EFFICIENT WINTER ROADWAYS FOR A RESTRICTED BUDGETARY CONTEXT.

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ABSTRACT

The current general situation of economic crisis in Spain has provoked that the investments in the sector of preservation and operation of roads had been reduced to a great extent. The current needs make the levels of quality and services as well as the the safety, fluidity and comfort on roads to be very demanding, which entails efficient management and optimisation of the available resources. Among the road maintenace activities are those related to help road management, which is the most important activity in terms of financial and material resources for winter roadway management.

In order to meet the budgetary adjustment goals it is necessary to work on and encourage resource efficiency and optimisation in the aspects addressed by the text hereunder.

1.- STAFF. TRAINING AND ORGANISATION:

1.1.- STAFF TRAINING:

The staff training should be focused on learning efficient driving so that it is possible to save fuel, extend machines and their components lifespan, and optimise the time used to move around, change shifts, refuelling, recharges, etc…

The technological evolution occurred over the last years has modified the design of vehicles to a great extent and it has allowed the introduction of relevant modifications in engines and different systems in order to increase performance and reduce fuel consumption and its emissions. ***These technological improvements require a new appropriate driving style from drivers to take advantage of them.***

Efficient driving has the following advantages:

- **Savings in fuel**. Drivers' behaviour has a great impact on the car's consumption of fuel, which can be translated into circa 10%.savings of fuel.
- **Lower maintenance costs**. The consumption reduction effect is linked to a lower fuel usage cost, but also to a lower vehicle's maintenance cost as the new patterns to follow make the vehicle's system (brakes, clutch, gearbox, tyres and engine…) to be subject to a lower effort than that of conventional driving.
- **Decrease of environmental pollution**. A decrease in fuel consumption through efficient driving is linked to a reduction of polluting emissions sent to the environment.

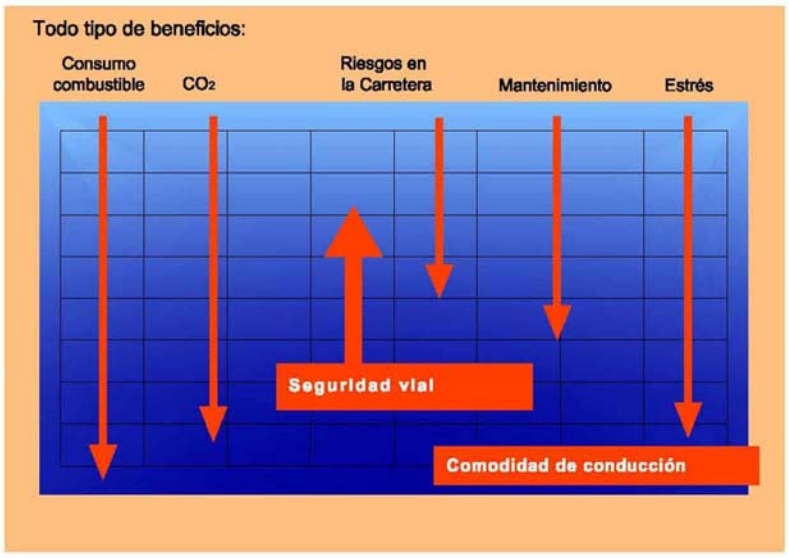


Fig. 1: Benefits of efficient driving

Winter road management is based on the use of very powerful trucks that are equipped with snowploughs. Therefore, in order to meet the before mentioned goals, ***driver operators must get ongoing training on efficient driving given by trainers specialised in this subject.***

A very important factor to consider is the **driver's attitude**. Efficient driving is based on a set of behavioural patterns that form a specific attitude when it comes to driving a truck. Efficient driving techniques are closely linked to this attitude facing driving, to the extent that without the application of these behaviour patterns the said techniques could not be executed in an appropriate accurate fashion.

Driving a snow plough truck entails a heavy **responsibility burden;** therefore, a convinced, decisive attitude is required, based on a series of guidelines to be considered:

- **Foreseeing** dangerous situations and **anticipating** the manoeuvres to execute in order to avoid being involved in compromised manoeuvres.
- Knowing the **available alternatives** in order to perform a manoeuvre, and being able to think about which is the most appropriate one.
- Avoiding **risky behaviours** which could create risk situations for the other users of the road.

Aggressive driving based on continuous accelerations and abrupt braking must be avoided. **Thanks to efficient driving more than 30% saving of fuel is achieved compared to more aggressive driving.**

Before entering the snow plough truck cab, the driver must perform a visual examination of some elements in the snow plough equipment to make sure they are in a correct state.

