of the problem for Quebec

Quebec is an immense region, which is three times the size of France, and is home to a population that is ten times smaller. 66 percent of all goods transported use the roads system. The following few numbers show the importance of winter for Quebec's roads.

- the provincial government is responsible for 31,000 km of roads, 20,900 km of which are maintained by entrepreneurs, 4,100 km by municipalities and 6,000 km by local government;
- a global budget for winter maintenance of C$175 million for the Ministère, a budget that is continually increasing;
- extremely hard climatological conditions
  Example of a region on the 47th parallel at sea level:
  frost: from the end of September to June;
  snowfall: from October to April;
  accumulations of snow: from 2.50 to 3.50 meters;
  number of days with snowfall: from 80 to 100
  number of days with ice formation on untreated pavement: around 30;
- the official winter season lasts 18 weeks on the 45th parallel, 28 weeks on the 50th parallel and 30 weeks in the middle mountainous regions (altitude of 500 to 800 m);
- on average 700,000 tons of salt are applied on the roads maintained by the Ministère (22 tons per kilometre);
- a total of 1,350,000 tons of salt are applied over 120,000 km of roads throughout Quebec's road network.

4. Needs analysis

In 1998, Quebec had ten road weather information systems. Three different technologies (French in Montréal, German in Hull and one locally developed around Quebec City) were implemented. A quick survey shows that the actual level of usage of these systems is pretty low. A lack of confidence, insufficient training and certain dysfunction explain this low utilisation.

Before embarking on massive installations of road weather information systems throughout Quebec's territory, the Ministère completed an analysis of needs of the potential users of these future stations, so as to develop specifications for an eventual call for tender. We have met with sixty people in six districts, as well as with ten snow removal entrepreneurs. All types of decisions passed through a review, from monitoring the situations to interventions, road management and snow removal contract follow-up.

Here is a summary of the main expectations of the people consulted:

a - Have good weather forecasting;
b - Have a global vision of the network to supervise;
c - Better knowledge of the parameters that allow the anticipation of black ice risks and the behaviour of snow on the road;
d - Measure the pavement's adherence in real time.

The operational personnel of the districts also expect significant support from the central technical services (training, normalisation, and technological intelligence).

The analysis of needs has also made it possible to distinguish 3 decision levels:

1) The decision to **ensure the tracking of frequent weather forecasts**, based on a regular weather forecasting bulletin and a road risk analysis, which involves close exchanges between the meteorologists and road operations personnel.
2) Based on frequent weather forecasts, the decision for **road surveillance**, provides the means for the definition of time, place, special observations to complete, follow-up of systems... consider placing intervention vehicles on standby directly on their routes.
3) The decision to **intervene,** based on the road surveillance and tracking of frequent weather forecasts, defines the mode (eventually preventive or curative), time and type of intervention, nature and dosage of materials to apply, etc… .

The needs analysis has revealed the principal qualities of information in decision-making. The information must be **pertinent** (scientific quality with regards to the problem at hand), **reliable** (metrological and technological quality) and **admissible** ("psychological" quality, people's capacity to integrate it in the mental scheme of decision-making). These qualities should be considered for each of the 3 decision levels.

5. Toward a real decision-making support system for winter maintenance

After this in-depth analysis of needs, it has become clear that the use of a road weather information system network was not the answer (at least not the only one). The necessity for a more global approach, more focused on the socio-psychological realities than on the technological aspects, has lead to considering the implementation of a real "decision-making support system for winter maintenance". This system is in fact a coherent ensemble of decision-making support tools that assist man in his winter maintenance decision-making. This ensemble includes the related accompaniment measures that follow in the same direction.

A **guiding principle** became clear to us: the decision-maker must remain in the centre of the process because the decision is a responsible act that must remain man's attribute and because the act of making a decision is the complex result of a number of "intelligence" types (intelligence from the territory managed, intelligence regarding present or future weather conditions, intelligence concerning the effects

of weather conditions on the network and on the traffic, intelligence concerning the effects of traffic on the road phenomena, intelligence on the efficiency and the limits of its means, intelligence on the users' needs).

We were then confronted with a major problem: how to reconcile an approach focused on man with a technological type approach while working on the means to really measure the progress brought about by these improvements?

