



Evaluation and Choice Criteria for Automatic Thawing Agent Spraying Systems

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Abstract

For about 25 years already, automatic thawing agent spraying systems have been a helpful contribution to the task of winter maintenance. These systems allow a quick intervention as soon as a risk of icing of the roadway appears by spraying a liquid thawing agent. The main goal of this paper is to supply an evaluation method that can justify the implementation of an automatic thawing agent spraying system, considering all important aspects.

The evaluation is carried out in two steps. First, an **opportunity examination** allows verifying whether a detailed project for a spraying system is justified. Several opportunity criteria are analysed and judged in a qualitative approach, using statistical or project data, for existing or planned roads respectively. These opportunity criteria are treating road safety, operations, road function and situation, as well as the climate.

If the detailed project is judged necessary, the **choice of equipment alternatives** helps finding the ideal configuration for the examined road stretch using a multi-objective analysis. The choice criteria are graded by the projector and weighed by a group of involved specialists, in order to determine the most adapted equipment alternative. The choice criteria are divided into four categories: economy, environment, traffic and operations.

Keywords

winter maintenance – road safety – evaluation method – multi-objective analysis – TMS – 5th Swiss Transport Research Conference – STRC 2005 – Monte Verità

1. Introduction

Automatic thawing agent spraying systems are used in order to assist the winter maintenance task and to keep certain parts of the road network at a satisfactory safety level, even if the meteorological conditions allow road icing or predict snowfall. The laboratory of traffic facilities (LAVOC) at the Swiss Federal Institute of Technology Lausanne (EPFL) has been mandated by the Swiss Federal Road Authorities (FEDRO) to carry out a research in order to recommend a method that allows evaluating whether or not the construction of an automatic thawing agent spraying system is justified.

Each project can thus be quantified and be considered according to the winter maintenance goals and the principles of sustainable development [1]. The recommended evaluation method consists of two steps, the opportunity examination and the choice of alternatives, and has been tested on several existing installations and some projects planned by different road authorities.

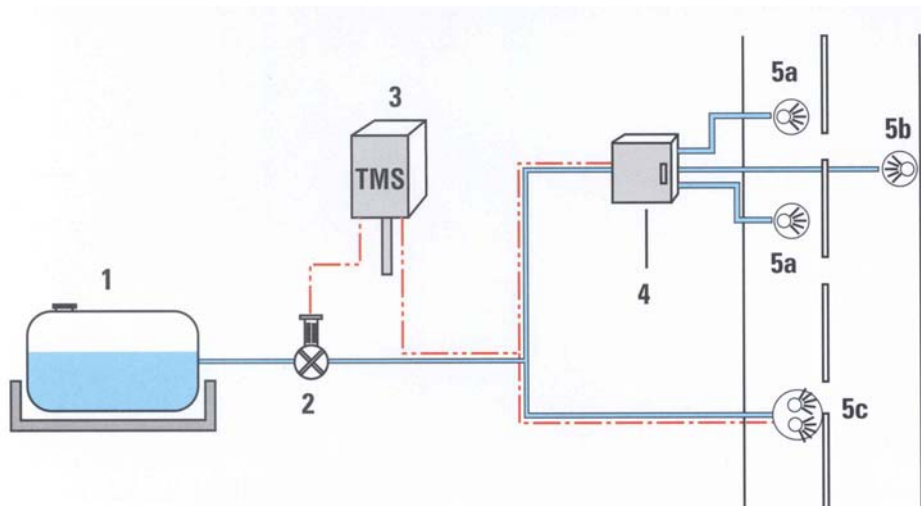
A questionnaire has been released among the members of the relevant committee (C17) of the World Road Association (PIARC), which has shown that the different authorities and road operators use different criteria and that the applied evaluation methods are usually a single-criterion optimisation. The inventory of several existing installations and the most often-used evaluation methods shows that the choices are made in a rather emotional and subjective manner.

In Switzerland the so far realised justifications are quite different from each other and vary from a simple description of a specific difficult situation on a certain road stretch and a detailed profitability calculation of the future installation using a cost/benefit ratio. The most often adopted criteria are economical ones and describe the annual cost and benefits. There is no standardised procedure for the profitability evaluation of these automatic systems, but the lively interest encountered by the researchers during their work shows the necessity of such a standard evaluation method.