In general terms, a correct previous revision should include at least the following aspects:

- **Liquid levels**: engine and hydraulic element oil, cooling system waters, etc…
- **Brake System**: brake air pressure and drainage of condensation water.
-**Assistance to driving tools**: cleaning and placing rear-view mirrors, checking lights functioning and light signal devices.
-**Vehicle assembly**: holding system of the snow ploughs, grips, coupling, etc.
-**Tyres**: pressure, use, embedded objects and holding.

1.2.- ORGANISATION. ROUTES:

On the other hand, the routes of snow plough machines can be optimised in winter road management operations, especially thanks to preventive treatments, in order to avoid unnecessary movements that in addition to implying an economic added cost would entail time losses, which are extremely important when it comes to winter road management under extreme conditions.

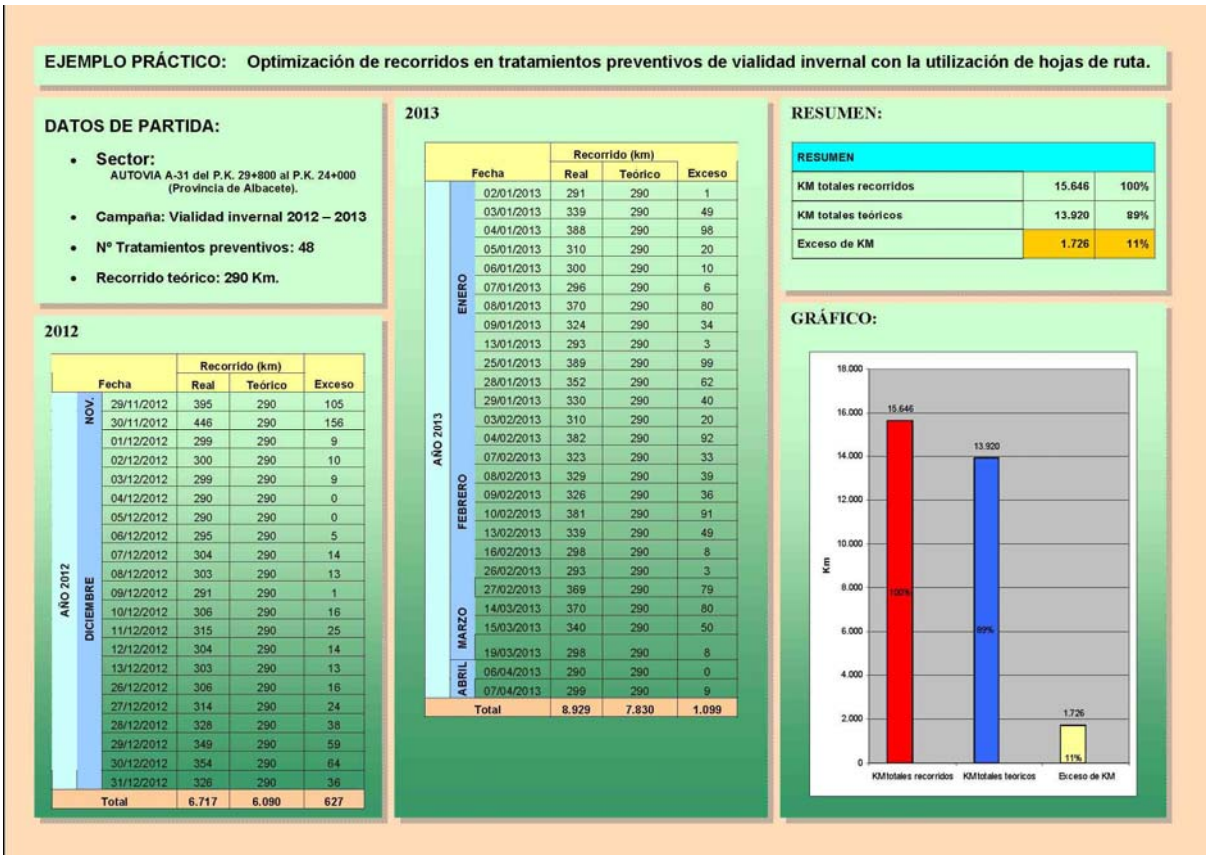
For this reason, the Spanish Preservation Centres should work in this regard ***by optimising the routes followed by snow removal teams***.
To do this, a possible solution would be to prepare a ***personalised road map for each snow removal team***, on which the following aspects should be included:

- ***Route to follow****, including changing direction spots, service roads, junctions, branches, etc...*
- ***Works expected****.*
- ***Speed of the vehicle*** *either for a movement or during works on the road.*
- ***Used snow melters and equipment****.*
- ***Stop and wait spots****.*

- ***Refuelling spots.***
- ***Snowmelt reloading spot.***
- ***Blade change spots***.