6. Implementing a pilot project

In the fall of 2000, the Ministère started up a pilot project that would be spread over two years. The goal of this project was to define the decision-making support system for winter road maintenance in Quebec and to fix the necessary accompanying measures. The project takes place in two pilot districts (Quebec has a total of 14 districts). It is based on the initial postulate inspired by the theories of Vilfredo Pareto:

Postulate no.: the greatest benefits are obtained by the least expensive activities.

Based on this postulate, five project activities were planned:

1 - Organisation: To decide is to take advantage, in space and time, of a certain amount of information. This information exists most of the time and its availability to the decision-makers is very often only a problem of data exchange, and therefore, a problem in the organisation of information between the various players. Beyond that, the administrative, legal and political contexts that play a fundamental role in decision-making had to be questioned. For example, how to manage the "right to be wrong", which encourages responsible adults to optimise their decisions? For us, these questions represent a prerequisite to all tentatives in technological improvements.

2 - Training: up to then the intelligence used in decision-making was mostly the fruit of many years of experience in the field. The contribution of structured knowledge in the new road weather information system should permit the appropriation of new information (weather and road parameters) and facilitate the links to establish in order to optimise decision-making.

3 – Weather forecasts: meteorological conditions to come make up the principal element in decision-making. The needs analysis had clearly underlined the low confidence of the operations personnel in the Environment Canada forecasts. This confidence had to be recreated, weather reports had to be optimised, and connections between the interested parties had to be strengthened.

4 – Patrol vehicles equipped with mobile road weather information systems: are the best means of finding out what is happening on the roads, as well as providing a means for doing the rounds. The patroller's senses and those of his vehicle, make up the most sophisticated and the most pertinent sensor of information that there is. During the analysis of needs, this expectation of an installed instrumentation on the patrol vehicles (air temperature, dew-point temperature, temperature of the pavement surface and also its adherence) was clearly expressed.

5 – Stationary road weather information systems: real "electronic sentinels", they are the most sophisticated tool with regards to decision-making support. Just how far should we go in terms of sophistication and how many to use? How to make the decision-makers have confidence in their data and use it fully? We wanted to give greater importance to an approach where **the decision-makers themselves define the nature, the number and the location of these systems.** All of the preceding activities of the project are necessary to this outcome. In particular, the equipped patrol vehicles allow the decision-makers to complete a direct and intelligent "thermal profile" in the complete set of winter conditions.

The rate of advancement in the five activities is different for each of the two pilot districts. In the first, activities 1, 2, 3 and 4 are completed in the first year, activity 5 takes place in the second year. The second district is limited to activities 1, 2 and 3 in the first year. The reason for this time lag is to measure the progress at the end of a winter season without technological contribution, simply by optimising the already existing means (organisation, personnel training, and weather forecasts).

Every year, we evaluate the benefits that result from the activities. The Support for Infrastructure Operations Divisions and the Improvement of Organisational Performance Division of the Ministère have adapted a tool for measuring the improvements by the context in which the decision is made, and not by the decision itself. Based on a written questionnaire, it evaluates the perception of "clarity to decide" of the decision-making personnel.

The means of accompaniment are defined by the participants as the project advances in the pilot districts. The Support for Infrastructure Operations Division participated in the implementation of the **response to project participants requests**. It is more a question of **accompanying the project rather than imposing technologies**.

The pilot project will end in the spring of 2002. We will then know the improvement/cost ratio of the different activities, and we will thus be able to determine which is the optimal system for Quebec. We will also be able to determine the conditions to meet in order to ensure its implementation and also, which user accompaniment will be necessary.

7. Principal results of the pilot project after one year

Year 1 of the project has permitted the completion of the following:

- Reflection on the irritations of decision-making.
- Setting up training modules for operational decision-makers and material operators.
- Improvement of the content of weather forecasting and the exchange process with Environment Canada.
- Completion of a mobile road weather information system prototype and assembly of a pilot production run on 13 vehicles from the first pilot district.
- Analyse the configuration of future stationary road weather information systems.

It also permitted the termination of two additional postulates to the initial postulate:

Postulate no. 2: the decision involves a full knowledge of local weather and road conditions. In reaction to these, the decision should be taken near the theatre of operations.

Postulate no. 3: the success of any technology depends on the operational decision-makers and the confidence they demonstrate in it.

