INNOVATIVE WINTER MAINTENANCE GUIDELINES IN AUSTRIA

J. NEUHOLD
Office of the Provincial Government of Lower Austria, Road Maintenance Department,
josef.neuhold@noel.gv.at
P. NUTZ & M. HOFFMANN & R. BLAB
Institute of Transportation Sciences, Vienna University of Technology, Vienna, Austria

Topic 5. Operational approaches, equipment and products for winter service

ABSTRACT RÉSUMÉ

The technology of using pre-wetted-salt in winter maintenance is a standard in Austria. In order to improve the winter maintenance techniques, the federal states, the Austrian highway operating company ASFINAG and the federal ministry of Transport (BMVIT) funded a research project at the Institute of Transportation (Vienna University of Technology). The goal was to investigate the question of necessary salt application rates and timing in order to optimize winter maintenance and improve the road safety. The developed holistic model allows a determination of optimal application rates and timing of de-icing agents as a function of precipitation rate, traffic volume and road surface temperature over several treatment-cycles. For the implementation of the findings, a compact summary and a winter maintenance guide were developed as well. Based on typical winter weather and road conditions, practical winter maintenance recommendations and application rates are given. The winter maintenance guide was tested in winter 2010/11 on selected roads in Austria for the first time. Based on this practical experience the maintenance guidelines were adapted and have been applied to all high level roads in Austria since the winter period 2011/12. In addition to the treatment principles, application rates for typical scenarios based on the developed model are presented. These scenarios consist of specific road-condition and weather-development situations. The scenarios are illustrated with pictures of typical road conditions and an overview of appropriate winter maintenance strategies and driving recommendations. Due to their generalized nature these recommendations cannot replace the expertise and responsibility of the winter maintenance staff. Therefore, the new findings of the salt-spreading-technology were brought closer to the personal in training sessions together with the Institute of Transportation from the Vienna University of Technology. An additional survey of the winter maintenance personnel provided feedback opportunity. The findings from practical experience have been incorporated as well. With a new salt-controlling-system both average salt consumption and savings due to the application of the maintenance guidelines could be detected.

1. STANDARDIZATION: STANDARD PROCEDURE IN WINTER MAINTENANCE

The allocation of winter maintenance personal and the specification of limits in salt application rates are in the responsibility of the road authorities. However, the ultimate responsibility for the implementation of winter maintenance, particularly for local salt application rates, still lies within each individual maintenance vehicle driver. Due to their visible assessment of the current road condition they are able to adjust the salt application rates based on their subjective experience. This experience-based winter maintenance practice leads to completely inconsistent application rates in comparable situations. Every

driver is convinced to know the right application rate from e.g. 10 g/m² up to a maximum amount of 40 g/m² per application interval. If 10 g/m² application rate is sufficient to achieve a lower freezing point compared to the pavement temperature, any higher application rate will also prevent freezing. Due to public and legal pressure, drivers tend to apply significantly higher total amounts of salt compared to actual needs.

The objective of an optimized winter maintenance lies therefore in limiting the application rate in similar situations to the necessary extent and to harmonise the different maintenance strategies. To achieve this goal, high quality winter maintenance recommendations and extensive training courses of the winter maintenance personal are required. Only then the different individual opinions on how to find the optimal approach in fighting snow and ice on the road can be replaced by a more optimized uniform strategy. In order to implement such an optimized uniform strategy the essential question „When is ploughing and salting necessary and how can the optimal application rate be determined?“ must be answered. Furthermore, the instructions must provide drivers with the means to make quick decisions during a treatment routine. If uncertainties cannot be dispelled through training courses and winter maintenance guidelines, large amounts of salt based on the principle “a lot of salt helps a lot” are applied. This costly overuse of de-icing agents regardless of the physical limits of winter maintenance will result in an overuse of resources and unnecessary damage of the environment [1].

Figure 1 provides an overview of the total amount of salting in the winter period 2011/2012 on federal state roads in Austria. The typical winter maintenance period in Austria usually lasts from 1st of November to the 31st of March. The average number of winter maintenance days amounts to 132 days with an average of 4,05 t/lane.km and year of the main de-icing agent sodium chloride. In total this figures correspond to an average of 0.03 t/lane.km or roughly 9,2 g/m^2 of pavement and winter maintenance day which is roughly 20% lower than the average of 11,7 g/m^2 of the winter maintenance periods 2004/2005 to 2009/2010 with the same average number of winter maintenance days.

