www.piarc.org
2023R39EN

INTEGRATION OF NEW TECHNOLOGIES IN WINTER SERVICE

A PIARC TECHNICAL REPORT

TECHNICAL COMMITTEE 3.2 *WINTER SERVICE*

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2020– 2023 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

This report is available from the internet site of the World Road Association (PIARC): http://www.piarc.org

World Road Association (PIARC)
Arche Sud 5° niveau
92055 La Défense cedex, France

International Standard Book Number: 978-2-84060-827-1

Front cover © Heimo Maier-Farkas MSc

INTEGRATION OF NEW TECHNOLOGIES IN WINTER SERVICE

A PIARC TECHNICAL REPORT

TECHNICAL COMMITTEE 3.2 *WINTER SERVICE*

AUTHORS/ACKNOWLEDGMENTS

This report has been prepared by the working group 3.2.1 as a part of the Winter Service PIARC Technical Committee in the 2020 – 2023 cycle. The TC was chaired by Peter Nutz (Austria). Julius Janeba (Czech Republic) was responsible for collecting case studies in this report.

The authors of this report are:

- Shogo Hayashi – Japan
- Julius Janeba – Czech Republic
- Otto Karki – Finland
- Marek Kasprzyk – Poland
- Maciej Kędzierski – Poland
- Peder Kristian Strømsvåg – Norway
- Janne Lappalainen – Finland
- Øystein Larsen – Norway
- Ryo Nakatani – Japan
- Peter Nutz – Austria
- Tomonori Ohiro – Japan
- Takanobu Onishi – Japan
- V.Partanen – Finland
- Jarkko Pirinen – Finland
- Petteri Tahvanainen – Finland
- Junichi Takato – Japan
- Kaszue Usui – Japan

EXECUTIVE SUMMARY

2023R39EN

INTEGRATION OF NEW TECHNOLOGIES IN WINTER SERVICE

A PIARC TECHNICAL REPORT

The purpose of the technical committee PIARC is to share knowledge. The technical committee Winter Service has been handling new approaches that can help perform road maintenance in winter conditions more effectively, environment friendly and with focus on users' needs. In the cycle 2012-2015 the final report "ADVANCED TECHNOLOGY FOR DATA COLLECTION AND INFORMATION TO USERS AND OPERATORS" was devoted to mutual communication and its further development. The next cycle ended 2015-2019 brought comprehensive collection "INTERNATIONAL DEVELOPMENT OF APPLICATION METHODS OF DE-ICING CHEMICALS – STATE OF ART AND BEST PRACTICE", that described trends especially in the field of de-icing materials.

In 2023, another cycle of 3.2. Winter service Technical Committee has come to its end. There were various topics discussed in frame of working group "3.2.1 INTEGRATION OF NEW TECHNOLOGIES IN WINTER SERVICE". This time there was no key issue, however, interesting experience from diverse themes and countries have been discovered. As a result of this effort, this collection of case studies has been gathered. On the following page, you can read some examples of progressive approach in the winter service technology. Nine case studies from six countries create a short excursion to modern maintenance attitudes. We hope they will bring you inspiration and new ideas. At the beginning of each study, author's email address is added to further contact, if useful.

CONTENTS

1. INTRODUCTION

In each country road administrators face different conditions. In the winter service plans they must consider many factors. Legal regulations, current road network condition and traffic demands, own equipment, and background available for the service performance, environmental issues, and finally cost effectiveness. Using spreading materials varies, but overall greater liquid proportion has shown as a reasonable way to secure long-lasting safe traffic conditions, above all in the conditions around freezing point. We can also see increasing importance of good weather prediction, well-timed preventive interventions. In some countries regional roads are spread with abrasives until today, whereas underwater and soil protection is the main argument against de-icing materials.

Technology progress affects all fields of industry and services, winter service cannot be an exception. Each ride of a spreader is monitored with dozens of sensors. Accurate position and other activities are delivered to online applications, that can be checked by all road-users. Visual information from cameras can be also both for operational needs and public. Great effort is then given into optimalisation of winter service. Every kilometre of mechanisation driven; every single gram of de-icers sprinkled should be carefully considered before done. Decision making process can be performed perhaps better with the aid of modern technology, or even artificial intelligence. Yet, human factor is still the most important and critical. Road administrators need experienced professionals behind the steering wheel, as well as at the management office.

There are many ways how new technologies can help improve winter service. In the case studies, following topics are being explored:

- Application of de-icing materials, alternative use of abrasives
- Environmental issues of de-icing materials
- Technology for data collection and sharing between users and operators
- New technologies to ensure most efficiency in winter service
- Technologies for handling of extreme weather situations
- New trends to improve specific tools in winter service

2. MONITORING AT MILK ROADS

Jarkko Pirinen & Otto Kärki
Finnish Transport Infrastructure Agency, Finland
jarkko.pirinen@vayla.fi & otto.karki@vayla.fi

V. Partanen & Janne Lappalainen
Centre for Economic Development, Transport and the Environment of North Savo
janne.lappalainen@ely-keskus.fi

Petteri Tahvanainen
Valio Ltd
petteri.tahvanainen@valio.fi

2.1. Abstract

In Finland, the condition of roads is monitored in different ways. The most typical methods are monitoring by fixed roadside equipment and road inspection by supervisors, contractors and supervision consultants. The roadside equipment network is moderately comprehensive on the main road network, but only very few on the lower road network. In this project, the approach is different than in normal road monitoring. The idea is that milk trucks would act as measure units. Milk is collected 24/7/365, geographically covering the entire country. Milk trucks travel around 18,000 km / month / vehicle, especially on the lower road network. Milk collection is a very strictly timed and optimized activity, the efficiency of which is undermined by unexpected weather or road conditions.

The aim of the pilot is to create an operating model and tools for real-time reporting of abnormal weather and road conditions. Milk trucks are connected in real time through their cabin terminals to the dairy company's operating system. The pilot involved the Finnish Transport Infrastructure Agency (FTIA), Centre for Economic Development, Transport and the Environment of North Savo (Ely-centre) and Finland's largest dairy company Valio Ltd.

In the first phase of the pilot, functionality was created for the milk truck cabin terminal to make a road condition report. In the second phase of the pilot, the possibility of attaching images to reports. In the third phase system expanded from three to 85 vehicles of the dairy company. The pilot was launched in 2015 and has continued to 2018. The pilot was tested in other areas and milk route reporting has expanded to several area maintenance contract after the pilots.

In the project, the programming company was responsible for creating the vehicle operating system and adapting it to the dairy company's operating system. The integration of FTIA's road maintenance monitoring system (HARJA) implemented with the other development of HARJA, which enabled efficient information sharing to various contractors and regional managers.

The experiences of the project have been good for example, reports are not substantiated and relevant, no unnecessary notifications and dairy truck drivers found reporting meaningful. Maintenance needs have identified faster, and maintenance work done earlier. Maintenance contractors have also been for correct feedback from client. Project's actions have reviewed by project's steering group. In some cases, this information has helped to find root factors to maintenance deficiencies. Overall, the original objectives have achieved through better access to information and faster repair action.

2.2. Introduction

The Milk Road pilot is based on the preliminary study (Malmivuo 2015) and the project plan made through it, prepared by the Finnish Transport Agency, Centre for Economic Development, Transport and the Environment of North Savo and Valio Ltd in cooperation with the Utilization of real-time data from milk collection in the maintenance of the service level of the road network.

In Finland, the condition of roads is monitored in different ways by the customer. The most typical methods are fixed monitoring through roadside devices and field visits by supervisors, contractors and supervision consultants. The roadside device network is moderately comprehensive on the main road network, but very sparse on the lower road network. In the Milk Road project, the approach is different from normal monitoring. The idea is that the milk trucks would act as measuring devices. Milk is collected 24 hours a day, seven days a week, every day of the year, geographically throughout the country. Milk trucks circulate especially on the lower road network approx. 18,000 km/month/vehicle. Collecting milk is a very precisely timed and optimized operation, the effectiveness of which is weakened by unexpected and exceptional weather or road conditions.

During the project, the reporting and monitoring system used by the FTIA's maintenance contracts was renewed and its name became HARJA. Users of the HARJA system are able to get real-time updated screens and reports of the work done, as well as monitor e.g. road maintenance, maintenance measures and feedback from road users in one place. Feedback from road users coming to Traffic management centre is forwarded directly to contractors using the HARJA system.

2.3. Project goals

The goal of the pilot is to create an operating model and tools for real-time reporting of unusual weather and road conditions and targeting of maintenance activities and improving timing. The idea was that the milk trucks are connected in real time through their cabin terminals to the milk company's operational control system and servers in order to control the collection and monitor the quality. Participated in the pilot Finnish Transport Infrastructure Agency (FTIA), Centre for Economic Development, Transport and the Environment of North Savo (Ely-centre) and Finland's biggest milk producer company Valio Ltd.

2.4. Project stages

2.4.1. Preliminary study

In the preliminary survey, was thought about what data (e.g. friction, unevenness, snow) could be produced? By what means, taking reliability etc. into account, would the information be obtained using different mobile technologies or otherwise develop the interaction between the milk truck drivers, the road manager, and the contractor, as well as the mutual sharing and utilization of information. The monitoring system used in milk trucks would enable, with relatively small changes, feedback on the condition of the road to be given directly from the vehicle. We would also like to be able to attach a picture to the feedback. In addition, the possibility of using sensor technology or car systems in further development was left. Utilizing the tracking system used in the milk truck was considered a good idea for further development. As a result, it was agreed to start the pilot in stages.

2.4.2. First stage of project

In the first phase of the pilot, functionality was created for the cabin terminal of the milk trucks to create a road condition report (location, form base, sending protocols) and for the KAMU server functionality for forwarding reports to the road manager and contractors as email and text message, and for archiving as a database.

Deviation notification of maintenance is needed, when

- Exceptional snowfall, which slowdown the schedule (a lot of snow or heavy drifting of snow)
- Exceptional slipperiness. Can't stay on schedule.
- Severe pavement damage that endangers traffic.
- Frost heave that makes difficult to stay on schedule (lowered carrying capacity).
- Fallen trees on the road.
- Frozen culverts that lift water onto the road or otherwise flooded areas.
- Very bumpy gravel road. Significantly slows driving and staying on schedule.