While awaiting the end of the pilot project, the first conclusions can already be made in each of the five activities:

With regards to organisation

It appears absolutely essential **to decrease the pressure** that the operational decision-makers are subjected to. Proposed solutions for the irritants in decision-making (police, media, politics, and hierarchy) have been made. The Support for Infrastructure Operations Division obtained an agreement to perform an analysis of a new winter maintenance approach in Quebec using a shared responsibility model. This analysis will undoubtedly lead to an operational plan of action at the end of the year 2001.

With regards to training

Performed on a large scale, the first training in road weather information systems has shown the importance of the efforts involved. The target "operators" was not planned at the start but accepted because the operator is often the "last decision-maker" in the field. There is still a great deal of work left to translate the new road weather data in the decision-making process. *In fini*, Quebec needs a heavy mechanism to meet all the training needs, and in particular, training the great number of entrepreneurs. A review is under way to evaluate this mechanism.

With regards to weather forecasting

Work accomplished the first year in one of the two districts has greatly improved the operational personnel's confidence in weather forecasting. The content of these forecasts has been improved by integrating the dew-point temperature and cloud coverage. New concepts (division into climatic zones, weather reports by zone and zone representative points; weather type; reliability index) have permitted to better outline the limits of weather forecasts and to re-establish the confidence between the road personnel and the forecasters.

With regards to mobile road weather information systems

This decision-making support tool corresponds well to the current appropriation capacities of operational personnel. It first allows to give a concrete expression to the concepts presented in training (why does humidity vary all along the route, how do weather conditions influence the gap between the road surface temperature and air temperature?). This data is collected at the same time that the road is perceived, giving a continuous picture which can be taken anywhere. For now, the patrollers make do with data on the dashboard instrument panel of the vehicle. They have not asked for the telemetry or the GPS positioning.

With regards to stationary road weather information systems

No systems have yet been set up in the pilot districts. An in-depth analysis of needs and market possibilities is presently leading toward two very different types of systems:

- **basic systems on representative points** (1 system by climatic zone) where automatic weather information systems do not exist. These systems meet one meteorological preoccupation above all else. The equipment of these basic systems would be limited in terms of "pavement" parameters to permit measuring and short-term forecasting of the roadway surface temperature. These systems would be integrated in the automatic weather information system network used in weather forecasting.
- **"custom made" systems at certain singular points of the roads network**. A methodological approach of singular points that allows to define the instrumentation at these sites.

8. General conclusion

Redefining the process in a socio-psychological approach to the detriment of an approach that was too technology-oriented has put the emphasis on the many-facetted reality of the operational decision-maker in winter maintenance.

Project leaders have been confronted with a double challenge to resolve the general questions raised and to satisfy the technological expectations of the operational personnel. Fortunately, these expectations are very reasonable, undoubtedly in keeping with the confidence that we can actually have in this type of instrumentation!

The general opinion is that the quality of a decision-making support system is conditioned by the **reliability** of the information it supplies. Current efforts around the world focus more and more on this criteria of reliability.

The expertise of the operational decision-makers is the outcome of many years of pragmatic experience. Training efforts accomplished have made it possible to convince them of the **pertinence** of the new road weather information system approach and especially the importance of basic measurements (Ta, Td, Ts). They have also demonstrated the complexity of decision-making and the necessity of making these decisions as close to the route as possible.

Beyond data reliability and convincing the decision-makers to use it, the problem lies in their capacity to integrate the ensemble of information that they receive into the decision-making scheme. The Quebec pilot project is built to measure the actual **ability to receive** information available today and thus conceive and calculate the dimensions of a decision-making support system perfectly suitable for its users.

The pilot project will certainly approach the possibility of using a "custom made" decision-making support system adapted to the realities of each district. Training has proven to be a key factor in the mechanism to be set up and the ministère des Transports intends to devote to it all the means necessary.

In a more general manner, accompaniment during the implementation stages will play a major role. This is why the Ministère is currently setting up a network of leaders-trainers in each of the districts.

Whatever the technological outcome of this project, the challenge of setting up the best decision-making support system for Quebec is as arduous as its winters! And all the players of this project have its success at heart. This approach, the fruit of a close cooperation between France and Quebec, challenges the current fashion of large networks of road weather information systems. It is sufficiently global to inspire other countries that have not yet succumbed to this fashion.