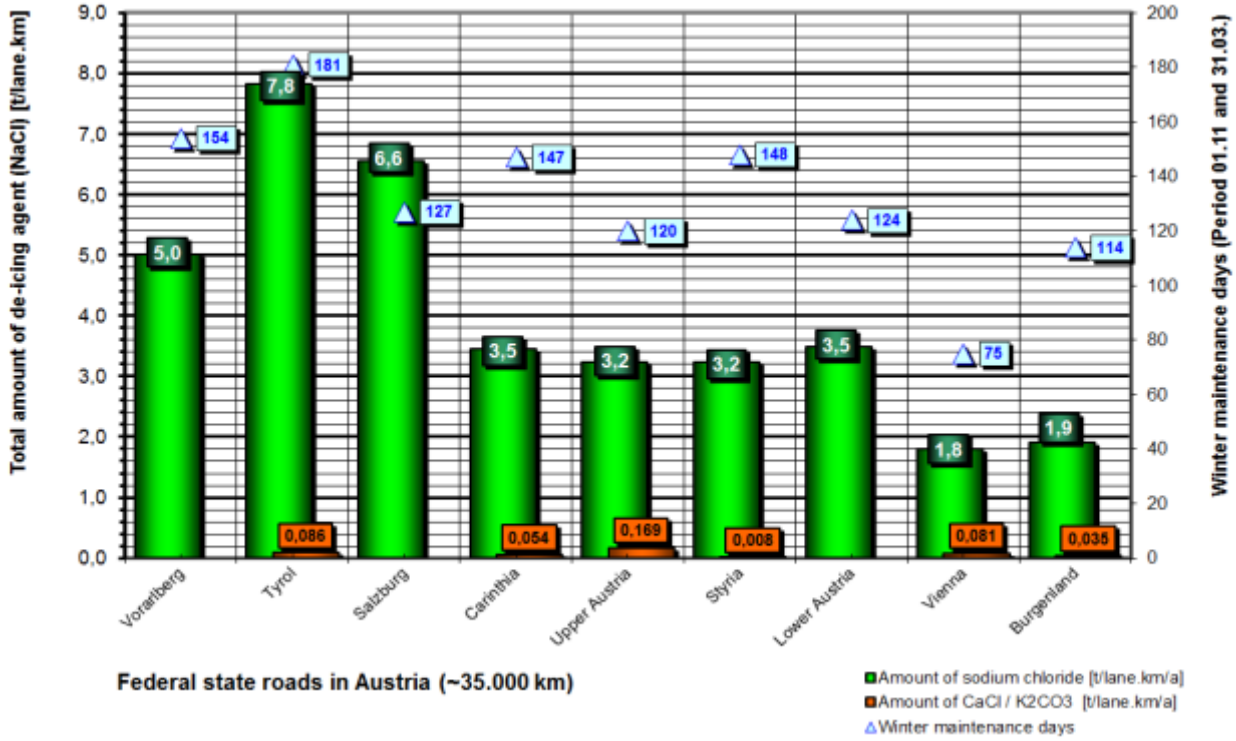

Fig. 1: Total amount of winter maintenance days and salting per lane-km on federal state roads for the winter period 2011/2012 in Austria

2. LIMITS: LIMITED DE-ICING CAPABILITY OF SODIUM CHLORIDE

The physical impact of salting is a lowered freezing point temperature of the solution of de-icing agents and precipitation on the road preferably below road surface temperature. The mainly used de-icing agent is sodium chloride (NaCl), with a maximum freezing point of -22,3 °C at a brine concentration of 23,4%. A further lowering of the freezing point temperature below this eutectic point of NaCl is not possible with sodium chloride. Laboratory tests with different salt concentrations of NaCl and $CaCl_2$ in a climate chamber show that, in contrast to other representations with super saturation of the brine, the freezing point does not increase or decrease.

For winter maintenance practice, the amount of salt applied in dry or pre-wetted application thaws snow and ice until a brine concentration is reached where the freezing point of the brine matches the road temperature. If the amount of snow during a treatment cycle exceeds that limit, the roads cannot be kept free of snow or ice during the entire treatment cycle resulting in a refreezing or gradually covering of the road with snow. One of the key points in the training courses of the winter maintenance personnel is therefore to show the physical limits of de-icing agents. According to the regulations in Austria (RVS 12.04.12, snow removal and grit spreading, from August 2010), the statutory treatment cycle on highways has to be shorter than 180 minutes and on regional roads shorter than 300 minutes. However, even with medium to strong snowfall and the maximal application rate in significantly shorter intervals of 90 to 180 minutes, the road cannot be kept free from snow or ice purely due to physical reasons.

In such cases, the attempt to handle the precipitation with high application rates up to 40 g/m² can be even counterproductive, as a snow-covered road has a slightly better skid resistance than a road covered in refreezing snow slush. In addition, a distinctly and visibly snow-covered road leads in general to an „adapted“ driving behaviour. Therefore, the frequently practised strategy in such cases „a lot of salt helps a lot“ is in most cases incorrect and costs considerably more. The amount of snow in centimetre that can be thawed theoretically with one treatment is given in Figure 2, based on salt application rate and road temperature. Each point on the lines corresponds to a freezing point of brine with the concentration resulting from the application rate and the amount of precipitation. According to the calculations snow quantities of >1.0 cm/m^2 cannot be thawed at road temperatures lower than minus 3°C even with a maximum application rate (of winter maintenance vehicles) of 40 g/m² purely due to physical reasons (Figure 2).

If salt losses out of drift and discharge losses due to traffic are taken into account, the available amount of salt for thawing is significantly lower. Based on previous measurement data from [1;2;3], the remaining amount of salt immediately after the application process can be roughly estimated with about 50% of the initial application rate. For the given scenario above the practical available amount of de-icing agents is roughly 20 g/m² with a physical thawing capacity of <0.5 cm/m^2 of snow. Depending on actual traffic volume between treatment cycles, this remaining amount of salt is scattered even further. Therefore, the road cannot be held free of snow or ice during the entire treatment interval for the afore mentioned scenario.

According to an in-depth analysis of all snow-fall events in the period 1st of November 2005 to 31st of March 2010 there are in average 11.4 days with snowfall events (0-300 MASL) and Ø3.77 cm snow per day respectively 18,5 days with snowfall events (300-600 MASL) and Ø4.89 cm snow per day. The rest of the winter maintenance days are mainly due to hoarfrost, freezing rain and preventive maintenance activities with 1 x 10 g/m^2

usually being sufficient. Depending on region and height above sea level there are in average one to two days per winter period with more than 10 cm snow per day. Due to the fact that the snowfall rates are not evenly distributed that it will not be possible to keep the roads free of snow at all times on at least 3 to 4 days. In general these few times do not pose a problem assuming a responsible driving style.