2. Advantages of an automatic thawing agent spraying system

Automatic thawing agent spraying systems (Figure 1) are in service since the late seventies. Nevertheless, in Switzerland their use still remains quite limited to certain motorway stretches and bridges that face specific winter maintenance problems. Most often, particular climatic conditions and unsatisfactory long intervention times by classical maintenance means are the decisive arguments for the construction of an automatic system.

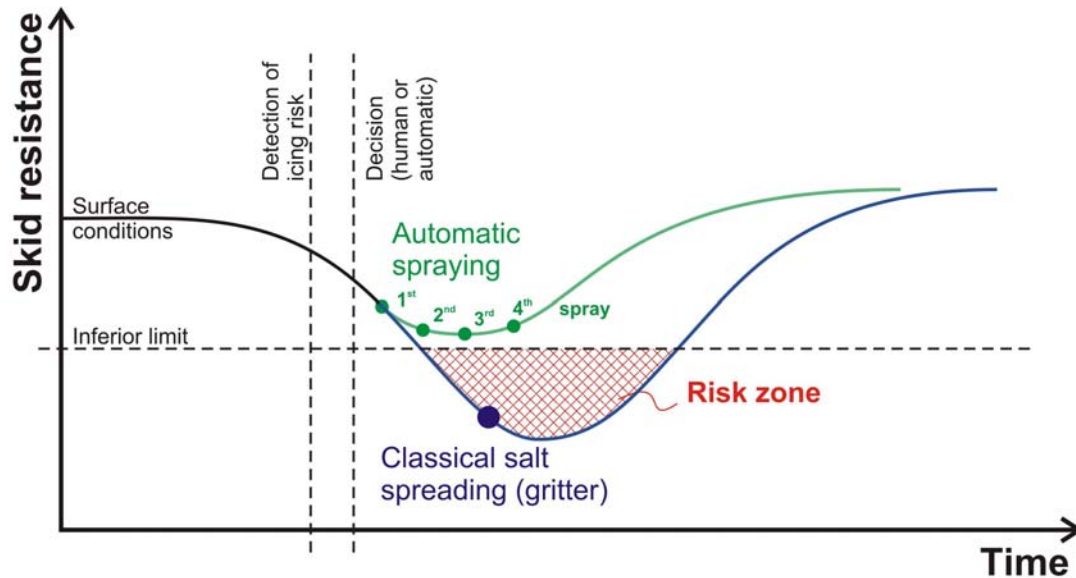
Figure 1 Functional representation and example of an automatic thawing agent spraying system: 1 = reservoir; 2 = pump; 3 = electronic command; 4 = valve chamber; 5 = spraying units



Source: Boschung Mecatronic SA

Also, constantly increasing traffic leads to more frequently congested areas, especially within and around cities and agglomerations. As soon as winter conditions appear, the congestion might immobilise the traditional winter maintenance vehicles or even block their access to the motorway. Even more important is the increase in road safety for the road users facing winter conditions. In fact, the automatic thawing agent spraying system allows an intervention at the appropriate moment, which is before the pavement's skid resistance drops below a dangerous level, which is not always possible with traditional winter maintenance means (Figure 2), and even though the Swiss standards [2] are fulfilled.

Figure 2 Comparison of intervention times of classical salt spreading and an automatic thawing agent spraying system



Other advantages of an automatic thawing agent spraying system include environment protection, as the system is known to reduce the amount of salt scattered, and more efficient operations management, because the personnel and the vehicles can be used in a more flexible manner. As the field of implementation of these automatic systems is growing and their cost are decreasing, it seems necessary to define criteria that justify their construction and to find an evaluation method which allows to choose the most adapted equipment alternative.