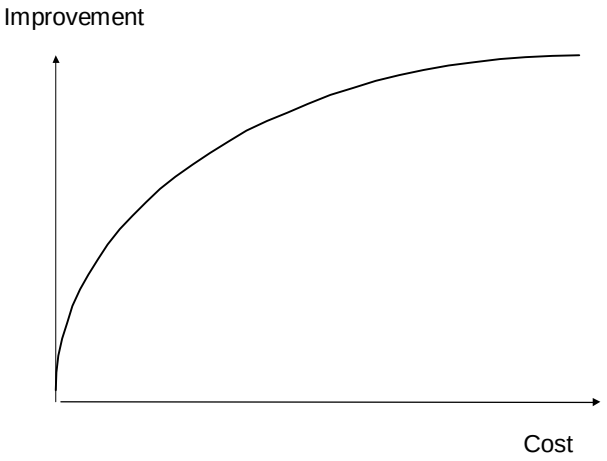

Diagram 1

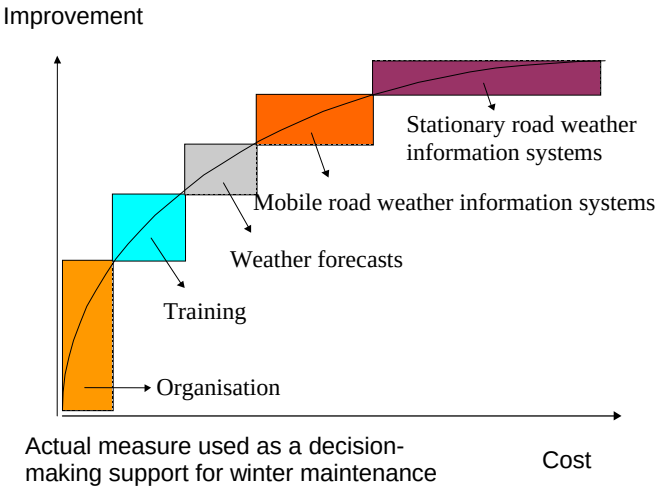

Diagram 2

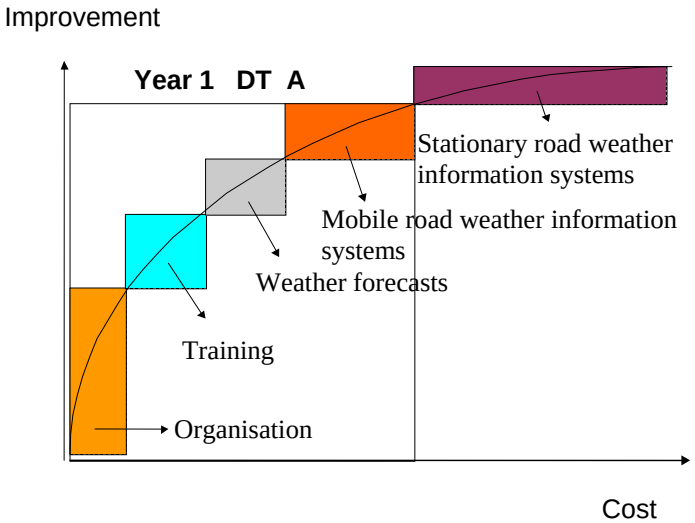

Diagram 3

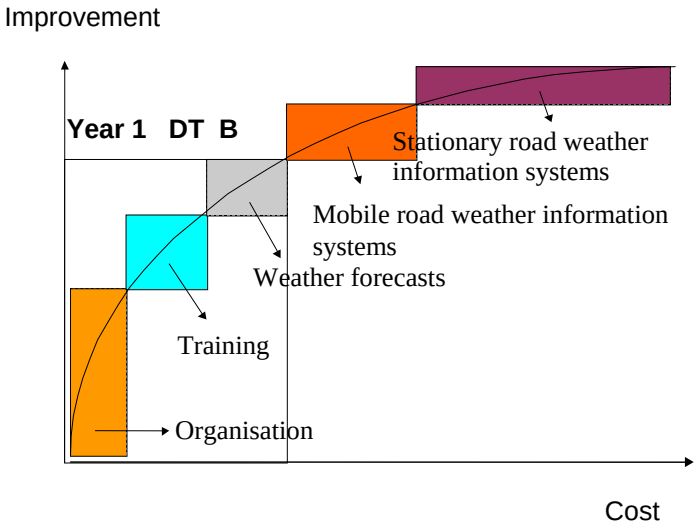

Diagram 4