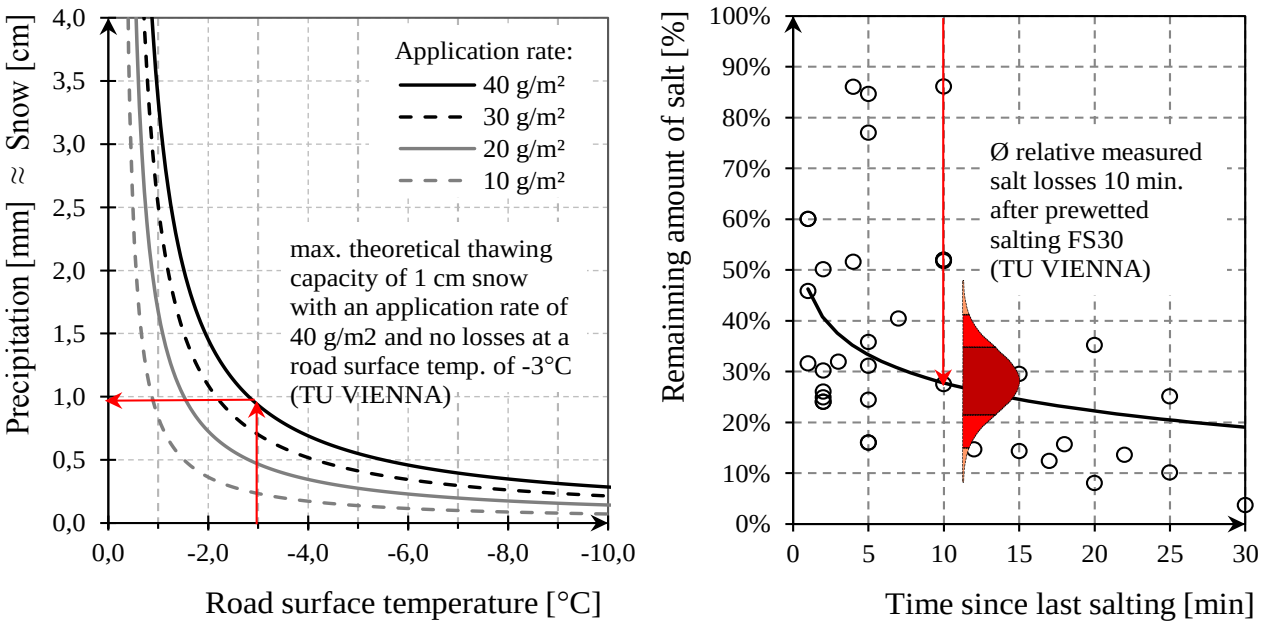

Fig. 2: Theoretical thawing capacity of sodium chloride with typical application rates of 10 to 40 g/m² (left) and relative salt losses after treatment for prewetted salting (right)

3. DEVELOPED MODEL: BASE FOR AN OPTIMIZED WINTER MAINTENANCE

To answer the question of the necessary salt application rate and timing for an optimized winter maintenance and improved the road safety a research project was started [1]. Based on extensive research, a mathematical model was developed that allows the determination of the application rate and timing of de-icing agents as a function of snow fall, traffic and road surface texture. Furthermore, the resulting skid resistance and speed limits for safe driving can be estimated based on the filling rate of the texture reserve depending on the occurrence of freezing processes. The preliminary model describes the residual salt loss and water quantity on the road based on several factors with the resulting time-dependent brine concentration. If the road surface temperature drops below the freezing point of the brine on the road, there is danger of freezing. Furthermore, sleekness results only, if the brine on the road freezes and the texture reserve is insufficient. The reserve in texture depends on the macro texture of the pavement and describes the amount of frozen precipitation needed to fill the texture to interrupt direct contact of the tire with the road resulting in a sufficient reduction of skid resistance.

The residual amount of salt is determined by resistance measurements (SOBO 20) at predetermined measurement points and is a function of application rate, traffic, road surface texture and speed. The thickness of the water film resulting from the precipitation, traffic and air temperature was measured by Vaisala - Cameras (DSC 111, DST 111). In simultaneously running measurements, the effective skid resistance and its development in various winter maintenance situations with known weather conditions and precipitation over the entire test section were examined (Grip Tester MK II). The combination of sand patch method, texture measurement by laser and RoadSTAR - data to determine the texture reserve guarantee a widespread applicability of the model on any road surface.

4. PREVENTIVE TREATMENT: MECHANISM AND APPLICATION STRATEGY

From the limited thawing capability of de-icing agents as well as the identified correlations in the model, the mechanism of preventive treatment can be derived. A preventive treatment is an application of de-icing agents prior to the occurrence of a precipitation events. This serves the purpose of avoiding potentially slippery roads (e.g. hoarfrost) and eases snowploughing in the next treatment. Therefore, a preventive treatment has to be performed prior to each precipitation event. In case of hoarfrost, water vapour in the air settles on the cold road surface in form of ice. Usually hoarfrost appears in the early morning between 02:00 to 04:00 am, usually not exceeding 100 g/m². With a preventive treatment and a salt application rate of 10 g/m² timed close to the beginning of hoarfrost, a slippery road surface can be largely avoided. However, a preventive treatment in the eve the day before is not effective due to usually occurring discharge and scattering losses.