Since most of the Preservation Centres have GPS fleet management systems, the routes followed by the snow removal equipment should be analysed to check the level of compliance of the planned road map, and correct, if need be, the deviations observed in order to optimise as much as possible the tours.

Below, there is a case study of how the road sheet can be practically used. In this example, the most common preventive treatment is considered, salting, in the complete sector covered by the Centre, for a temperature lower than 2ºC (light frost).



EJEMPLO PRÁCTICO: Optimización de recorridos en tratamientos preventivos de vialidad invernal con la utilización de hojas de ruta.

DATOS DE PARTIDA:

- **Sector:** AUTOVIA A-31 del P.K. 29+800 al P.K. 24+000 (Provincia de Albacete).
- **Campaña: Vialidad invernal 2012 – 2013**
- **Nº Tratamientos preventivos: 48**
- **Recorrido teórico: 290 Km.**

2012

	Fecha	Recorrido (km) Real	Teórico	Exceso
AÑO 2012 / DICIEMBRE	29/11/2012	395	290	105
NOV.	30/11/2012	446	290	156
	01/12/2012	299	290	9
	02/12/2012	300	290	10
	03/12/2012	299	290	9
	04/12/2012	290	290	0
	05/12/2012	290	290	0
	06/12/2012	295	290	5
	07/12/2012	304	290	14
	08/12/2012	303	290	13
	09/12/2012	291	290	1
	10/12/2012	306	290	16
	11/12/2012	315	290	25
	12/12/2012	304	290	14
	13/12/2012	303	290	13
	26/12/2012	306	290	16
	27/12/2012	314	290	24
	28/12/2012	328	290	38
	29/12/2012	349	290	59
	30/12/2012	354	290	64
	31/12/2012	326	290	36
Total		6.717	6.090	627

2013

	Fecha	Recorrido (km) Real	Teórico	Exceso
AÑO 2013 / ENERO	02/01/2013	291	290	1
	03/01/2013	339	290	49
	04/01/2013	388	290	98
	05/01/2013	310	290	20
	06/01/2013	300	290	10
	07/01/2013	296	290	6
	08/01/2013	370	290	80
	09/01/2013	324	290	34
	13/01/2013	293	290	3
	25/01/2013	389	290	99
	28/01/2013	352	290	62
	29/01/2013	330	290	40
FEBRERO	03/02/2013	310	290	20
	04/02/2013	382	290	92
	07/02/2013	323	290	33
	08/02/2013	329	290	39
	09/02/2013	326	290	36
	10/02/2013	381	290	91
	13/02/2013	339	290	49
	16/02/2013	298	290	8
	26/02/2013	293	290	3
	27/02/2013	369	290	79
MARZO	14/03/2013	370	290	80
	15/03/2013	340	290	50
	19/03/2013	298	290	8
ABRIL	06/04/2013	290	290	0
	07/04/2013	299	290	9
Total		8.929	7.830	1.099

RESUMEN:

RESUMEN		
KM totales recorridos	15.646	100%
KM totales teóricos	13.920	89%
Exceso de KM	1.726	11%

GRÁFICO:

Hence, the conclusion was drawn that if routes are adjusted to a predetermined road map, 11% savings could be obtained in the routes followed, with the resulting saving in fuel, maintenance, staff working hours, etc…

2.-EQUIPMENT:

The current trend in Spain is to carry out preventive and curative treatments (under some specific circumstances) using sodium chloride brine due to their higher efficacy and lower use of melters. For this reason, the Spanish Preservation Centres must have the appropriate equipments to optimise work, and have high production brine plants and store brine enough to supply snow plough truck under extreme conditions. Likewise, the Preservation Centres must try to be equipped with brine spreaders and “combi”-type brine

spreaders (brine + solid melters), which allow to use different treatments with the same machine, either brine, solid melters or liquids.

Photo 1 – Brine Production Plant

Spreading melters is carried out with a specially adapted equipment to this end, called spreader, which are installed on trucks that are normally equipped with a pushing instrument for snow removal.

Considering all the melting spreading machines, we can say that spreaders vary according to the way melters are used: solid or granular state, liquid or humidified state.

In the first case classic spreaders are used, either manual or automatic, and they can be subdivided into transported or towed.

Photo 2 – Solid melter spreader with humid road system

The current trend in developed countries consists in using automatic and transported spreaders, which have, in essence, a special 3 to 10 m³ capacity steel or plastic material hopper installed on the bed of a truck. The distribution of solid products is carried out by means of one or two revolving plates that can be height, angle or zone to cover adjustable.