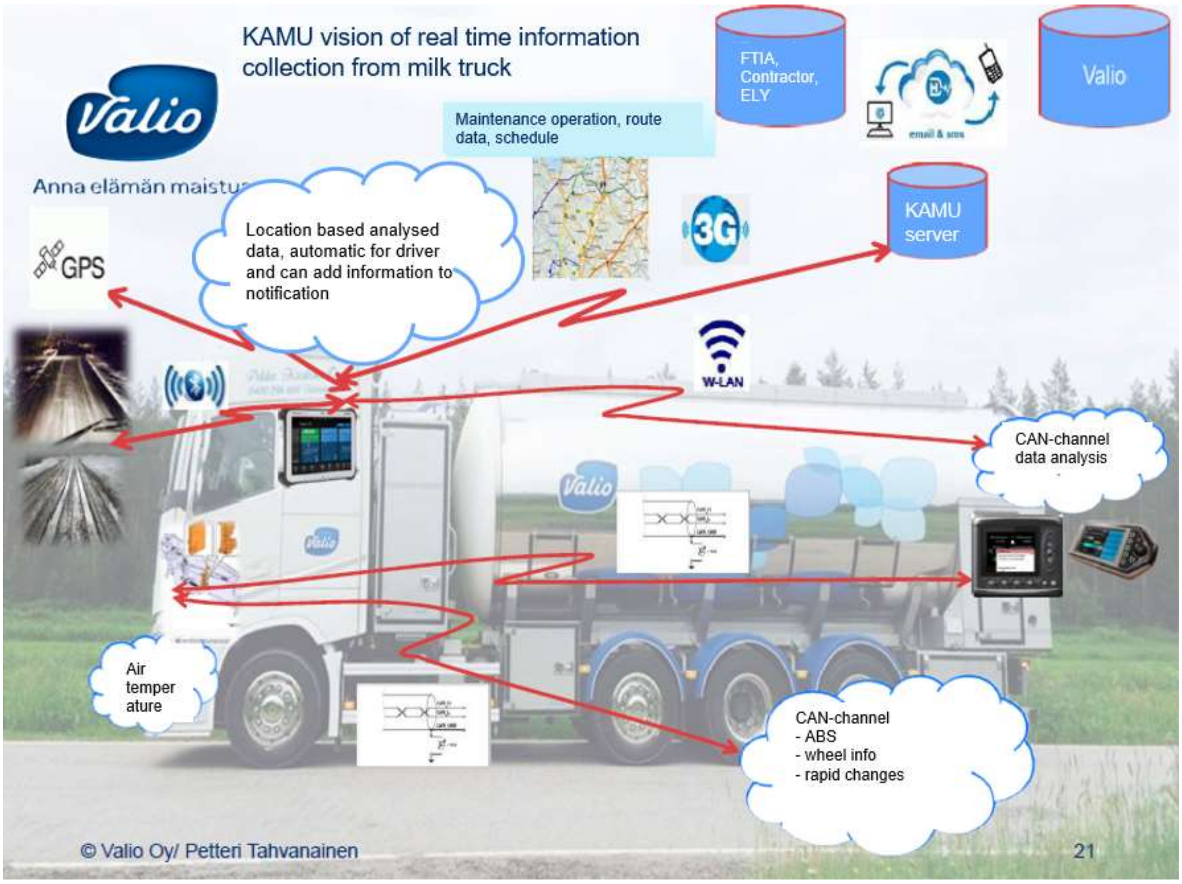

Figure 1 – KAMU vision of real time information collection from milk truck

The reporting functionality was tested in three pilot vehicles operating in the area of the Kiuruvesi and Iisalmi regional maintenance contracts. The testing started in December 2015. Encouraged by the good experiences, it was decided to continue the testing until the end of the year, deviating from the original plan (June 2016).

2.4.3. Second stage of project

In the second phase of the pilot, the option to attach still automatically and manually images to road condition reports was created. Still image series increase the report's informativeness and facilitate the contractor's response and, on the other hand, the targeting of the client's supervision. The vehicle cameras were programmed to take a still image at certain time intervals, from which a series of images from the reporting point (before/after) of a certain period of time is recorded in the report. Positioning is also automatically obtained from the reporting point.

The piloting of the second phase was tested in three vehicles that operated on the roads of the Kiuruvesi and Iisalmi regional maintenance contracts. The road condition reports were distributed to regional contractors and regional managers trained in the operating model via the KAMU server or with a manual LIITO message (later called HARJA-message) made by the Finnish Transport Agency. A wider implementation would have required the integration of the Finnish Transport Agency's systems and the training of all regional maintenance contractors and supervisors into the operating model.

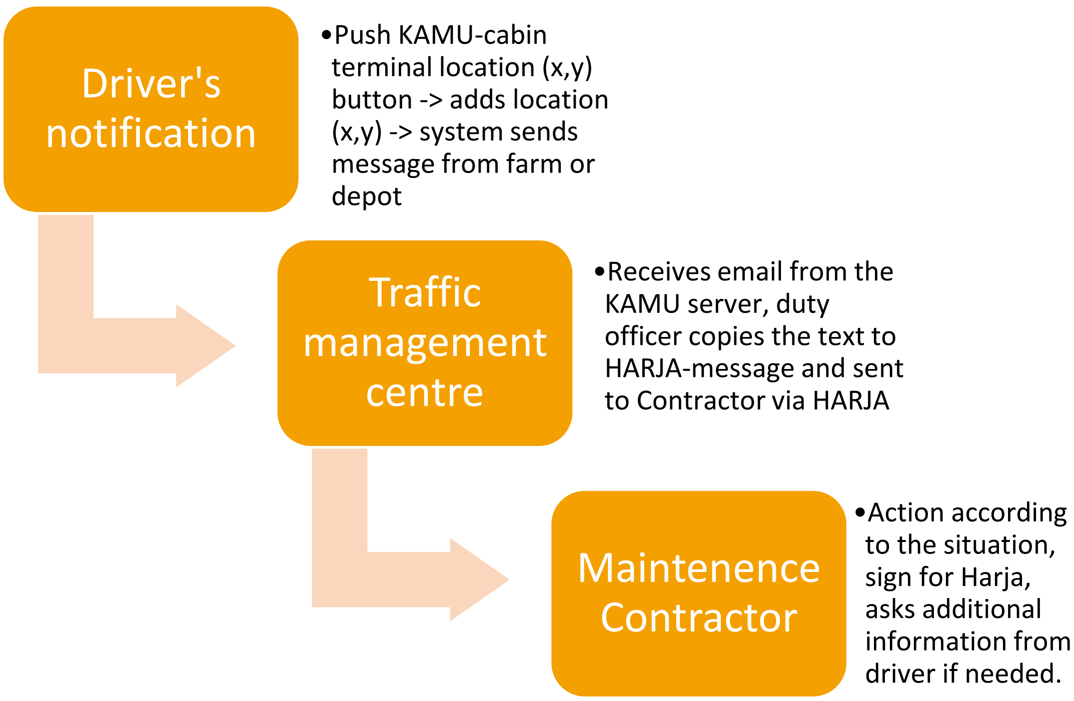

Figure 2 – KAMU operating model

In March 2017 The pilot was expanded from three to five vehicles when, in addition to Kiuruvesi and Iisalmi, the Parkano and Sastamala regional maintenance contract areas were included. In the beginning, there were problems with attaching the pictures, because the cameras in all vehicles did not stay online. The problem was removed with a software update. The conversion of the location data into a road address was made to work, the FTIA uses the road address instead of x,y coordinates. Use of the road address is easier for the contractor and the supervisors. It is not possible to add images to the HARJA system, but an image link was made in the HARJA messages for viewing the image. The pictures increase the information in the reports, serving the Traffic management centre as well as the regional maintenance contractor and the supervisor.

2.4.4. Third stage of project

In the third phase of the pilot, the number of vehicles was expanded to several dozen vehicles. In the project, the programming company was responsible for creating the vehicle's operating system and adapting it to the milk company's operating system. The milk company was responsible for the distribution of the software to the vehicles and driver training for its own personnel. The integration of FTIA's road maintenance monitoring system (HARJA) was carried out in connection with the other development of HARJA, which enabled efficient information sharing to different contractors and regional managers. In the third stage, it was also intended to add the selection of the prioritization of maintenance work of HARJA-message (TUR= action needed / scheduled work, TPP= needs immediate action / serious problem). The third stage of the project was finished at the end of 2018.

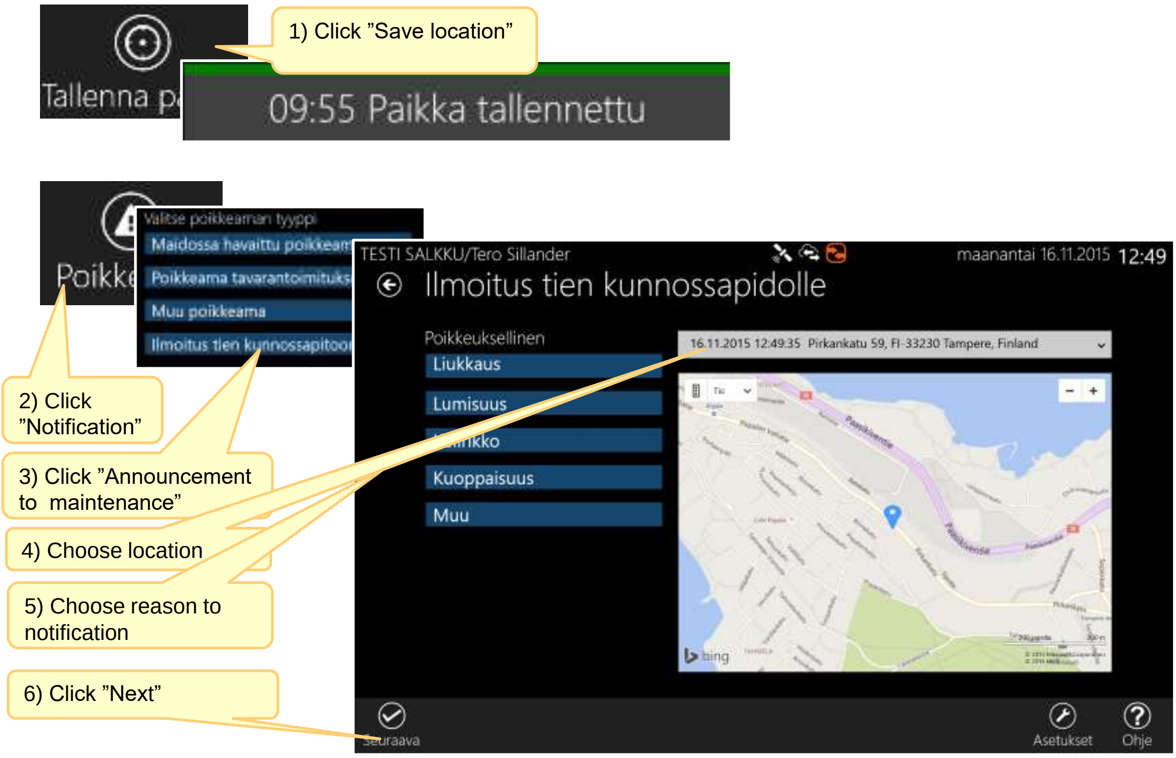

Figure 3 – KAMU user interface

2.4.5. Using system

The system was taken into production use in 2019. The system has been put into use more widely than the original area in central Finland. The introductions have been made with the same concept as in the pilot phase. Use has been incorporated into normal operation. Follow-up meetings are held locally, which have been considered good information exchange meetings, problems have been solved and activities have been developed. In addition, steering group meetings are held a few times a year, where the entire country's situation is reviewed, and information is shared with different parties.