If the thawing capacity of the applied de-icing agent is exceeded due to the amount of snow between two treatments cycles and the remaining snow after the first snowploughing, the development of snow slush cannot be avoided. This snow slush freezes after further dilatation of the brine on the road due to on-going precipitation. The result is a lower skid resistance compared to a snow-covered road. In addition, it is easier for the road users to adapt their driving style and speed to an observable snow covered road compared to a freezing and poorly visible snow slush. In such cases a preventive application of 10 g/m² is usually sufficient to form a release coating. This release coating has to be renewed after each treatment and prevents the adherence of snow or ice on the road surface, without creating large amounts of snow slush. For anticipated amounts of snowfall, temperatures and road traffic loads where the road can be kept free of snow and ice, the necessary application rates are established in practical tables (Figure 4).

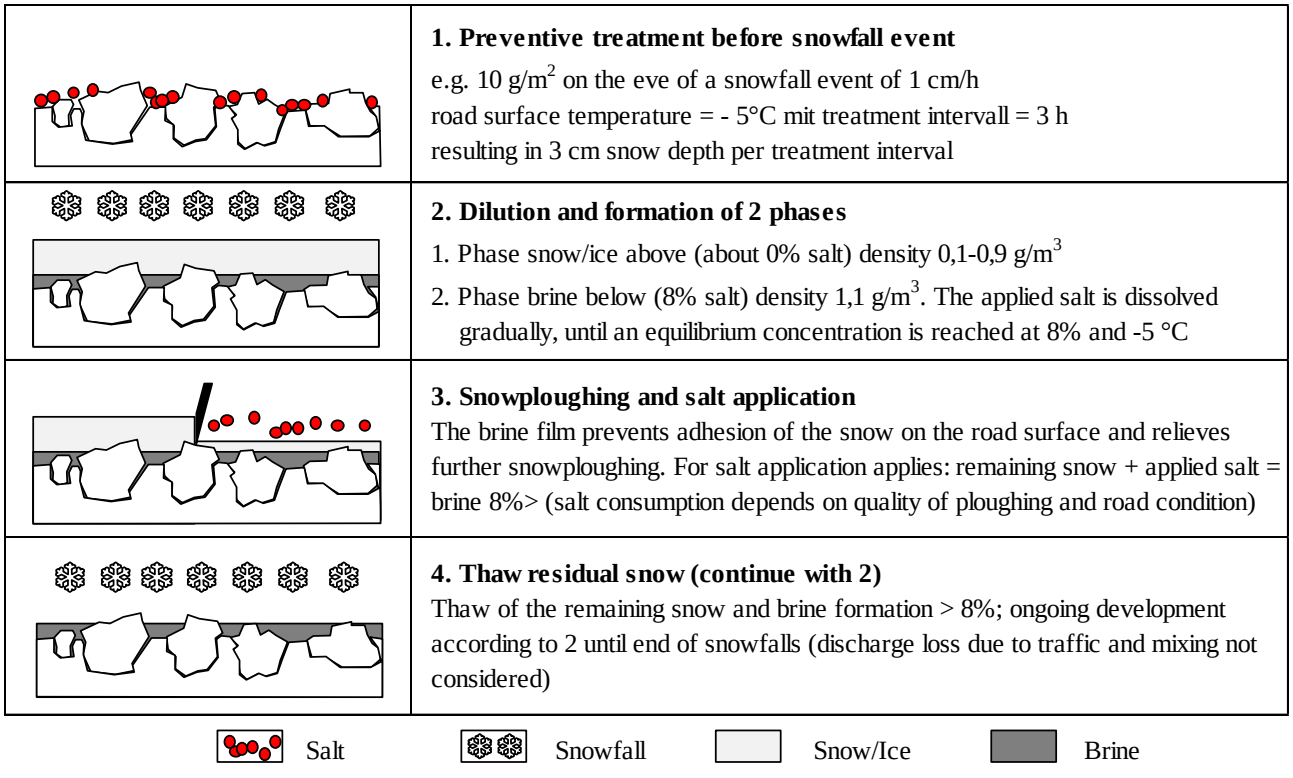

Fig.3: Mechanism of preventive treatment in winter maintenance to form a release coating for snowfall amounts that cannot be thawed in typical treatment intervals

5. APPLICATION RATES: PRINCIPLES AND QUANTITY DETERMINATION

From the existing legal framework and standards, the surveys of the winter maintenance authorities and the previous studies and results of the developed holistic winter maintenance model following treatment principles can be derived:

- On highways, express roads and their junctions the maximum treatment interval (cycle time) is 3 hours in the period between 0h to 24h (category A).
- At high-level country roads with AADT > 5.000 vehicles per day the maximum treatment interval is 5 hours in the period between 4h to 22h (category B).
- At high-level country roads with AADT > 1.000 to 500 vehicles per 24 hours at the maximum treatment interval is 5 hours in the period 5h to 20h (category C).
- Pre-wetted salt has less discharge and a better spread pattern as dry salting, and is preferably applied up to a brine amount of 30% (BADELT 2007).
- The amount of snow that can be thawed is limited for physical reasons. Therefore snow or ice-free roads cannot be maintained with heavy snow falls (> 1cm/h) and very low temperatures (<-5°C).
- Reducing the treatment intervals still further increases the costs without significantly improving the road condition.
- The application rate of de-icing agents should not exceed the necessary amount. Larger application rates lead to disproportionate high costs without improvement of road conditions but unnecessary environmental damages.
- The salting has to be timed as close as possible previous to any precipitation event (about 5 - 10 g/m² preventive application < 0-1h previous to precipitation).
- Hard-packed snow or ice on the roads cannot be removed quickly enough with the application of salt. A mechanical removal must therefore always take place previous to salting.