Triggering rollers, augers and plates is done by hydraulic engines fed in one of the following ways:

- *By a pump that is dragged by a wheel lying on the pavement which moves as the truck moves.*

- *By a pump that is moved by a power take-off of the truck.*

- *By a stand-alone engine.*

In the event that melters are humidified the equipment used is usually made up by:

- *A classic spreader equipped with a distribution system.*

- *One or two lateral or front tanks to store the liquid with a humidifying system that varies according to the model used.*

Lastly, when the melters used are in a liquid state, spreading is done by using tank trucks that have a low pressure spreading system, and are fed by pumps especially designed to this end.

Photo 3 – Spreader of liquid state melters

No matter what system is used, all the spreading control functions must be able to be carried out from the truck's cab. This, in most modern equipment, control functions are fulfilled through a small computer to which the signals arrive from the several sensors that are placed at the main mechanisms in motion, and it regulates the different spreading parameters like width, dose, liquid/solid relation, asymmetry of spreading, consumed material, etc., from the cab using a microprocessor.

The diversity of the different sectors of preservation, in terms of the type of roads, concrete, layout, altimetry, meteorological variables, makes that the future trend, seeking efficiency for tight budgets, should rely on having multi-functional spreaders that would allow adapting the different treatments of the pavement to the specific circumstances of the road.

These multi-functional melter spreaders already exist on the market and are usually known as “COMBI”, their main characteristics being as follows:

- *Equipment made up by a solid melter hopper + brine tank.*

- *Equipped with a revolving plate to spread solid melters that are height, angles and area to cover adjustable.*

- *Equipped with liquid melter spreading devices melters that are height, angles and area to cover adjustable, as well as with brine feeding pumps or brine to work on humid roads.*

- *Switchboard at the cab for all the equipment functions.*

This equipment enables spreading of melters to be performed in the following ways:

- *Spreading of solid melter.*
- *Spreading of solid melter on a humid road.*
- *Spreading of liquid melter.*

Photo 4 – Image of the “COMBI”-type melter spreading equipment

The multi-functional variety of this equipment enables to decide on the spot the kind of treatment that is considered as the most appropriate one for the characteristics of the road and the meteorological conditions at that moment, as the winter road management operation is being carried out within the same sector of roads.

For example, if temperatures are expected to be low and a preventive treatment was planned, with this equipment sodium chloride brine is applied, but if operators come across an area where rain fell along the route they are following, solid melters can be applied.

Therefore, based on the characteristics of each sector of roads, the corresponding winter road management means should be provided, although the trend should be to rely on multi-functional equipment in order to quantitatively and qualitatively optimise the use of melters, which has the following advantages:

- *Saving of melters.*

- *Saving of fuel.*
- *Reduction of environmental costs.*
- *Higher efficiency of the treatment.*

To meet the aforementioned goals, and to be more efficient, renewing and investments in new melter spreading machinery should be geared towards the implementation of multi-functional equipment, according to the needs of each sector of roads.

Since investment in this kind of machinery is heavy, and many spreaders of conventional melters are still not amortised and are in a good shape for operation, the possibilities should be studied to adapt the current equipment to the "COMBI" types.

On the other hand, it is extremely important to perform a melter spreading **equipment calibration**, in order to correct the possible deviations in terms of melter supply and spreading width.

To do this, it is considered that each Preservation Centre should regularly establish some method prior to the beginning of each winter road management campaign in order to take samples of the spreading equipment melters, both static and in motion **to evaluate it and correct mistakes and deviations**.

Likewise, the kind of snow removal blades used should be analysed (steel ones, "vulkollan"-type synthetic ones, rubber, neoprene, ceramic, etc.) and have the kind of blades that better adapt to the different types of pavement, snow thickness, types of snow, etc. at each Centre, since ***this allow to optimise the work, reduce the time spent and also reduce fuel consumption***.

A good selection of snow removal blades might have the following advantages:

- Higher resistance to usage.
- Good moving properties and less impact on the running layer of the pavement.
- Lower fuel consumption.
-Reduction in movements and in the times spent to replace blades.

As an example, we can talk about the use of neoprene blades that adhere perfectly well to the running layer, completely removing the snow from the pavement.

These blades, in addition to yielding better results in terms of cleaning, provide a series of advantages like the fact they do not deteriorate if they collide against an obstacle, they have a long lifespan, and offer a low level of noise during the operative phase.

Likewise, the material the body of snow removal blades consists in should also be analysed, since a polyethylene plough in addition to offering better snow removal requires less power of the vehicle and therefore lower fuel consumption.