Observations along the same lines have been seen in all areas: in the first years, places that cause problems are typically found - the contractor learns to maintain these points or areas better, after which the number of feedback drops, i.e. FTIA and ELY-Centre get closer to customer-oriented road maintenance.

Operations have been normalized and the new KAMU 2.0 is already being prepared in 2022. The new system will improve the information system and usability. KAMU 2.0 also enables the use of additional features in the future.

2.5. Results

Experiences from the project have been good, e.g. the reports are justified and appropriate, there are no pointless or unnecessary notifications and the drivers felt the reporting was meaningful. In the pilot areas, it has been possible to monitor the lower road network more widely and more often than previously. As a result, maintenance deficiencies have been detected more quickly on the road and deficiencies have also been repaired earlier. The maintenance contractors have also been satisfied with the right kind of feedback.

The activity has been monitored through a local monitoring group formed by different parties. In some cases, based on this information, it has been possible to get to the root causes of maintenance deficiencies. The activity has been perceived as successful and we are ready to continue the activity and even willing to expand the activity.

2.6. Conclusions

As a whole, it can be said that the original goals have been achieved in terms of better access to information and speeding up maintenance procedures and lower road network monitoring is better covered.

It can be said that with the cooperation of a major road user, better results can be achieved, and it is possible to offer a better-quality level for the customer's needs at a normal cost level.

REFERENCES

- Hänninen, H. (2019). Maitoautopilotin kolmas vaihe - Final report, Tieto Ltd
- Lappalainen, J. (2018). Maitotiepilotti - PowerPoint slide show, Centre for Economics, Transport and Environment
- Malmivuo, M. (2015). Maidon keräilyn reaaliaikaisen tiedon hyödyntäminen tieverkon palvelutason ylläpidossa, Finnish Transport Agency

3. VIENNA MODEL FOR THE INFILTRATION OF ROAD WATER

Peter Nutz
City of Vienna, Austria
peter.nutz@wien.gv.at

3.1. INITIAL SITUATION AND PROBLEM DEFINITION

In order to ensure optimal usability of the public road network in winter and at the same time to keep fine dust emissions from winter road maintenance low, the Municipal Department 48, which is responsible for winter road maintenance, prefers to use modern pre-wetted salt or brine sprinkling in the event of black ice and snow, which significantly reduces salt consumption. However, in order to protect green spaces, soil and groundwater, the application of pre-wetted salt or brine is only permitted in the following streets according to the Winter Service Ordinance of the Municipality of Vienna:

- Public transport roads incl. bus stops
- bridges
- cycle paths / footpaths and cycle tracks
- roads with a structural boundary to unsealed ground surfaces and
- Streets with drainage of surface water into the public sewer system.

Due to the above-mentioned provisions of the Winter Service Ordinance, MA 48 rejects the infiltration of surface water in all Viennese streets and paths that do not fall under the above-mentioned exemption. Conventional infiltration of surface water into roadside green troughs is thus not possible in part of Vienna's road network.

For ecological reasons, but also to avoid overheating of the public space, the goal is to infiltrate as much precipitation water as possible into roadside swales or, even better, to allow it to evaporate.

Ultimately, in connection with climate change, there is an increase in heavy rainfall events in Vienna, which in some cases exceed the capacity of our sewage system. If appropriately dimensioned, roadside green swales can provide sufficient retention space for rainwater during heavy rainfall events and thus ensure the necessary flood safety.

In order to meet current ecological and urban climatic goals and requirements on the one hand, and to comply with the provisions of the Winter Service Ordinance on the other, the Viennese model for infiltration of surface water in public road space was developed.

Within the framework of a pilot plant in aspern Urban Lakeside, the developed system is to be tested for practical suitability over a period of 3-5 years by means of accompanying monitoring and, if necessary, adapted. Subsequently, it is planned to extend the pilot test to the new streets of the Urban Lakeside North and thus to apply it on a broader scale.

3.2. DUAL SYSTEM OF ROAD DRAINAGE

3.2.1. Central principle

The "Vienna Model" for the infiltration of road water provides for the discharge of chloride-contaminated winter water into the sewer and the separation of chloride-free road water for infiltration in roadside swales.

3.2.2. Central requirements

- Discharge of chloride-contaminated road water in winter
- Infiltration of the less polluted road water into roadside swales.
- Low discharge into partly overloaded sewers
- Flood safety during heavy rainfall events
- Uncontrolled system - self-circulating - as simple as possible!
- High operational safety / simple maintenance
- At the lowest possible cost
- Attractive green design in the street space

3.2.3. Valid legal situation

Keyword WRG, EU-WRRL, EU-HWRL, QZV Chemie GW, Winter Service VO of the Province of Vienna etc.

3.2.4. System description

- Collection and storage of chloride-polluted road water by means of inlet shafts in the system of an elevated, small-dimensioned DN 150 storage channel.
- The inlet chambers are constructed in accordance with the MA 28 60/60 cm data sheet with a pump sump and a removable throttle plate with DN 30 borehole and possibly a dirt basket.
- Throttling of the storage channel as low as technically controllable (for maintenance)!
- Qab of the throttle depends on the throttle cross-section and on the damming height.
- The roadway/walkway separation to the infiltration trough is made by means of 4 cm high ledge stones up to the respective inlet shaft, then a level field of 2.0 m as trough inlet.
- Inlet shafts serve as high overflows to the infiltration trough B = 6.60 m,
- Discharge of all events after full filling of the storage channel (catch basin)
- Connected sealed area: approx. 2,000 m² road surface and approx. 1,300 m² ÖDG (via separating structure)

3.3. DESCRIPTION OF THE PILOT PLANTS

3.3.1. Seepage troughs Edith-Piaf-Straße

In the southern section of Edith-Piaf-Strasse in aspern Urban Lakeside - BT Süd, four cascade-shaped seepage troughs will be constructed, which are connected to each other by a separating dam with trough overflow. Between the second and third swales there is a concrete swale with a box channel underneath.

The street water is discharged into throttled inlet manholes. The throttle is dimensioned in such a way that the heavily loaded surface water (especially in winter) is discharged in its entirety into the elevated roadside storage channel. During peak rainfall events, there is an overflow from the throttled inlet shafts into the seepage troughs (cf. enclosed plans and system description under point 3).

For the individual swales, the terrain conditions, the different inflow volumes of the swales as well as the varying sizes of the connected catchment areas result in different flooding safeties. For example, Swales 2 and 3 relieve Swales 1 and 4 from a rainfall event of about 5 years. However, for the entire system of seepage swales in Edith-Piaf-Strasse, there is a 30-year flood safety.

Due to the low load of the discharged surface water, an attractive green design of the swales with trees and grasses is possible. Six tree species are planned (maple, hackberry, ash, leather pod tree, wild pear and elm).

3.3.2. Separating public passageway

The most northerly of the soakaways described in section 2.1. is used as a separating structure to channel road runoff from the adjacent public thoroughfare. With the help of this separating structure, it is possible to infiltrate less polluted surface water during heavy rainfall events. Here, too, the more heavily polluted surface waters (especially the chloride-contaminated winter waters) are fed into the sewer system with the first flush through a throttled outlet.

The developed separating structure enables the infiltration of surface water if roadside green swales are not possible, e.g. for reasons of space.

3.3.3. Wide application of the Vienna Model in Urban Lakeside North

In aspern Urban Lakeside, very committed Smart City goals are being pursued. The Urban Lakeside would also like to take on a pioneering role in ecological terms. The aim is therefore to equip the roads and paths in the subordinate road network with green troughs for the infiltration of as much of the road water as possible.

With the help of the pilot systems described in 2.1. and 2.2., experience with the developed "Vienna Model" for the infiltration of street water will be gathered from 2017 onwards and the concept will be further optimised. The aim is to use the system for infiltration of surface water in the course of further development of the aspern Urban Extension area in the subordinate road and path network.

The attached plan ZNR.: 440/2016 provides an overview of the planned drainage of the public roads and paths in the urban development area aspern Urban Lakeside North. According to this plan, traditional drainage into the sewage system is planned for the heavily loaded main traffic routes, such as the access road to the planned S1 junction points Seestadt West and Ost and Sonnenallee. For all other roads with motorised individual traffic as well as the public transport roads, the newly developed "Vienna Model" is to be applied. Pure footpaths as well as footpaths and cycle paths are to be drained entirely via green troughs.

3.4. MONITORING

The following accompanying studies are planned as part of the pilot test at least until the end of 2019:

3.4.1. Water quality

Typical pollutants for road runoff will be monitored in the inflow and leachate of selected infiltration sites by means of scoop samples. In addition, changes in water composition over time will be monitored at selected sites using online water probes (temperature, conductivity).