Precipitation 0,0 mm to 0,25 mm - Snow hight 0,0 cm to 0,25 cm
Hoarfrost or slightly visible snowfall

Traffic during interval	Application rate [g/m²]	Road surface temperature [°C] -1	-2	-3	-4	-5	-6	-7	-8	-9	-10
	250	5	16	26	36	10	10	10	10	10	10
	500	6	16	27	37	10	10	10	10	10	10
	1.000	6	17	28	39	10	10	10	10	10	10
	1.500	6	18	30	10	10	10	10	10	10	10
	2.000	6	19	31	10	10	10	10	10	10	10
	2.500	7	20	33	10	10	10	10	10	10	10
	3.000	7	21	35	10	10	10	10	10	10	10
	3.500	8	23	37	10	10	10	10	10	10	10
	4.000	8	24	40	10	10	10	10	10	10	10

Precipitation 0,25 mm to 0,5 mm - Snow hight 0,25 cm to 0,5 cm
Very light snowfall

Traffic during interval	Application rate [g/m²]	Road surface temperature [°C] -1	-2	-3	-4	-5	-6	-7	-8	-9	-10
	250	11	32	10	10	10	10	10	10	10	10
	500	11	33	10	10	10	10	10	10	10	10
	1.000	12	34	10	10	10	10	10	10	10	10
	1.500	12	36	10	10	10	10	10	10	10	10
	2.000	13	38	10	10	10	10	10	10	10	10
	2.500	14	10	10	10	10	10	10	10	10	10
	3.000	14	10	10	10	10	10	10	10	10	10
	3.500	15	10	10	10	10	10	10	10	10	10
	4.000	16	10	10	10	10	10	10	10	10	10

Precipitation 0,5 mm to 0,75 mm - Snow hight 0,5 cm to 0,75 cm
Light snowfall

Traffic during interval	Application rate [g/m²]	Road surface temperature [°C] -1	-2	-3	-4	-5	-6	-7	-8	-9	-10
	250	16	10	10	10	10	10	10	10	10	10
	500	17	10	10	10	10	10	10	10	10	10
	1.000	17	10	10	10	10	10	10	10	10	10
	1.500	18	10	10	10	10	10	10	10	10	10
	2.000	19	10	10	10	10	10	10	10	10	10
	2.500	20	10	10	10	10	10	10	10	10	10
	3.000	22	10	10	10	10	10	10	10	10	10
	3.500	23	10	10	10	10	10	10	10	10	10
	4.000	24	10	10	10	10	10	10	10	10	10

Precipitation 0,75 mm to 1,0 mm - Snow hight 0,75 cm to 1,0 cm
Light/moderate snowfall

Traffic during interval	Application rate [g/m²]	Road surface temperature [°C] -1	-2	-3	-4	-5	-6	-7	-8	-9	-10
	250	22	10	10	10	10	10	10	10	10	10
	500	22	10	10	10	10	10	10	10	10	10
	1.000	23	10	10	10	10	10	10	10	10	10
	1.500	24	10	10	10	10	10	10	10	10	10
	2.000	26	10	10	10	10	10	10	10	10	10
	2.500	27	10	10	10	10	10	10	10	10	10
	3.000	29	10	10	10	10	10	10	10	10	10
	3.500	31	10	10	10	10	10	10	10	10	10
	4.000	33	10	10	10	10	10	10	10	10	10

Fig. 4: Melting capacity of salt depending on precipitation, road surface temperature and traffic including drift and discharge losses during a treatment cycle.

Based on the holistic model, the required application rate as a function of precipitation or snow depth, temperature and traffic volume in the treatment interval is provided in grams per square meter (Figure 4). In the coloured region up to a maximum application rate of 40 g/m², the road can be kept free of snow and ice during the whole treatment interval. In the grey-coloured areas a preventive treatment with 10 g/m² is sufficient to form a release coating according to the previous presented strategy. The given application rates from the model are calculated on the conservative side, considering the upper limit of precipitation. In addition, the heating of the wheel tracks due to traffic volume of about 0,001 °C per car and hour is neglected. This has a considerably positive effect on thawing, especially in temperature ranges between 0° and -2° Celsius on heavily loaded roads. Taking into account the reserves and/or a cascaded treatment, the controllable area with snow and ice-free roads may be expanded substantially. However, this has to be compared against the substantially higher salt costs and environmental impacts and local uncertainties and is therefore usually only an option under special circumstances or on highways.

6. ROAD SAFETY: DRIVING AND TREATMENT RECOMMENDATIONS

In addition to the treatment principles, application rates for typical scenarios based on the developed model are presented. These scenarios consist of the road condition and weather development descriptions according to their importance for winter maintenance vehicle drivers and road users (Figure 5). These scenarios are illustrated with pictures of typical road conditions along with an overview of winter maintenance strategies and driving recommendations. The treatment recommendations based on typical road situations should not replace the expertise and responsibility of the winter maintenance staff including the adaptation of the application rate on special local requirements (e.g. on bridges, drain asphalt, etc.). However, they can help to harmonize the appraisal of the situation in order to achieve better winter maintenance results.