Photo 5 – Snow removal plough with steel blade

3.- MELTERS:

In Spain, the most generally used melters are: sodium chloride (NaCl) and, under certain conditions, calcium chloride (Cl_2Ca).

The use of these melters in Spain versus other melters like urea and acetate products is due to the following factors:

- *Very competitive price.*
- *Guaranteed supply and availability.*
- *Reasonable impact on the environment.*

It is very important for Preservation Centres to have adequate stores for melters, and also to carry out an appropriate treatment of melters so that those remaining from one campaign can be used for the following one.

It is well known that the sodium chloride (the mainly used melter) that remains from one campaign losses its properties under summer meteorological conditions in terms of humidity, getting harder and creating, in some cases, a really thick crust. Once the crust is removed sodium chloride remains lumpy which can provoke major problems when it comes to use it as melter, as it can get stuck in the machine and cause a failure in the spreader.

The disposal of the remaining sodium chloride of one campaign has a high economic cost, and the use of sodium chloride from one campaign in another campaign, if not under the appropriate conditions, might lead to major problems in the implementation of winter road management operations.

Facing this tight budgetary framework, the Spanish Preservation Centres must seek to optimise resources. To do this, the remaining sodium chloride from one campaign must be adequately treated before the beginning of the next campaign; the tasks to be carried out are as follows:

- Removing sodium chloride storages.
- Sifting sodium chloride to separate lumps.
- Mashing the lumps rejected by the sifting procedure.
- Adding anticaking products.
- Mixing products.
- Storage in stocks.

Photo 6 – Sifting the NaCl remaining from one winter road management campaign.

Optimising the collection of NaCl losses is important, of that coming from the treatment of melter stocks, snow plough equipment loading areas, machinery cleaning areas, polluted waters, etc.

These remaining elements can be stored in evaporation pools and, after filtering them they can be reused as melters of for the manufacturing of brines.

As far as the types of treatments conducted are concerned, either preventive or curative, everybody is aware of the general recommendations in this regard which can be summarised as follows:

PREVENTIVE TREATMENT:

- On a dry road: Brine or brine humidified melter can be used.
- On a humid road: Brine or solid state melter can be used.

It is important to note that for melters' humidification only brines made up by ClNa or Cl_2Ca can be used, based on the work temperature, and never can water alone be used.

In general terms, all preventive treatments are performed according to the recommendations of the chart below:

DOTACIONES EN LOS TRATAMIENTOS PREVENTIVOS			
Estado de la calzada	Fundente	Dotaciones	
		gr/m^2	cm^3/m^2
Calzada seca (Hr<75 %)	Salmuera de NaCl	5-10	18,5-37
Calzada seca (Hr>75 %)	Salmuera de NaCl ó NaCl humidificada	5-15	18,5-55
Calzada ligeramente húmeda	NaCl humidificada ó NaCl sólida	5-10	-
Calzada muy húmeda	NaCl sólida	10-15	-

Chart 1 – Amounts of preventive treatments

CURATIVE TREATMENTS:

When the situation requires the snow to be removed from the road, curative treatments should be considered, i.e., melters will continue to be spread and the dose is increased as well as the frequency of treatments.

Curative treatments are performed according to the charts below:

Tipo de nieve	Temperatura (°C)	Fundente	Dotación (gr./m^2) espesor (e)	
			e ≤ 2 cm	e > 2 cm
Tratamientos curativos contra la nieve. Esparcimiento único				
En Fusión	Mayor de -5°C	Cloruro Sódico sólido	20 - 30	30 - 40
	Entre -5°C y -15°C	Mezcla sólida de 2/3 de Cloruro Sódico y 1/3 Cloruro Cálcico	20 - 30	30 - 40
	Menor de -15°C	Cloruro Cálcico sólido	15 - 20	20 - 30
Seca o apelmazada	Mayor de -5°C	Cloruro Sódico sólido o humedecido con salmuera	20 - 30	30 - 40
	Entre -5°C y -15°C	Mezcla sólida de 2/3 de Cloruro Sódico y 1/3 Cloruro Cálcico humedecido con salmuera	20 - 30	30 - 40
	Menor de -15°C	Cloruro Cálcico sólido humedecido con salmuera	15 - 20	20 - 30