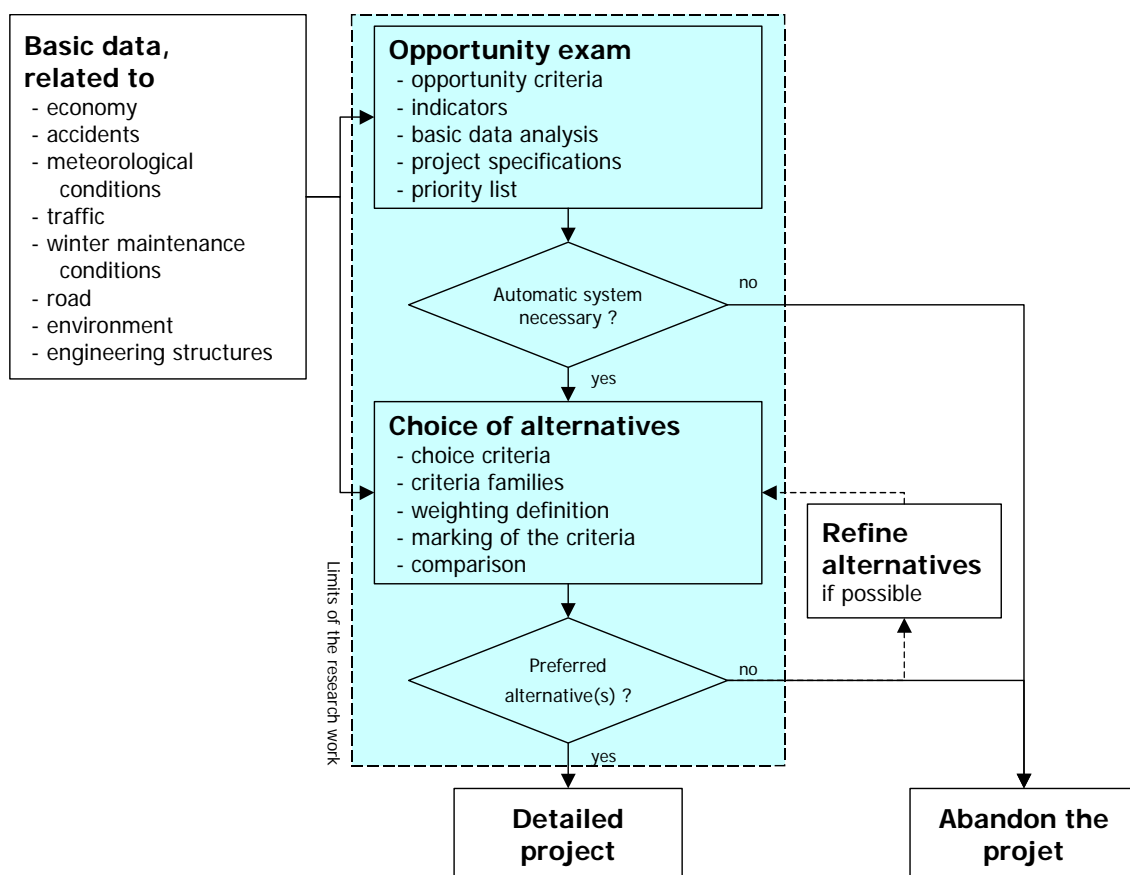
3. The evaluation method

3.1 Introduction

The adopted evaluation method has to define the conditions that justify the construction of an automatic thawing agent spraying system on a defined road stretch, considering all the important aspects like climate, topography, geometry, ecology, profitability and safety. This new approach has to be compatible with the goals of a project evaluation according to the principles of sustainable development.

The method has to serve the administrations and the project designers as a basis for the justification of an automatic thawing agent spraying system. Its application will also allow a certain comparability on a national level, which is particularly interesting for the federal road authorities who co-finances the automatic thawing agent spraying systems on the national motorways.

Figure 3 Adopted evaluation method



Based on the current state of the art, the research team has chosen a method that integrates all the important criteria and for which the parameters are easy to quantify or to estimate. This method is divided into two steps: The opportunity examination checks whether planning a certain project more in detail is justified or not. It is followed by the alternative choice in order to isolate the most adopted equipment alternative for the considered road stretch.

3.2 Step 1: opportunity examination

In general, an efficiency analysis of the future automatic thawing agent spraying system is carried out before its installation. Currently this evaluation is most often limited to a simple cost/benefit ratio. The assumptions made during that process are rarely checked and verified by a study after the system is installed. There are, however, some reports available on long-term observations [3-5].

The profitability of winter maintenance by classical spreading of a thawing agent was shown by a research work by Ruess [6], which compares actually the spreading of salt to spreading of gravel. It summarises the results of several foreign research reports and estimates furthermore that the safe passage of 140 vehicles is enough to reimburse traditional salt spreading on a roadway, if taking into account the reduction of social cost, user cost and road operation cost.