3.4.2. Substrate

The 30 cm thick natural soil filter consists of humic biological topsoil according to ÖNORM 2506-1. In the tree area, the "Vienna street tree substrate" will be installed. Checking the infiltration and seepage performance of individual infiltration points immediately after completion and at regular intervals using standardised methods. In the laboratory by infiltration rate and slurry grain tests (ÖNORM 2506-3), in the field by infiltrometer in selected test variants. It is planned to monitor the qualitative change of the substrate especially in the area of the inlets and at the tree plantations by means of soil probes (depending on the question: temperature, conductivity, water content).

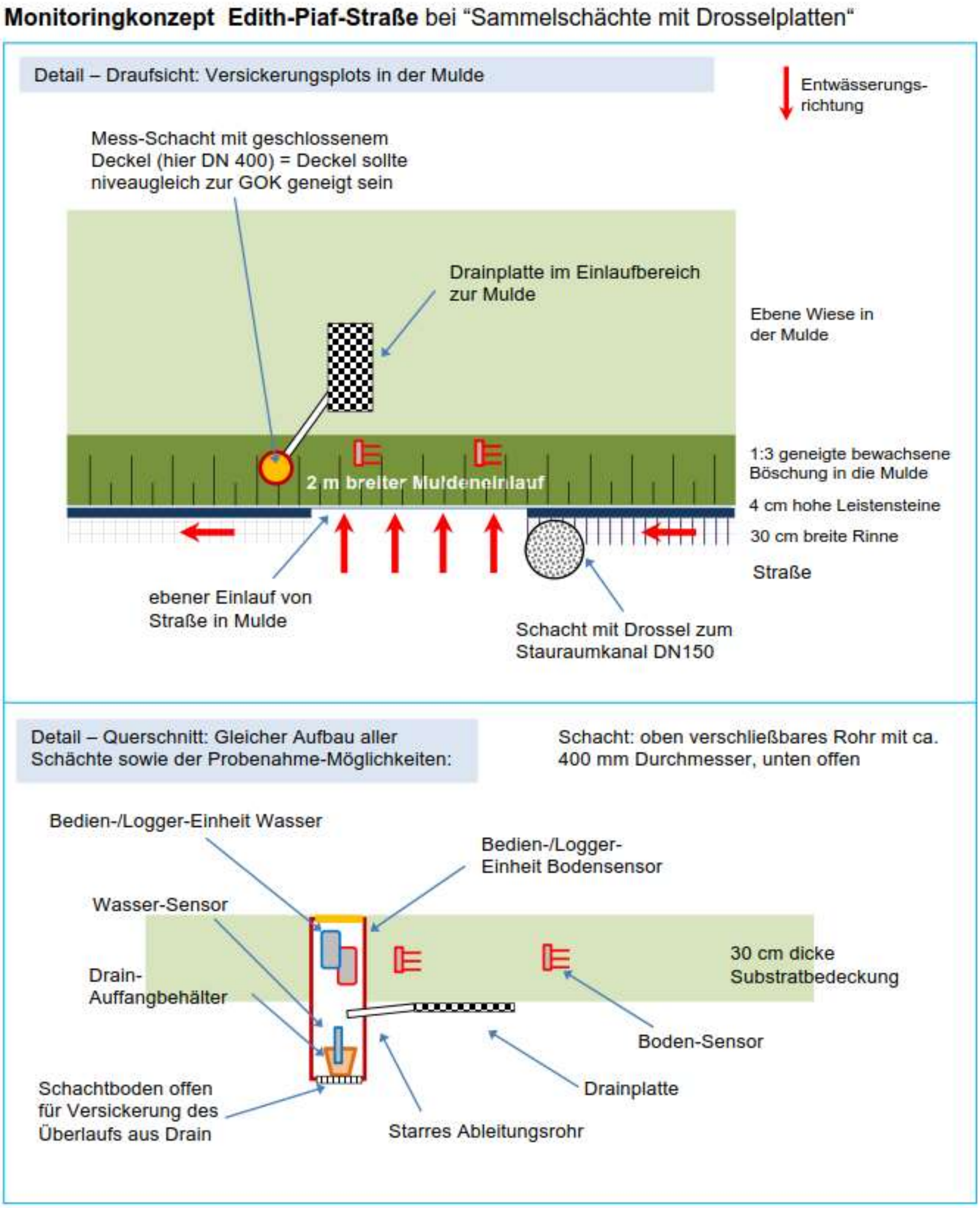

Figure 1 – Monitoring concept, Edith-Piaf street

3.4.3. Planting

In addition to standard lawn seeding, street trees are to be tested for their compatibility with the infiltration trough system in the first stage.

The 6 different tree species that are compatible with the city are: Acer campestre 'Elsrijk', Celtis australis, Fraxinus excelsior 'Altena', Gleditsia triacanthos 'Skyline', Pyrus calleryana 'Aristrocat' and

Ulmus 'New Horizon'. The planting quality corresponds to the standard size of the City of Vienna (H mB Sth 300, StU 20-25) and the planting is done in the Vienna street tree substrate.

3.4.4. Function of the dual system

Field tests: the hydraulic function is tested by applying a known amount of water. The flow rate above which the volume of water can no longer be absorbed by the channel and enters the swale is to be determined. At the same time, the surface can be treated with salt and the discharged salt load over time can be determined.

Online monitoring:

- Separating structure public passage: continuous determination of the water level and conductivity in the manhole (manhole base), determination of the time of overflow into the swale by means of a suitable probe.
- Collection manholes with throttle plates: continuous flow measurement and conductivity at discharge DN 150 to combined sewer

3.5. Project status

It is still on-going.

3.6. Project partners

The project is being carried out by MA 28 together with Wien 3420 Aspern Development AG as the development company for the Urban Lakeside Aspern and at the same time the cost unit for the project in question.
Further project partners in the implementation of the project are:

- MD BD - Environmental Engineering and Official Procedures
- MA 42 - Vienna Municipal Gardens
- MA 45 - Viennese Waters
- MA 48 - Waste Management, Street Cleaning and Vehicle Fleet
- Ingenieurbüro Neukirchen ZT-GmbH as planning office in charge of the detailed planning and dimensioning of the pilot plant
- BOKU Vienna, Institute of Sanitary Engineering, Industrial Water Management and Water Protection (monitoring)
- Vienna 3420 Aspern Development AG

4. NEW SUSTAINABLE CONCEPT FOR SNOW POLES

Peder Kristian Stromsvag
RoadTech, Norway

Øystein Larsen
Norwegian Public Roads Administration (NPRA)
oystein.larsen@vegvesen.no

4.1. INTRODUCTION

A new concept for snow poles reduces waste and costs, prevents plastic in nature and increases road safety. The technology has been tested and developed in Norway and is now ready for the world market.

This innovative solution from the Norwegian company RoadTech is the result of a development project in cooperation with the NPRA and Norwegian road contractors. The purpose has been to develop new technology for a more sustainable handling of snow poles; from production, deployment, and collection to cleaning, recycling and storage.

4.2. CURRENT SITUATION

A large percentage of snow poles in Norway disappear or are damaged during the winter. This may be the result of vandalism or theft, or they may be damaged or knocked down by the snow plough. Missing snow poles represent an increased risk of accidents but is also an environmental problem in that unwanted plastic ends up in nature. At the same time, replacement of the missing snow poles costs considerable amounts of money each year. The work to reinstall snow poles on snowy and slippery winter roads also represents a risk of accidents for the road contractor.

4.3. NEW SUSTAINABLE CONCEPT

The company RoadTech has for several years been working on developing a new concept for snow poles based on the challenges experienced in connection with snow poles. This has been done in close cooperation with the NPRA. Several prototypes have been tested in recent years, and the first machine was sold in 2020. This prototype has so far installed and removed 20,000 snow poles on Norwegian roads. The vehicle is part of a comprehensive concept consisting of an installation machine, screw-down snow poles, a snow pole terminal, and a cloud-based control and follow-up system.

The installation machine is a fully automatic machine for installing and removing snow poles, carrying out these operations at speed. The machine has significantly higher capacity compared to solutions currently in the market and provides improved HSE for the operator and increased road safety. It is built for easy installation on a lorry with standard equipment and is easily operated by the driver. GPS and data collection from the work operation is central, allowing contractors to ensure continuous improvement. There is a storage solution for easy transport and storage of poles, which minimizes extra handling.

Figure 1 – Snow pole installer in action

The snow poles are recyclable screw-down poles with extra reinforcement, to be screwed down into the ground. Tests carried out by the NPRA show that these poles are four times as securely attached as today's snow poles. This reduces waste and the need for replacements.

Figure 2 – Screw-down snow pole

There are plans to establish pole terminals where poles can be delivered after collection and prepared for the next season. Here the poles will be cleaned, sorted, repaired or recycled and supplemented with right number for next season. In this concept, the system supplier takes care of all tasks beyond the contractor's core activities.

The cloud-based control and follow-up system gathers data from all work processes and facilitates continuous improvement and optimization of processes and costs in connection with snow poles. The system makes it possible to extract a number of reports, including the total CO_2 footprint for the handling of snow poles. The system also provides an overview of missing poles and makes it possible to see trends over time and uncover areas of substantial waste.

TimeStamp	Antenna Latitude DEG	Antenna Longitude DEG	Rail_XPo	Screw Ang	ScrewDep	ChiselDep
01.09.2020 13:29:42	62,55440521	11,31941128	3733,768066	0	180,4972992	200,015564
01.09.2020 13:30:23	62,55401611	11,31874943	3818,633057	0	179,1000519	200,0259857
01.09.2020 13:31:06	62,55363464	11,31810093	3788,540527	0	167,1408691	200,4183197
01.09.2020 13:31:58	62,55324554	11,31744194	4732,230957	0	170,3076782	200,3229828
01.09.2020 13:32:44	62,55286026	11,31678104	3890,668945	0	191,6588745	200,4855499
01.09.2020 13:33:26	62,55247879	11,31612015	4157,014648	0	235,1131744	200,0404053
01.09.2020 13:34:08	62,55209351	11,31546211	4071,049805	0	171,0493317	200,2301025
01.09.2020 13:44:33	62,55170441	11,31478691	4820,272461	0	181,0277405	200,0856781
01.09.2020 13:45:15	62,55131531	11,31412888	4008,978027	0	159,4625854	200,5546417
01.09.2020 13:45:57	62,55093002	11,31346607	3916,532715	0	200,5573425	200,3681946
01.09.2020 13:46:41	62,55054092	11,31280613	5132,716797	0	231,9772491	200,6458588
01.09.2020 13:47:21	62,55015182	11,31214333	3795,173828	0	212,8273773	200,3488312
01.09.2020 13:47:59	62,54976273	11,31147766	4548,51123	0	200,430069	200,2963257
01.09.2020 13:48:37	62,54938126	11,31082153	3927,59082	0	200,2289124	200,81073

Figure 3 – Documentation of installation time, location and depth (mm)

4.4. ENVIRONMENT AND SUSTAINABILITY

The environment and sustainability are central to the new concept. The CO2 footprint is reduced as the machine has a higher speed than current solutions. Deploying snow poles at speed also reduces fuel consumption compared to the current method, which requires starting and stopping for each pole.