Tipo de nieve	Temperatura (°C)	Fundente	Dotación (gr./m^2) espesor (e)	
			e ≤ 2 cm	e > 2 cm
Tratamientos curativos contra la nieve. Esparcimiento mixto				
En Fusión	Mayor de -5°C	Cloruro Sódico sólido + Salmuera de Cloruro Sódico	15 - 30	30 - 40
	Entre -5°C y -15°C	Mezcla sólida de 2/3 de Cloruro Sódico y 1/3 Cloruro Cálcico + Salmuera (2/3 Cloruro Sódico + 1/3 Cloruro Cálcico)	20 - 30	30 - 40
	Menor de -15°C	Mezcla sólida de 2/3 de Cloruro Sódico y 1/3 Cloruro Cálcico +Salmuera (2/3 Cloruro Sódico + 1/3 Cloruro Cálcico)	20 - 20	30 - 40
Seca o apelmazada	Mayor de -5°C	Cloruro Sódico sólido o humedecido con salmuera	20 - 30	30 - 40
	Entre -5°C y -15°C	Mezcla sólida de 2/3 de Cloruro Sódico y 1/3 Cloruro Cálcico + Salmuera (2/3 Cloruro Sódico + 1/3 Cloruro Cálcico)	20 - 30	30 - 40
	Menor de -15°C	Salmuera de Cloruro Cálcico	20 - 30	30 - 40

Chart 2 – Recommendations for curative treatments

The use of brines in the application of curative treatments is increasingly usual, ***and over the last years their use has been generalised for the Spanish territory road system***. This kind of treatments might be especially useful under extreme meteorological conditions and above all when the wind blows and it is necessary to accelerate the action of melters as much as possible when facing these difficult situations.

The use of brines in the application of preventive treatments has been generalised to nearly the entire national territory. Most of these preventive treatments correspond to the light frost forecast with temperatures close to 0ºC. The brine used for this type of treatment in most of the Spanish Preservation Centres is generally sodium chloride brine, with a concentration close to the “Eutectic Point”, which is: 23.1%.

Preventive treatments account for an important part of the economic cost of winter road management campaigns, and should be analysed in order to find higher efficiency.

On the other hand, it is noteworthy that the level of requirements of the Spain State General Administration in terms of winter road management is very demanding, giving road safety a high priority.

It is also noteworthy that the Administrative Clause Document for the Comprehensive Preservation Contracts from the Ministry of Public Works of Spain indicates in Section 2 of Clause 28 the “Penalties” that can be incurred “when traffic issues arise related to the contract’s activities, and the contractor does not comply or fails to comply the conditions under which these activities should be carried out; as a result, the Administration might opt to either terminate the contract with the subsequent loss of guarantees or to impose a penalty”.

Likewise, in first generation highway contracts, indicator I17, related to Winter Road Management, establishes that penalties will be imposed if punctual thresholds or the response times included in the contract are not respected. These values refer mainly to the deadlines established for Service Tier 1, in addition to the obligation to treat the entire road with melters when the real or forecast environment temperature is lower than 2ºC.

As indicated above, the level of demand of the Spanish State General Administration is really high, prioritising road safety above all. This is why on many roads in Spain an surplus of melter can be seen at first sight.
Therefore, the goal must be to increase efficiency maintaining the service levels that insure safety on the road
.

To optimise the use of melters in preventive treatments, based on the current technological means, the safety margin established between the use of melter and road safety should be target, making always sure that safety is sought after.

In this connection, the following pathway should be worked out:

- ***Equipping Preservation Centres with stocks of brine according to their composition and concentration, ready to be used when facing the forecast meteorological conditions.***

- ***Developing reliable technology capable to provide real time information on the concentration of melter on the road.***

To meet the second goal, efforts should be done to develop a system that would allow to control the amount of melter that is on the road, so that it is possible to determine on real time what areas of a road sector have a sufficient salinity level and those that do not have it.

These data, backed by on the spot information sent by surveillance vehicles need to be reliable enough to be able to make decisions when it comes to plan the preventive treatments.

On the other hand, the conditions under which a preventive treatment is applied should also be analysed. As indicated above, preventive treatments are applied currently in Spain when the meteorological forecast indicated temperatures lower than 2ºC, not taking into account other factors. For this reason, it is necessary to include other factors such as humidity, if the road is wet or not, if there is for or not, as this will allow saving unnecessary preventive treatments.

Success in the implementation of the aforementioned works will have the following advantages:

- ***Savings in melters.***
- ***Savings in fuels.***
- ***Reduction of environmental costs.***
- ***Reduction of staff costs.***
- ***Reduction of overhead costs.***

4.- METEOROLOGY:

In order to adequately plan winter road management works it is vital to have an accurate meteorological forecast adjusted to the local scope of each Preservation Centre. This allows optimising the use of winter road management resources available. To do this, it is necessary to rely on local meteorological stations equipped with road sensors. In addition, training should be provided in order to interpret the meteorological data recorded by meteorological stations and also knowing the local climate is important.