The opportunity examination consists of the confirmation whether a further elaboration of a certain project is justified or not. The main goal of this procedure is that the main actors discuss all the important aspects of the project and also to show them its consequences. The technical feasibility and the financial aspects are not yet taken into account during the opportunity examination, as these points are not considered to be decisive at this stage [7].

Table 1 shows the adopted opportunity criteria and their indicators. The same criteria are applied either on an existing road (E) or a planned and yet to be built one (N). In this last case no historic or statistic information is available and certain indicators cannot be evaluated. For every indicator the administration has to judge (based on available data) whether an automatic thawing agent spraying system is unnecessary, worth considering or essential.

The result of this opportunity examination, a summary based on a non-mathematical analysis will allow elaborating the system specification, defining the goals and the constraints of the future installation. Furthermore, the authorities can establish a project priority list if they have several potential road stretches to equip.

Table 1 Opportunity criteria

Opportunity criteria	Indicator	Application	
		N	E
Accidents in icy conditions	Frequency		X
	Severity		X
Local meteorological conditions	Winter roughness	X	X
	Specific conditions	X	X
	Condition changing speed	(X)	X
Difficulties in winter maintenance	Distance to the maintenance yard	(X)	X
	Disturbance by traffic		X
	Personnel and material		X
Road function	Hierarchical position in the network	X	X
	Traffic volume and structure	(X)	X
	Acceptable risk: frequency and duration of icing risk	X	X
Ecologically sensible zone	Hydrogeologic sensibility	X	X
	Pedological sensibility	X	X
Protection of engineering structures	Quantity of thawing agent		X
	Scattering of thawing agent		X
Road geometry	Curves	X	X
	Slopes	X	X
Road environment	Rate of engineering structures	X	X
	Pavement	X	X
New technologies	Political willingness to use new technologies	X	X

3.3 Step 2: choice of alternatives

Once the relevance of an automatic thawing agent spraying system has been shown by the opportunity examination, the second stage, the choice of alternatives using a multi-objective decision aid method, can be started. This choice will allow choosing the most adapted equipment configuration for a given road stretch. Generally, there are at least two alternatives to consider: The installation of an automatic thawing agent spraying system and the traditional winter maintenance using gritters. In some cases it is recommended to analyse the possibility to equip only certain segments of the studied road stretch, which are sort of intermediate alternatives compared to the two basic ones. Several solutions can thus be judged:

- Traditional winter maintenance (status quo for an existing road)
- Spraying system on bridges only
- Spraying system on the segments with high accident risk potential
- Spraying system on the entire road stretch
- Etc.

As there are quite a few criteria to be evaluated it is proposed do regroup them into four families (Table 2). The weighing is then prepared for the both levels. It is important to stress that the evaluation method is not applied at the two levels separately, but at one time using a double weighing for each criteria: the weight of each criterion is multiplied by the weight of its family. Preferably, the project team having analysed all the necessary data sets the grades for the criteria, whereas different experts of the affected fields (operation, maintenance, user interests, environment protection, etc.) do the weighing of the criteria and the families. This procedure has been applied by the LAVOC for a spraying system project on the motorway A12 between Châtel-St-Denis and Vevey [8].

Table 2 Choice criteria

Family	Choice criteria
Economy	Payment (annual cost) Operation cost Maintenance cost
Environment	Quantity of thaw agent Quantity of fuel (in case of congestion) Impact on engineering structures Impact on residents
Traffic	Accident severity Congestion due to winter maintenance Congestion due to accidents in winter conditions
Operations	Personnel management Intervention speed Information Adaptation faculty

It is important that the opinion of each specialist is taken into account separately, which is done by establishing the choice of alternative using all the weighing combinations suggested. This also serves as sensitivity analysis, as the results for each specialist vary with the different weighing. Nevertheless, the final rankings and grades allow the authority to take a decision having taken into account all the important aspects.

4. Examples for the use of the method

In order to test the feasibility and the realism of the suggested method the research team has applied the two-step analysis on some existing installations in Switzerland, particularly the motorway bridge in Flamatt and the belt motorway of Lausanne. In both cases the choice to construct an automatic thaw agent spraying system has been justified. The special conditions of the bridge as well as the meteorological and geographic conditions in Flamatt justify an automatic system. In Lausanne the new configuration of the belt motorway with three lanes, important slopes, the porous asphalt and the amount of traffic made the traditional winter maintenance difficult. Figure 4 shows an example of the opportunity examination on an existing road.