The snow poles have screw threads and are screwed into the ground. This means that they remain more securely in place, which reduces waste, pollution, and the need for new installation during winter. This also means that the costs of reinstalling poles during the winter season are saved. The snow poles can be produced from recycled plastic collected from households. This is done in cooperation with a refuse collection company. Broken snow poles are used as raw materials in the production of new snow poles and thus contribute to a circular economy.

4.5. IMPROVED HSE

The poles can be deployed at a constant speed of about 8 km/h, reduced to about 4 km/h if it is necessary to use a chisel to create holes. This may be the case where ground conditions are hard and uneven. Reduced time on the road improves safety for the operator as well as for road users. The screw-down solution also reduces the need for reinstallation and manual collection of broken snow poles.

The pole installation machine comes with room for all the poles you need for one shift. This minimizes the need for handling by the operator. The machine comes as a container solution that both secures the equipment and reduces the risk of distraction for road users. Improved efficiency makes it easier to schedule work processes for times of day with low traffic.

The pole installation machine comes complete with equipment required for roadworks warning and is prepared for connection to a trailer attenuator where this is required by the work notification plan. The machine provides a better working environment for the operator, without starting/stopping and noise/vibration.

4.6. Pilot project

RoadTech has carried out a pilot project together with Svevia, the largest road contractor in the Nordic countries. Managing Director of Svevia Norge AS, Lars Reitan, says the following about their experience:
"Environmental requirements in contracts are becoming clearer and more significant. RoadTech's innovative and sustainable solution helps meet these requirements. In addition, we wish to emphasise increased road safety and better HSE for operators."

4.7. Expectations and further work

Reducing time on the road, reducing the need for reinstalling poles, and using the vehicle for other purposes provide financial benefits for contractors. In addition, road safety, environmental benefits and improved HSE are also important factors for road owners. The NPRA has expectations that the new method will be able to contribute in this direction.

As a supplier, RoadTech has high expectations for the innovation, both in the Nordic countries and in the rest of the world. The concept is patented in Norway, Europe, the US and Canada. The company is now working on developing additional solutions such as verge marker post cleaners and sign cleaners. These operations will also be carried out at speed to reduce time on the road.

4.8. How it works

You can watch a video of the system in use at www.roadtech.no or by scanning this QR code.

5. ON-BOARD CAMERAS

Maciej Kędzierski & Marek Kasprzyk
General Directorate for *National Roads* and Motorways, Poland
mkedzierski@gddkia.gov.pl, makasprzyk@gddkia.gov.pl

5.1. ABSTRACT

Collecting information about the weather conditions is crucial to provide fast and reliable winter maintenance. Fully equipped weather stations provide detailed data but they are expensive and cover only a small area. A good and cost-effective alternative could be on-board cameras. The cameras mounted on the snowplow decks provide live view of the road conditions.

This solution proved to be a dependable source of information as well as a cost-effective one and easy to implement.

Full paper will be based on two-year experience with on-board cameras mounted on the fleet of 18 snowplows. It will include: detailed information about the specification of the whole system, cost calculations and possible ways for further development.

The idea was taken from one of the presentations held during The World Winter Congress in Gdansk in 2018 and we believe it is worth disseminating.

Figure 1 – View from on-board camera

5.2. INTRODUCTION

The place on the map where the country of Poland is located lays on a merging area of two kinds of climate zones where warm and humid Atlantic air is mixing with dry and freezing continental masses from Asia. The situation contributes to extreme weather conditions with dependence of current atmospheric situation. Heavy snowfalls, frost mixed with warm and wet periods may happen in relatively short intervals. Therefore, Road Agencies have been facing a need to have a good monitoring system of road conditions, especially during wintertime.

The idea for the solution was born during the PIARC Winter Congress in Gdansk in 2018, where experiences of other countries where presented. We were lucky enough that our existing agreements with contractors were about to end and we were about to commence preparation of a new tender with new assumptions and rules. The decision to equip all the salt spreaders with on-board cameras with online data transfer was made and agreed upon, and we announced the new tender with new requirements.

Before new winter season (for the first time in whole State of Poland) there were 18 vehicles fully equipped with on-board cameras and 2 local maintenance stations for winter coordinators.

5.3. COMPONENTS OF THE SYSTEM

5.3.1. On-board cameras

An HD dash cam, and a router with a SIM card are installed in the cockpit of a salt spreader. A car battery supplies the energy after the ignition. The live view from the cameras is sent through the Internet and it could be viewed at any computer with internet access and proper software.

A video recorder enables to store the data on a hard drive in a desirable interval or as a full video in a compressed format.

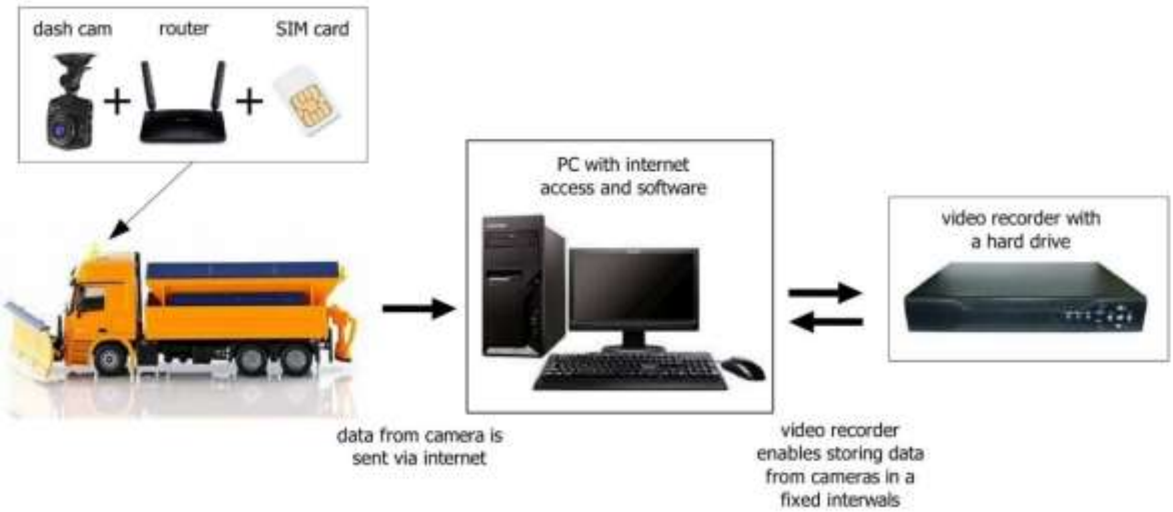

Figure 2 – Components of the system - mobile units

5.3.2. Stationary cameras

In the locations where the weather tends to be harsh and unpredictable, stationary cameras are mounted in order to enable 24/7 viewing of the road conditions. In most cases, cameras are mounted on lighting posts. During the day, when the streetlights are off the power is supplied from a battery. At night, when the lights are on the battery is charged. This solution enables continuous work without building additional power supply that could be cost consuming.

If there are problems with the network coverage, additional directional antennas are used to enhance the signal. Similarly, to mobile cameras the data is sent via a router with a SIM card. In this case it is possible to add additional sensors like thermometers etc.

Solar panels could be used if there is no power supply from the streetlights or other existing equipment.