In the first scenario with dry roads a preventive treatment with 5 to 10 g/m^2 is only necessary, if road surface temperatures are expected to drop below 0°C and hoarfrost is to be expected. Wet roads are in general no problem if road gradient and drainage work well and no freezing is to be expected. However, if road temperatures are below zero and rain is to be expected the situation may become very critical with a preventive treatment of high amounts of salt being crucial. If there is already snow on the road it depends whether or not the snowfall continues. If there is no more snowfall ploughing and salt application until a full removal of snow are appropriate. With further snowfall it depends whether or not the snow can be thawed in the treatment cycle. If ice is already on the road (due to a lack of preventive treatment) it is best to send out warnings and operate at full capacity.

With the minimum curve radius and necessary range of sight from the planning guidelines in Austria (eg. RVS 03.03.23) as well as the required minimum skid resistance, safe driving in both dry and wet conditions is possible (Figure 5). With snow or ice on the road, careful driving and a reduction of the speed compared to the actual speed limits is required. Since a snow-covered road is usually accompanied by snowfall and poor visibility conditions, the resulting braking distances are particularly problematic. Due to these conditions the necessary braking distances cannot be met without a severe reduction in speed compared to the speed limits. Based on the noticeable road conditions, a good assessment of the situation becomes feasible. With the holistic model, an adapted driving behaviour for safe driving in accordance with § 20 of the road traffic regulations (STVO) from 1964 can be defined. The driver can assess the road conditions according to the reference images and should therefore be able to reduce the speed accordingly.

Picture documentation	Road conditions	Treatment recommendations	Driving recommendations
Dry Road:	**Very good (usually no problems)**	**Minimal salt application:**	**No limitation:**
	High skid resistance μ = 0,7 – 1,0 Road surface temperature -30°C to + 60 °C	No treatment required	No restrictions within speed limits based on road conditions are required.
	No sleekness due to hoarfrost expected	No treatment required	The road is generally safe to use within speed limits
	Sleekness due to hoarfrost possible	Preventive Treatment 5 - 10 g/m² with beginning hoarfrost (usually between 02:00 - 04:00)	The road is usually safe after treatment (consider visibility in case of fog!)
Wet Road:	**Good (black ice possible!)**	**Treatment only at tempetrures below 0°C**	**Speed reduction nessecary:**
	Road surface temperature ≥ 0°C no spray Medium skid resistance μ = 0,4 - 0,7	No treatment required	Adapted driving style
	Spray medium to low skid resistance μ = 0,3 - 0,6	check lane grooves (risk of aquaplaning)	Speed restriction when lane grooves below 70 km/h (highways and regional roads)
	Road surface temperature < 0°C risk of black ice; very low skid resistance μ = 0,1–0,6	Preventive treatment is crucial! Ploughing & salt application from 20 to 40 g/m² & warning messages	Risk of black ice, massive speed reduction below 30 km/h or walking pace is highly recommended
Snow next to wheel tracks:	**Fair (problems when changing lanes)**	**Ploughing and salt application as required**	**Careful driving and speed reduction necessary:**
	No snowfall	Ploughing and salt application 20 - 30 g/m²	Adapted driving style. Speed reduction of 20 - 30%
	Wheel tracks dry or weg skid resistance μ = 0,3 – 0,5	Ploughing and salt application 10 - 20 g/m² when less than 0,5 cm snowfall in treatment interval	Adapted driving style. Speed reduction of 20 - 30%
	Snowfall, Snow remains in wheel tracks (grey - white surface) low skid resistance μ = 0,2 – 0,4	With snowfall > 0,5 cm ploughing & salt application of 10 g/m² until end, then 20 g/m² to 30 g/m²	Adapted driving to road conditions, reducing the speed limit by up to 50%
Snow in wheel tracks:	**Bad (very low skid resistance)**	**Ploughing and salt application as required**	**Adaptive driving and speed reduction necessary:**
	No snowfall, cleared low skid resistance μ = 0,2 - 0,3 road surface temperature ≤ 0°C	Treatment with ploughing and salt application to clear the road of snow	Reducing the speed limit below 80 km/h (highways) and below 50 km/h (regional roads)
	Snowfall, cleared, not cleared, precipitation < 0,5 mm in treatment interval (≈ 3 - 5 mm snow)	Preventive treatment prior to preciptitation event if possible, then ploughing and salt application	Reducing the speed limit below 70 km/h (highways) and below 50 km/h (regional roads) - Visibility!!
	Snow > 0,5mm in treatment interval low skid resistance μ = 0,2 - 0,3 road surface temp. -20°C to 0°C	With snowfall > 0,5 cm ploughing & salt application of 10 g/m² until end, then 20 g/m² to 30 g/m²	Reducing the speed limit below 50 km/h (highway) and below 30 km/h (regional roads) - Visibility!!
Black ice:	**Critical (almost no skid resistance)**	**Mechanical removal & maximum salt application, closing of roads:**	**Driving restrictions (walking pace may be allowed)**
	No precipitation Roadway surface satin silk to reflective Almost no skid resistance μ=0,1–0,2 Precipitation (Snow) Road surface temperature ≤ 0°C	Preventive treatment if possible, maximum salt application at icy parts. Staggered treatment. Closing of roads only in consultation with the police, then mechanical removal combined with maximum salting to remove the ice. Best strategy to avoid accidents is to close the roads until a sufficient skid resistance is reached again.	Possible driving restrictions have to be considered. Postpone unnecessary trips. During a trip continue in exceptional cases and reduce velocity on potentially dangerous parts to walking pace.