Also, as a support to abovementioned ideas, hiring private meteorological services should be analysed so that they can provide detailed information of a local scope as well as advice of on duty meteorologists, to be able to schedule the appropriate winter road management works in time and form.

Concerning this work of meteorology applied to winter road management, there are many fields to be developed, as indicated below:

- Development of continuous salinity sensors mounted on vehicles equipped with real time data collection and transmission software.
- Integration of equipment and systems the different road sectors rely on, like meteorological stations, asphalt smart sensors, mobile meteorological stations, historic local and meteorological data, etc.
- Development of tools that integrate the different existing equipment and systems, models and meteorological forecast, information on the salinity existing on the road, to optimise the decision-making process in planning preventive treatments according to the real needs of the road.

Getting powerful tools to support the planning of preventive treatment will provide the following advantages:

- Reduction of overhead costs.
- Safety in decision-making.
- Planning preventive treatments that fit the current circumstances.

On the other hand, it is necessary that prior to the aforementioned items, objective, appropriate and efficient criteria are adopted, establishing under what circumstances treatments are to be applied, mainly preventive treatments.

To do this, we will analyse a real case in Spain on how winter road administration actions are treated in first generation highway contracts, and particularly, the section of Highway A-31 (Madrid - Alicante) between kilometres 29.8 and 124.0, which is 94.2 km long.

As indicated above, the level of requirements of the State General Administration in terms of winter road management is really demanding, giving road safety a high rank in priorities.

For this, in the aforementioned contracts a quality and service indicator is referred to, named Indicator I17 on "Winter Road Management", in which the following thresholds are established:

- Ice sheets: none. In the event of non-compliance, in addition to penalties, a serious misconduct would have been incurred and the contract can be terminated.
- Length percentage (%) with salt treatment applied with real environment temperature or temperature lower than 2 ºC: 100 %. In the event of non-compliance, in addition to penalties, a serious misconduct would have been incurred and the contract can be terminated.

As seen in the indicator abstract above, the only criterion pre-established by the Administration for decision-making on whether or not applying a preventive treatment is real or forecast temperature. This detail is important, since for a section as the one described here (nearly 100 km long) actions need to be taken several hours before the forecast hour when temperature is lower than 2 ºC.

For the highway section, for instance, during the 2012-2013 winter road management campaign, the indicator stipulation obliged us to carry out preventive treatments 61 days before, and the total consumption of brine accounted for over 1,800 tons.

Mes	Tratamientos realizados por Aullasa en la campaña de vialidad invernal 2012-2013				
	Tratamientos preventivos		Tratamientos curativos		
	Días tratados	Tn salmuera	Días tratados	Tn salmuera	Tn sal
nov-12	4	130	0		
dic-12	18	540	0		
ene-13	16	492	0		
feb-13	15	462	1	113	258
mar-13	6	188	1	74	128
abr-13	2	60	0		
Total fundentes empleados (tn)		**1,872**		**187**	**386**

Chart 3 – Treatments performed by Aullasa during the 2012-2013 winter road management campaign

By applying a preventive treatment the idea is to face the phenomena that might impact the road and consequently the road's users. These phenomena are, mainly, frost and rainfall in the shape of snow. We shall focus on frost.

Frost is a climate phenomenon that consists in environment temperature falling to levels that are lower than the water freezing point, making water or the steam of water in the air to freeze and to deposit on surfaces in the form of ice.

Particularly, the World Meteorological Organisation talks about frost on the ground to refer to the different types of ice covers on the ground produced as a result of water steam being directly deposited.

Therefore, for ice to be produced there must be water well in liquid form, due to precipitation (rainfall or snow) or otherwise in form of water steam combined with the temperature adequate to the frosting process.

The water freezing point, as everybody knows, is 0 ºC for clean water, therefore, we can consider that the indicator establishes a 2ºC “safety margin” to perform preventive treatments when facing frost.

But for ice formation, in addition to the temperature condition, it is necessary that a second condition is produced, which is the relative humidity of the air being above 60%. This is the threshold for frost creation that could be considered as the first stage in the ice formation process.

Related to relative humidity, and perhaps the most intuitive concept, is the dew temperature concept, which is the temperature to which the water steam in air starts to condensate producing dew, fog or frost or ice if temperature is, in its turn, lower than 0ºC.

However, the indicator’s thresholds mentioned before do not consider this factor in spite of being a necessary condition for ice formation.