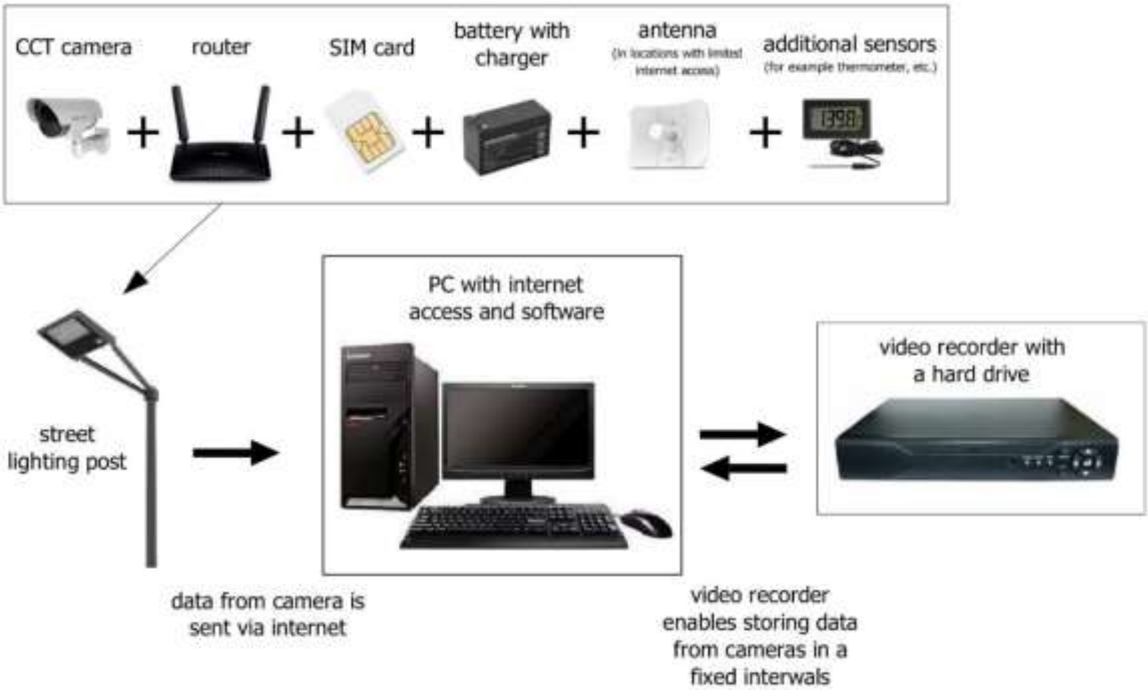

Figure 3 – Components of the system - stationary units

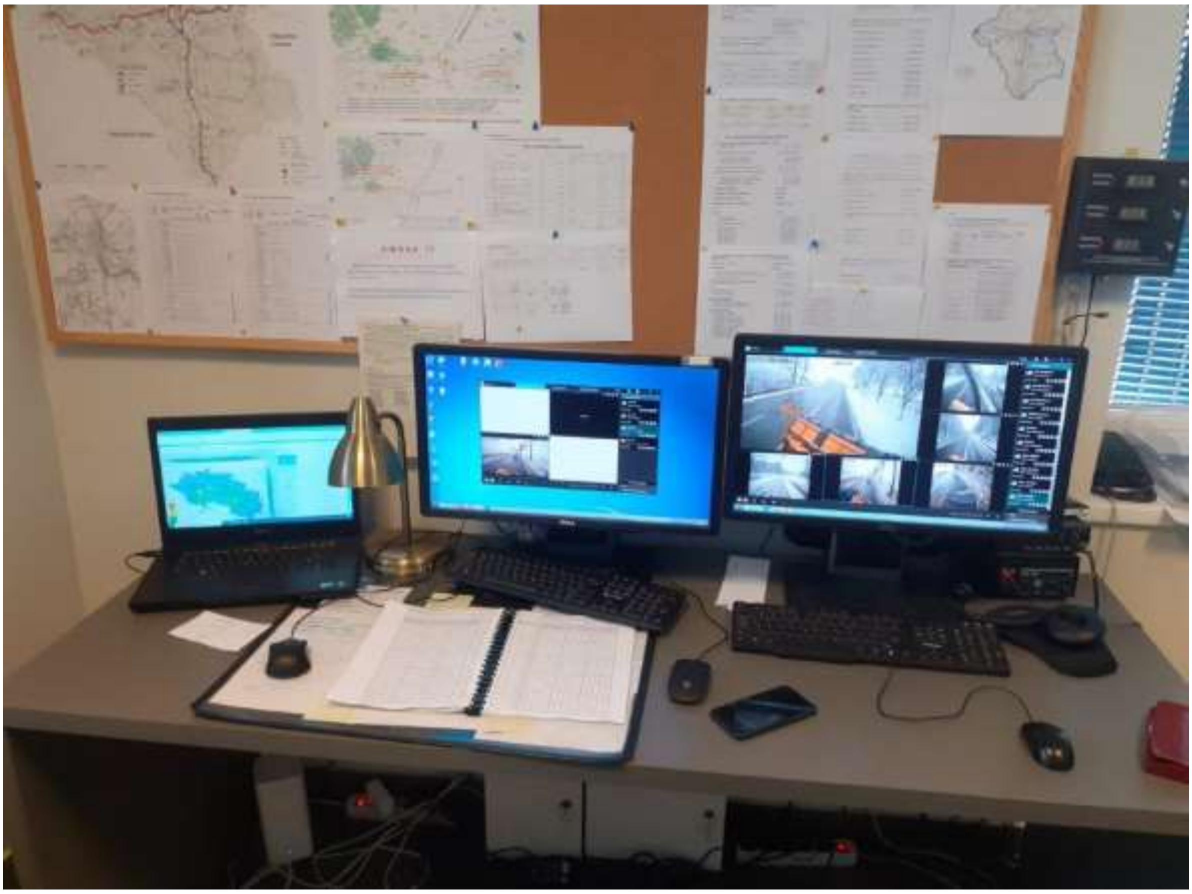

Figure 4 – PC with the view from cameras in a local maintenance station

5.4. Costs

Costs of the whole system include purchase of the equipment, installation and SIM card subscription. In the table below the cost of 18 mobile cameras and 2 stationary cameras is presented.

Table 1 - costs of the mobile cameras

LP	Component	Estimated costs [euro]	Quantity	Value
1	Dash cam	300	18	5400
2	Router	80	18	1440
3	SIM Card with 36 months subscripsion	300	18	5400
4	Instalation	80	18	1440
5	PC Computer	1000	1	1000
6	Video recorder with a hard drive	300	1	300
	Instalation and software configuration	80	1	80
			Total	**15060**

Table 2 - costs of the stationary cameras

LP	Component	Estimated costs [euro]	Quantity	Value
1	CCT camera	300	2	600
2	Router	80	2	160
3	SIM Card with 36 months subscripsion	300	2	600
4	Battery with charger	150	2	300
5	Antenna	50	2	100
6	Thermometer	50	2	100
7	Installation	80	2	160
			Total	**1860**

The costs of the PC and the video recorder are not calculated because the same are used for mobile cameras. If there are over 20 cameras, an additional computer monitor could be needed.

The cost of the system was 0.67% of the total value of a 3-year contract for winter maintenance.

5.5. Advantages

One of the biggest advantages is live view of the road conditions that enables faster winter service. This helps to make quicker decisions concerning increasing or decreasing the forces and means used for winter maintenance. It also stands as a support for the Road Agency to supervise the winter maintenance contractors more effectively. The advantages include low cost of purchase and installation of cameras, and our experience has shown that the system is practically completely failure-free. For instance, the cost of installing a fully equipped weather station is about 40 times higher than one point with stationary cameras. The data saved on the hard drive can be used as evidence of the actions taken by the Road Agency in cases of incidents on the road.

Cameras mounted at stationary locations are used to aid summer maintenance as well.

5.6. Disadvantages

The disadvantages include problems with transmitting live data in locations with limited network coverage. In this case data could be saved on an SD card inside the camera and then it could be sent when the Internet connection is back. For stationary cameras, directional antennas are used to ensure proper connection. Problems can also occur with access to power supply in places where there is no street lighting. This could be solved by installing solar panels, but it generates additional costs.

System of cameras is an additional functionality of the spreader so there is a need to find means to execute from the contractor the permanent capability to work without problems. In order to force the contractor to maintain their continuous work, it was necessary to establish compelling methods (penalties etc.). Previously we decided that the vehicle without full functionality of the system will not be allowed to render services at all until fixed. Then in the next tender we are going to force the contractor to exclude from the winter service units with faulty on-board cameras. The rule still needs some modifications.

5.7. Further study

Further work shall take into account our experience and will be focused on 2 main streams. During planning each of them there must be different aspects analysed and possible problems solved or at least pointed out and indicated:

- As the system as a whole is based mainly on electronics equipment there is lots of ways to develop it:
  - Use of the recordings from cameras and publish theme on web-site – risk to violate e.g., personal identity of people or cars recorded,
  - Add extra rear-view camera to check out effect of the spreader’s performance – data bandwidth risk,
  - Producing an automatic system to convert data from recording into numeric data and display as coloured map on-line with indication of road condition, circulation time

etc. – risk of producing illegible and unusually panel because of significant number of different data (need for customer satisfaction research),

– Interconnecting the vision system with GPS to achieve better visualisation for the users – data bandwidth risk,

- As the solution with cameras was implemented for the very first time in whole country of Poland. There was nobody here to give us a hand and provide a bit of knowledge and experience. Probably most of difficulties and issues that emerged, and the beginning (tender and implementation process) may be avoided if we had a kind of guide to use. So, preparation of such a report or instructions is crucial before the system will be implemented in other areas of the country. The guide shall take into account:

  – Own experience,

  – The information and knowledge from PIARC Technical Committee A.2 Report from 2019 „Evaluating the Transformation of Transport Administrations" shall be analysed and implemented. Use of that knowledge in essential because the paper includes the best practises and their analyse about Change Management in a very wide approach,

  – In accordance with current work of PIARC Technical Committee TC1.1 there shall be performed a series of interviews with all users (as the costumers) of it to gain data from their experience. The data may be used in further development of the system.

5.8. SUMMARY

At the very beginning of our work for preparations tender documentation we met couple of issues related to the new idea. There was a doubt of the Road Agency about additional costs of the implementation. Then potential bidders were complaining about new requirements that they had to meet without previous experience. Our stuff had a fear of their new responsibilities and the new technologies. All the issues disappeared after a short period of work with the system – almost from day to day all parties became happy!

Despite that there was some number of issues during the implementation process, the final effect turned out as a success as a cheap and effective tool. The fruits of new solutions that we have, are now consumed by all parties involved in the system. The topic which emerged in front of our Agency is to use our and PIARC experiences to prepare guidelines for future implementations in other areas of the country.

6. DEVELOPMENT OF AN AUTOMATIC WINTER TIRE DETERMINATION SYSTEM

Shogo Hayashi
West Nippon Expressway Engineering Shikoku Co., Ltd., Japan
shogo.hayashi@w-e-shikoku.co.jp¨

Takanobu Onishi & Junichi Takato
West Nippon Expressway Co., Ltd. (NEXCO WEST), Japan
t.onishi.ae@w-nexco.co.jp

6.1. NECESSITY AND BACKGROUND OF DEVELOPMENT

To ensure traffic safety in winter, road administrators implement winter tire regulations depending on the road surface conditions. As the regulations cause traffic congestion in heavy traffic hours, it is necessary to secure many workers, including tire checkers and traffic guides. However, this regulation requires enormous personnel burden due to long work time; therefore, labor-saving and speeding-up measures for checking work are necessary.

6.2. SOLUTION (DEVELOPMENT/INTRODUCTION METHOD)

To improve the road service by reducing the waiting lines during winter tire regulation, and reduce the workload of checkers on winter tire, NEXCO WEST has started developing a system that can automatically determine the tire type by photographing the tire tread with a highly sensitive camera and applying image processing technology.