Fig. 5: Typical weather and road conditions with winter maintenance and driving recommendations for highways and regional roads in Austria [1;4]

7. TRAINING AND FEEDBACK OF WINTER MAINTENANCE STAFF

For the winter service staff training sessions were conducted before the start of winter. Especially the driver of the salt-spreading-trucks were invited. For the further optimization of this training program a questionnaire for an assessment of the guidelines and training course were created. The results of the survey for the training course (Figure 6) show a high acceptance of the training content. The winter maintenance guidelines (Figure 7 and Figure 8) had a similar high appraisal.

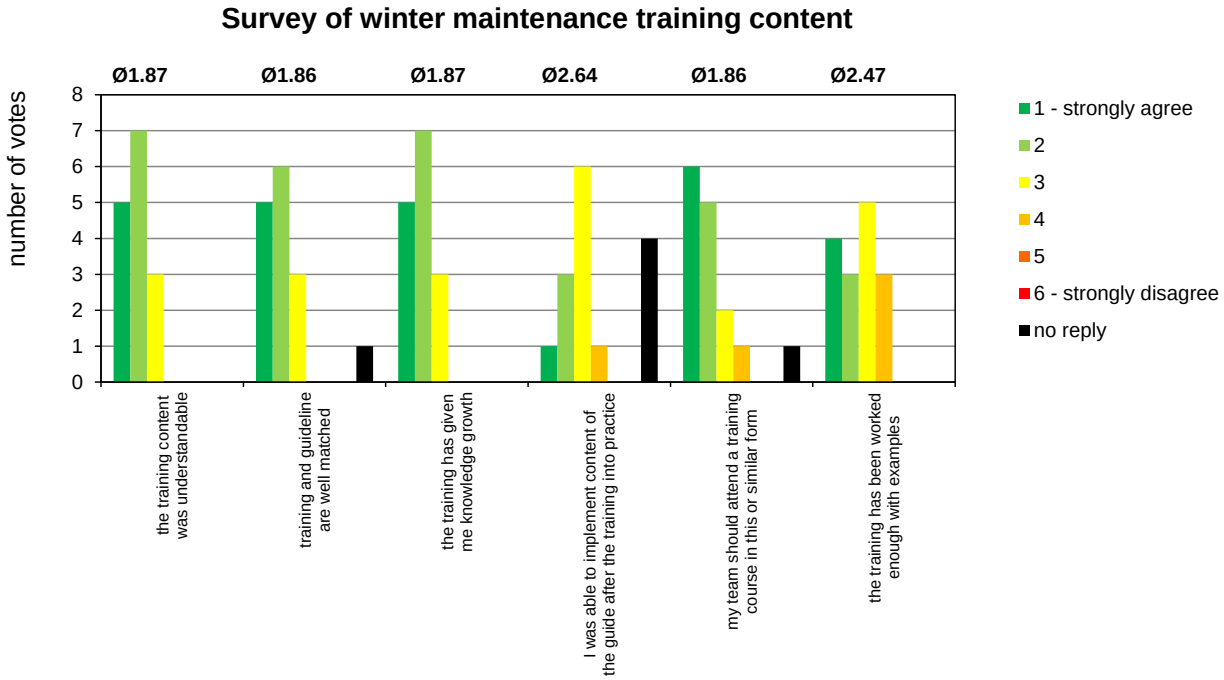

Fig.6: Survey of winter maintenance training content for road maintenance personnel in Lower Austria 2012