The current meteorological forecast systems are considered to still have a certain degree of accuracy. In the section we are studying, the contracting company has three meteorological stations. As an example, please see below the chart with forecast temperatures versus recorded temperatures of one of the meteorological stations:

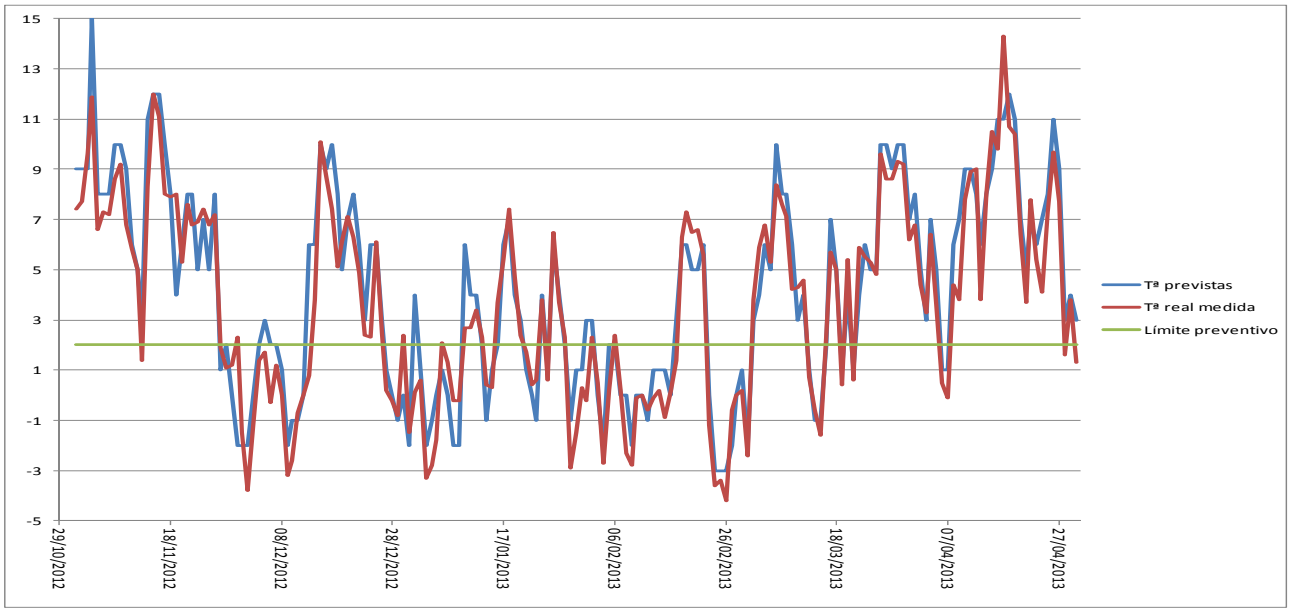


Fig. 2: Forecast temperatures vs. actual temperatures

The chart below corresponds to the State Meteorology Agency of Albacete, located less than 2 km far from the section and lees than 5 km away from the station in the section of the study.

Of the 70 days the State Meteorology Agency forecast that temperature would lower than 2 ºC, 62 days recorded this temperature (< 2 ºC). The 8 remaining days recorded higher temperatures. However, 8 days recorded temperatures that were lower than 2 ºC even if they were not forecast by the State Meteorology Agency. This means that practically 90% of forecast was fulfilled, indeed.

On the other hand, of these 70 days 60 had relative air humidity higher than 60%, therefore, 10 days did not have the conditions in place to get frost formation.

Modification of thresholds following efficiency criteria

Two modifications of the action criteria can be concluded from the explanations given above, which represent a clear improvement of efficiency:

- reducing the temperature threshold for preventive treatments since the current meteorological forecast systems enables it, **moving from 2 ºC to 1 ºC**.

For the data analysed on winter road management campaigns, we would have moved from the forecast 70 days to 60 days, therefore reducing preventive treatments by **15%**.

- incorporating the air relative humidity temperature threshold so that this criterion is not exclusively a temperature-based criterion, but a combined one, establishing to obligation to perform a preventive treatment **when temperature (either real or forecast) is lower than 1 ºC and relative humidity higher than 60%.**

Taking the analysed campaign as an example again, for the Albacete meteorological station combined temperature and relative humidity criteria would have entailed to act 51 days before, compared to the 70 days envisaged, which account for **27%** of the envisaged treatments.

During the first 2013-2014 winter road management campaign a comprehensive monitoring of the before mentioned parameters will be conducted concerning forecast temperatures versus current relative humidity, dew temperatures, etc., in addition to incorporating other parameters like wind, precipitation, type of precipitation, etc.