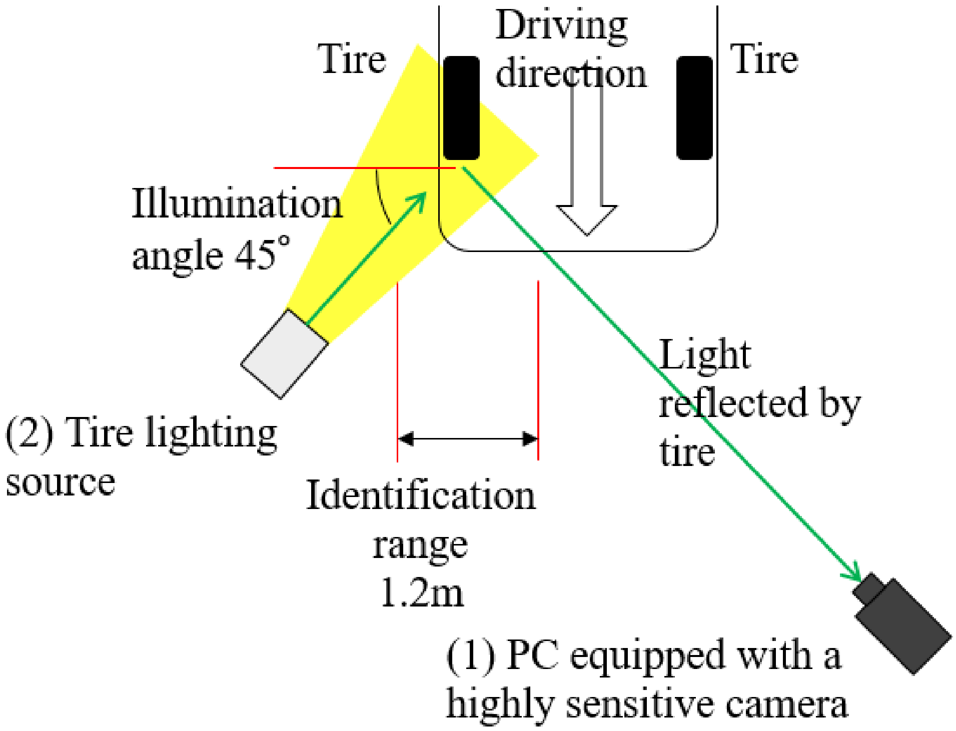

Figure 1 – Positioning of camera and lighting source

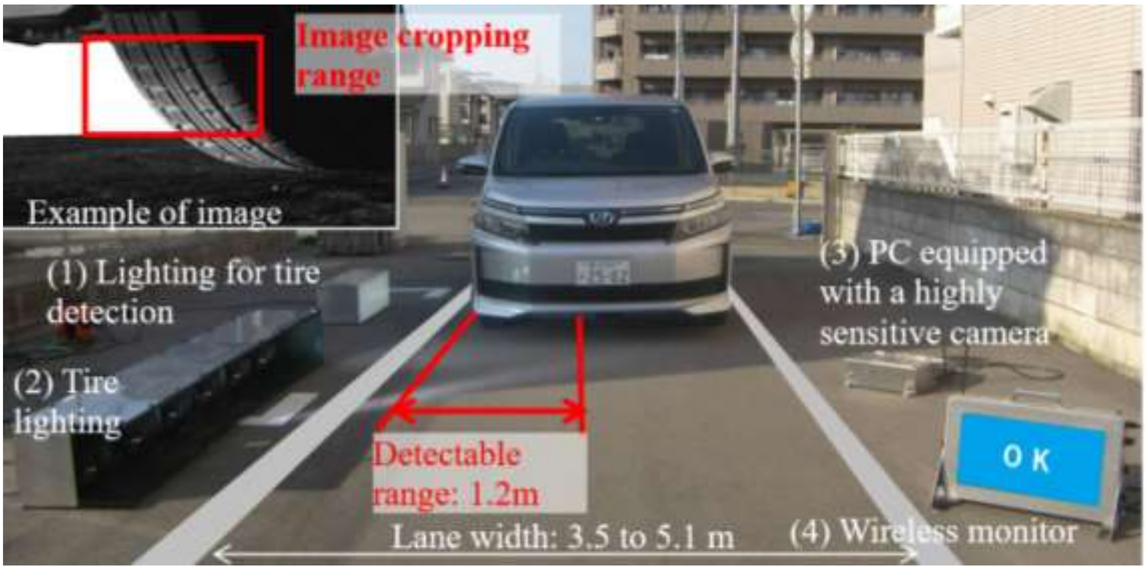

Figure 2 – Device setup

The tire type is determined by checking the marks engraved on the tire sidewalls. However, there have been some cases where the marks on the tire sidewalls do not match a specific tire type due to the use of recycled tires on large vehicles in recent years. Therefore, the system (Photo 1) determines the tire type using the images of the tire tread obtained by positioning the lighting source in the place where its reflection light on tire is mirrored in the camera (Fig. 1). The system detects the silhouette of the tire that passes in front of the backlighting and identifies only the images of tires. By using a highly sensitive visible image camera, still images of the tire tread of vehicles that pass at a speed of 30 km/h or less are obtained, and studless tires are automatically differentiated from other tires instantaneously using image processing and artificial intelligence (AI). The targets were tires of passenger cars (including light vehicles), medium-sized vehicles and large-sized vehicles. The system is robust against changes in the photographing environment and does not require adjustments depending on whether the road surface is wet or dry, whether it is raining or snowing or whether it is day or night.

6.3. ADVANTAGES FOR ROAD MANAGEMENT COMPANIES (TRAFFIC MANAGERS, MAINTENANCE WORKERS)

Since this system does not make the dangerous mistake of identifying a normal tire as a studless tire, it can save the checking work for the tires automatically identified as a studless, which is labor-saving and improves the efficiency of the work. By introducing automatic identification, tire checking work can be reduced by approximately 60%, and the hourly checking capacity can be increased approximately three times. It is an effective technology for reducing the burden on workers.

6.4. ADVANTAGES FOR ROAD USERS

Winter tire checks should be conducted by restricting the main lane and pulling user cars into service areas. Road users need to wait for long periods when the traffic is congested. Using this system is expected to relieve such congestion and improve the quality of the road service.

6.5. Findings

In FY 2018, the system was verified in the trial operations where photographing was conducted under various conditions (e.g., during the day and the night, and rainfall and snowfall) on the Maizuru-Wakasa Expressway (under the jurisdiction of the Fukuchiyama Expressway Office), the Chugoku Expressway (Chiyoda Expressway Office) and the Oita Expressway (Oita Expressway Office). The total number of photographing was 27,652.

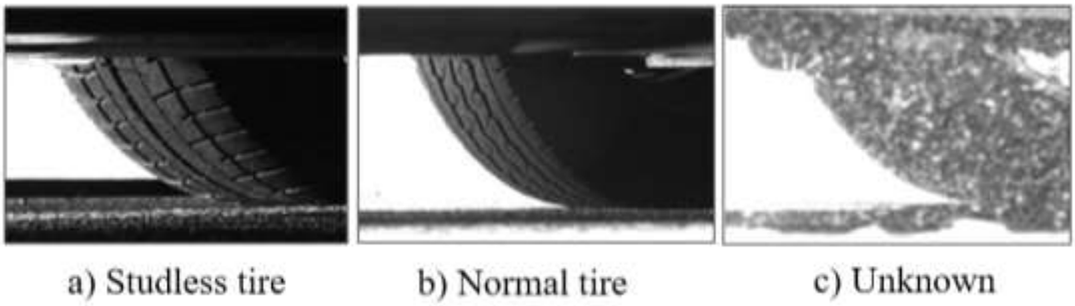

Figure 3 – Examples of images for AI identification

The photographed images were divided into three types – studless, normal and unknown – by visual checking (Photo 2). The results of comparison between the visual and automatic judgments are as shown in Table 1. The system did not make the dangerous mistake of identifying normal tires as studless, and the matching rate was 84.3% (23,399 (total of the yellow parts)/27,652). The identification rate of studless tires among all tires was approximately 66% (18,248/27,652), Figure 2 shows the matching rates during the day and at night. For all test sites, the matching rate tended to be higher during the daytime by approximately 6%, it was assumed that the results were affected by the brightness (solar light) of the surroundings. Looking at the hourly identification accuracy (Figure 3), the matching rate was changing greatly. The changes were especially significant in Chiyoda, dropping to 43.7% at 9:00 p.m. on the 17th. By overlapping the hours when snow was observed in the images photographed in Chiyoda (snowfall hours) to this graph, it can be seen that the identification accuracy tended to decrease at the time of snowfall. This suggests that the identification accuracy is affected greatly by the weather and the road surface conditions.

		Automatic identification results			
		Studless	Normal	Unknown	Total
Visual	Studless	18,248	3,592	761	22,601
	Normal		4,890	32	4,922
	Unknown			129	129
	Total	18,248	8,482	922	27,652