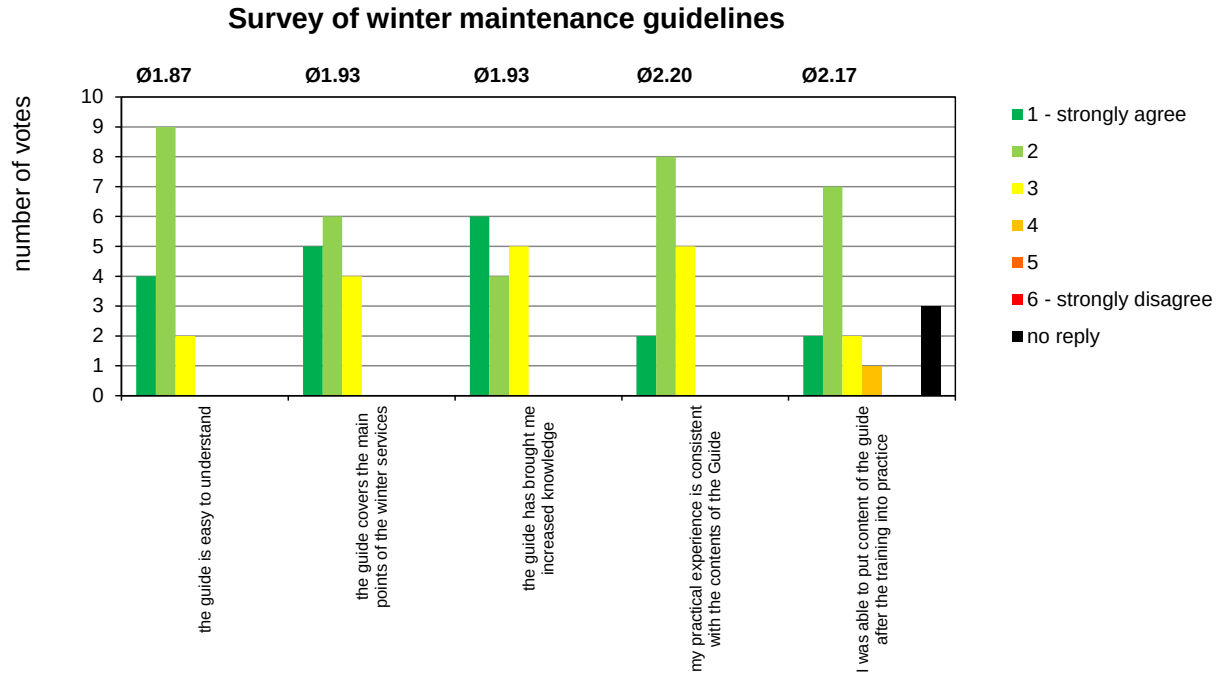

Fig.7: Survey of winter maintenance guidelines for road maintenance personnel in Lower Austria 2012 in general

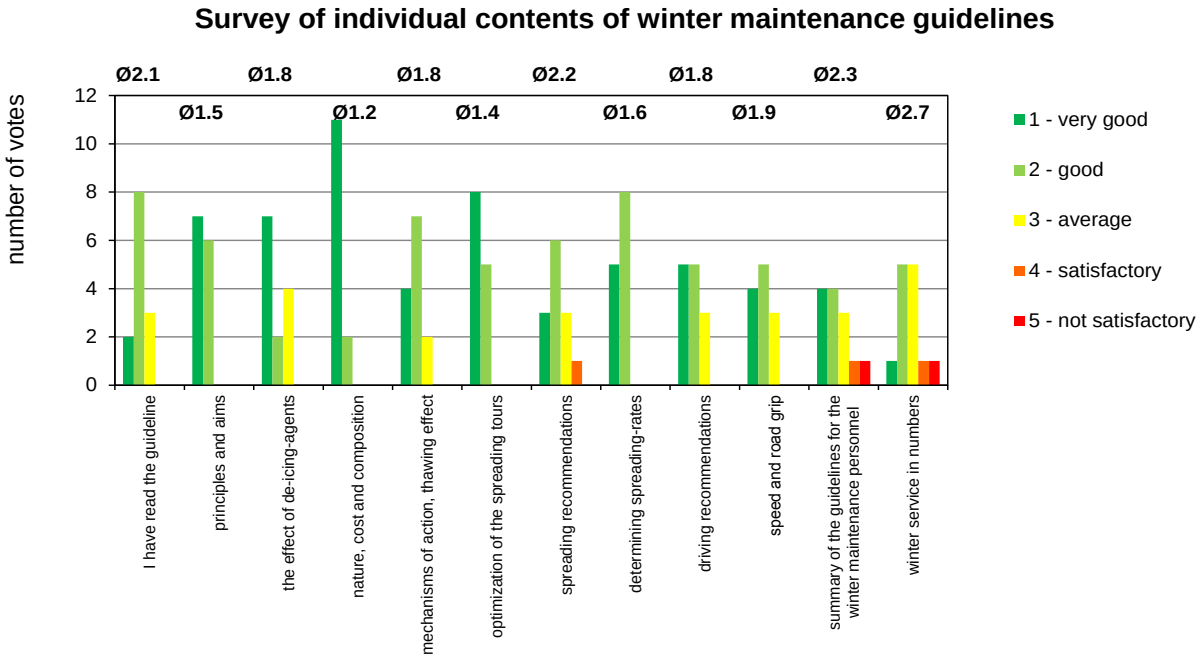

Fig.8: Survey of winter maintenance guidelines for road maintenance personnel in Lower Austria 2012 in detail

8. CONCLUSIONS AND OUTLOOK

The planning guidelines in Austria for highways and regional roads minimize accident risks during dry or wet conditions due to a lack in skid resistance given the compliance of speed limits. With snow or ice on the road, careful driving and a reduction of driving speed compared to actual speed limits is required. Since these conditions usually come with snowfall and poor visibility, the necessary braking distances to avoid collisions are usually insufficient without severe speed reductions. The goal of winter maintenance is to improve the accessibility of regions and the safety of the roads during the long winter periods in Austria. The physical impact of salting is to lower the freezing point temperature of the solution of de-icing agents and precipitation on the road below road surface temperature. To make this possible, the accumulating snow has to be cleared constantly and the salt losses due to spreading losses and scattering have to be replaced. With the developed holistic winter maintenance model these processes considering all important influence factors can be simulated. With this simulations the optimal timing, necessary application rate of de-icing agents and costs of each treatment cycle can be predicted.

Further experiments to verify and improve the model will continue during the next winter periods on highways and regional roads in Austria as well as the laboratory of the Institute of Transportation. With the joint efforts of all project partners, we will be able to implement further improvements, both to the model and the winter maintenance practise. In the medium term our goal is the implementation of the model as a semi-automated decision system in order to create winter maintenance forecasts for all main roads in Austria. The developed winter maintenance guidelines are based on the findings of the model and are already implemented on highways and state roads in Austria. The guidelines are constantly evolving and have delivered promising results towards better road conditions and cost savings. But even the best guidelines cannot replace a careful, responsible adaptation of the strategies and application rates by the winter maintenance personnel. Above all stands a responsible and adapted driving style in order to achieve safer roads for all road users.

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