Figure 4 Example of the opportunity examination

<i>Opportunity criteria</i>	<i>Indicator</i>	Automatic system		
		unnecessary	worth considering	essential
Accidents in icy conditions	Frequency		X	
	Severity		X	
Local meteorological conditions	Winter roughness		X	
	Specific conditions			X
	Rapidité de modification des conditions		X	
Difficulties in winter maintenance	Distance to the maintenance yard	X		
	Disturbance by traffic			X
	Personnel and material		X	
Road function	Hierarchical position in the network			X
	Traffic volume and structure			X
	acceptable risk: frequency and duration of icing risk			X
Ecologically sensible zone	Hydrogeological sensibility		X	
	Pedological sensibility	X		
Protection of engineering structures	Quantity of thawing agent	X		
	Scattering of thawing agent	X		
Road geometry	Curves		X	
	Slopes			X
Road environment	Rate of engineering structures	X		
	Pavement	X		
New technologies	Political willingness to use new technologies		X	

The application of the method in the case of a project on an existing motorway section (A12 above Vevey) in all its extents [8] have confirmed that the evaluation is quite easy to carry out and can lead to a decision by the authorities. The following figure illustrates an example of the second step, the choice of equipment alternatives:

Figure 5 Example of the choice of equipment alternative

<i>Grading table of the alternatives</i>							
Family		Criteria		Alternative 1		Alternative 2	
	Weight		Weight	Grade	Weighed grade	Grade	Weighed grade
Economy	30	Payment (annual cost)	50	2.5	125	2	100
		Operation cost	35	0	0	0.5	17.5
		Maintenance cost	15	1.5	22.5	1	15
		Family value (Sum)		$V_{1,1} =$	147.5	$V_{1,2} =$	132.5
		Global family grade		$N_{1,1} =$	1.5	$N_{1,2} =$	1.3
Environment	10	Quantity of thawing agent	20	0.5	10	0.5	10
		Quantity of fuel (congestion)	50	0	0	0	0
		Impact on engineering structures	20	1.5	30	1	20
		Impact on residents	10	0	0	0	0
		Family value (Sum)		$V_{2,1} =$	40	$V_{2,2} =$	30
Global family grade		$N_{2,1} =$	0.4	$N_{2,2} =$	0.3		
Traffic	30	Accident severity	50	0.5	25	3	150
		Congestion due to winter maintenance	10	1	10	2	20
		Congestion due to accidents in winter conditions	30	1	30	3	90
		Family value (Sum)		$V_{3,1} =$	65	$V_{3,2} =$	260
		Global family grade		$N_{3,1} =$	0.7	$N_{3,2} =$	2.9
Operations	30	Personnel management	15	1	15	2	30
		Intervention speed	50	3	150	3	150
		Information	15	1.5	22.5	3	45
		Adaptation faculty	20	2	40	1	20
		Family value (Sum)		$V_{4,1} =$	227.5	$V_{4,2} =$	245
Global family grade		$N_{4,1} =$	2.3	$N_{4,2} =$	2.5		

<i>Ranking table of the alternatives</i>					
Family		Alternative 1		Alternative 2	
	Weight	Grade	Weighed grade	Grade	Weighed grade
Economy	30	1.5	44.3	1.3	39.8
Environment	10	0.4	4.0	0.3	3.0
Traffic	30	0.7	21.7	2.9	86.7
Operations	30	2.3	68.3	2.5	73.5
Alternative's global value			138.2		202.9
Ranking		2		1	

5. Conclusions

Automatic thaw agent spraying systems are an efficient tool for the task of winter maintenance. The possibility of intervening almost instantly whenever an icing risk appears raises considerably the winter service level and road safety. Nevertheless, the still quite high installation and operation cost of these systems call for a preceding evaluation by the authorities in order to justify the investment.

Once the two steps of the suggested evaluation method carried out, the decision to set up an automatic thawing agent spraying system can be taken being reassured that all important and necessary aspects have been analysed. The examples treated during the research project show that the decisions taken until today were justified and the systems well adapted to their specific situation.

The suggested evaluation method is supposed to be independent from technical development and the cost evolution. The automatic thawing agent spraying systems evolve and their installation is getting more accessible: the construction is getting easier and the maintenance and operation cost decrease. The adopted method remains valid despite this development, as the most important criteria for the justification and the equipment choice don't change.

6. Literature

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