Table 1 – Automatic identification accuracy

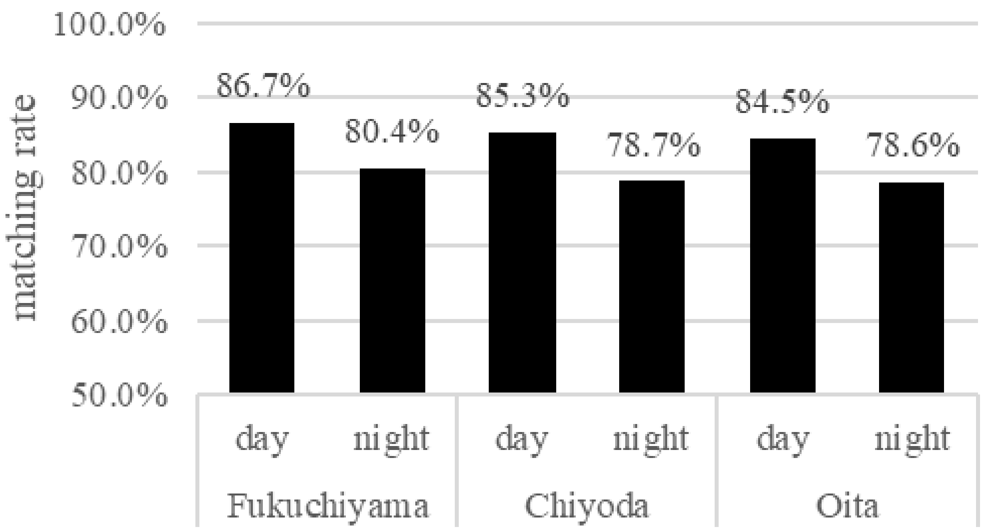

Figure 3 – Comparison of day and night matching rates

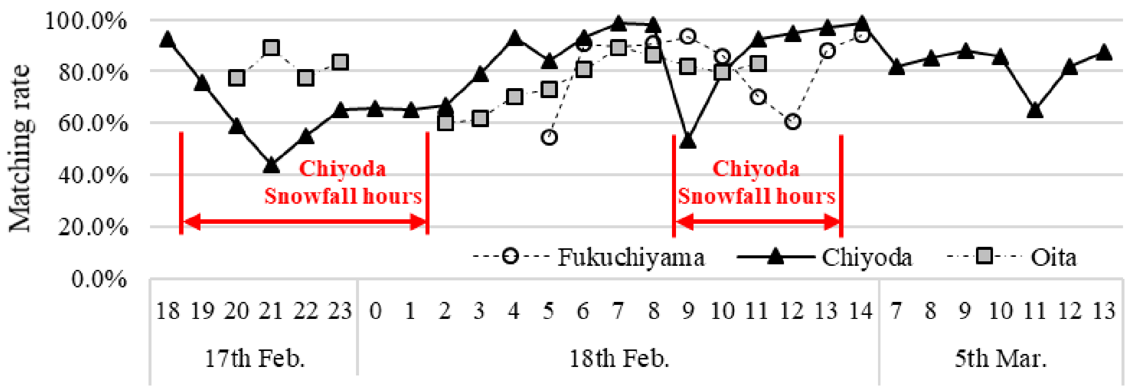

Figure 4 – Hourly matching rates

This system obtains images at certain intervals (50 images/sec.), and has the function of estimating the vehicle passing speed based on the amount of tire movement in the images. Figure 4 shows the relationship between the speed and the matching rate. The results of counting the passing speed range per 5 km/h, the matching rate was around 80% up to 35 km/h and stable identification was possible. Although the matching rate decreased dramatically over 35 km/h in Chiyoda, the data used for verification was limited (111 tire images).

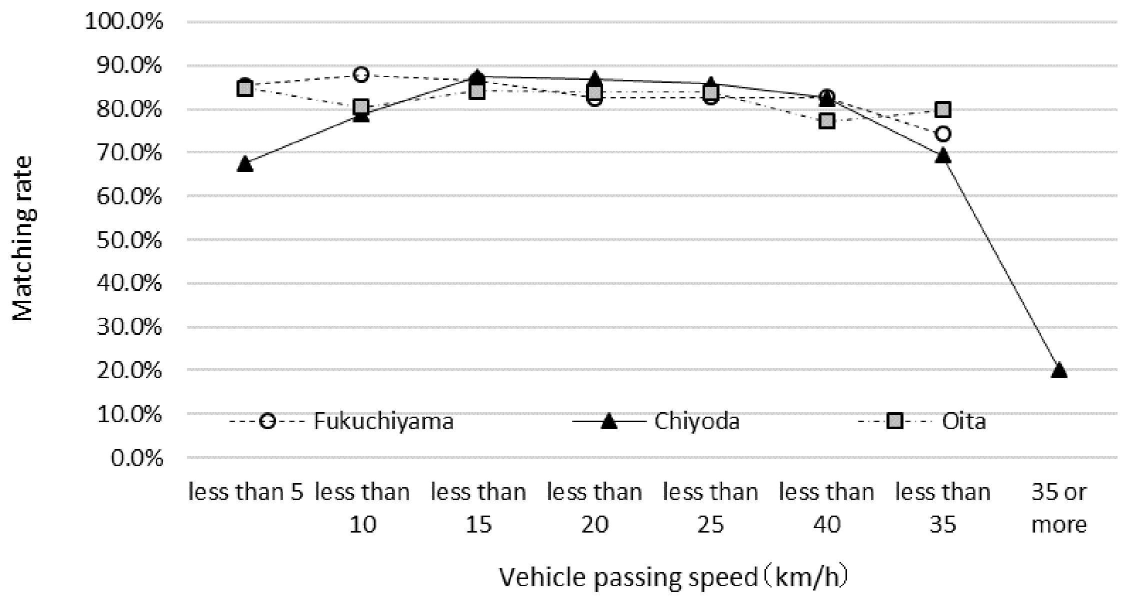

Figure 4 – Matching rate by vehicle passing speed

6.6. FUTURE PLANS

Since the system enables automatic identification of the tire type, it is considered that the development of a vehicle guidance device that works in conjunction with the system will improve the service level by further reducing the waiting lines. This is expected to enable smooth vehicle guidance and to improve efficiency of checking work further.

6.7. CONCLUSION

This system has performed high matching rates for actual on-site operations without making any dangerous mistakes such as identifying normal tires as studless, and it is not necessary to check tires identified as studless by the automatic identification system, that can contribute to save labor, improve efficiency and speed up winter tire regulations. However, there is risk of accuracy reduction when photographing conditions deteriorate. It is difficult to solve the quality deterioration of the obtained images only by improving the AI identification because it is the operational conditions that are currently affecting accuracy the most (future task).

- By introducing this system, the tire type can be identified automatically at an accuracy of 84.3% while eliminating dangerous mistakes.
- By introducing automatic identification, check work can be reduced by approximately 66%.
- When the road surface conditions deteriorate due to the accumulation of sherbet-like snow on roads or other reasons, the identification accuracy decreases even if there are no dangerous mistakes. To improve the decrease in identification accuracy, operational improvement, such as road surface management, will mainly be necessary.

7. INTELLIGENT SALTING CONTROL OPTIMIZATION SYSTEM (ISCOS) THAT CONTRIBUTES TO A REDUCTION OF SALT APPLICATION

Ryo Nakatani & Tonomori Ohiro
East Nippon Expressway Co., Ltd. (NEXCO EAST),
NEXCO Engineering Hokkaido Co., Ltd., Japan
r.nakatani.ab@e-nexco.co.jp

7.1. PURPOSE AND BACKGROUND OF DEVELOPMENT

NEXCO EAST spreads sodium chloride (salt) and other deicers to suppress the occurrence of road surface freezing on expressways. When conducting this operation, workers visually judge the road surface conditions (e.g., dry, snow-covered, sherbet, frozen) by prior patrol and determine the total amount of salt to be loaded on the spreading vehicle through accumulating the amount to be applied for each road surface condition. In the site, the deicer is loaded in increments of 0.5 ton, and vehicle operators change the spreading amount, width and direction according to their visual judgment on surface condition based on the instructions of the road administrator. Meanwhile, sufficient work experience is necessary to make suitable decisions on deicer spreading, and such decisions are qualitative and sometimes on the safe side. In addition, the entire loading amount must be spread at the end so that no deicer remains in the tank.

In Japan, it has become difficult to secure workers who are familiar with snow and ice control work and can make appropriate decisions due to the aging of skilled operators and a decrease in the working population. It is also important to reduce spreading of excess deicer to prevent deterioration of road structures and any influence on the roadside natural environment, as well as from the aspect of management cost.

Therefore, NEXCO EAST developed the Intelligent Salting Control Optimization System (ISCOS), which automatically optimizes and quantifies each operation by linking a tire sensor that automatically detects the road surface condition with an automatic salting control device, and is expanding its operation on expressways in Hokkaido.

7.2. DEVELOPMENT OF THE INTELLIGENT SALTING CONTROL OPTIMIZATION SYSTEM

As a sensor to automatically detect the winter road surface conditions, NEXCO EAST focused on the Contact Area Information System (CAIS®) tire developed by Bridgestone Corporation. This tire, which has an accelerometer, a transmitter and a power generator inside it, detects road surface conditions based on the waveforms of vibrations transmitted from the road surface, and then transmits the data. By adding tire running sounds to this, it has become possible to detect seven types of road surface conditions per each 100 meters. NEXCO EAST also developed the device that automatically spread the optimum amount of deicer over each 100 meters based on the CAIS judged data. Moreover, to improve the operational effectiveness, a special hopper (DD hopper) that loads deicer at increments of 0.1 ton and a supplementary system that involves people to correct CAIS errors and determine the implementation of spreading were developed. The Intelligent Salting Control Optimization System (ISCOS) integrated these four systems was then completed in 2015 (Fig. 1).

Figure 3 shows the four systems that make up ISCOS – CAIS (winter road patrol vehicle), supplementary system (winter road patrol vehicle and regional command control desk), optimum amount deicer loader (DD hopper (Fig. 2)) and automatic dicer application system (deicer spreader) – and the total deicer application flow that connects them. The center of this deicer application flow is called the data center, with a web server that has a function to manage the image database consisting of the front still images from the vehicle-mounted camera (road images), the road surface database consisting of the CAIS judged data, spreading section database and other databases. The CAIS judged data here means the road surface conditions detected by CAIS, and the spreading section data means the information on the deicer application obtained from the CAIS judged data and manual input of the supplementary system. The deicer application flow also includes the road administrator who makes the final decision on deicer spreading.

Deicer is spread in four steps: 1) collection of road surface and other information, 2) decision to implement spreading, 3) preparation for spreading and 4) implementation of spreading. ISCOS collects road weather forecasts, weather observations and other data, CCTV images, road patrol reports, road images of each 100-meter section and surface data, and supplementary system data in the spreading section as information to make decisions on the deicer application. The road administrator decides the implementation and method of deicer spreading based on the collected information and calculates the application amount. After receiving radio contact from the administrator, deicer storage workers load the designated amount of deicer in increments of 0.1 ton onto the deicer spreader using the DD hopper. The operator of the deicer spreader, who also receives radio contact from the administrator, conducts 100-meter-section or all-section application based on the spreading section data downloaded from the data center web server.

7.3. Effectiveness of introducing ISCOS

NEXCO EAST introduced ISCOS for expressways in Hokkaido in 2015 and is currently operating it on sections of approximately 700 km. Spreading section used to be decided for each section of several kilometers based on visual judgment of patrol workers. As ISCOS equips spreading system based on the surface condition of each 100-meter section, it became possible to precisely identify dispersed short sections that do not require deicer application. The deicer application amount has thus been reduced by approximately 7% (Table 1) compared with the conventional spreading method, resulting in improved durability of structures and reduced influence on the surrounding environment.

With automatizing the surface condition judgment and machine operations, ISCOS has had diverse effects to improve the accuracy, efficiency and safety of snow and ice control works, such as the use of workers and operators without a wealth of experience, improved work accuracy and reduced workload.

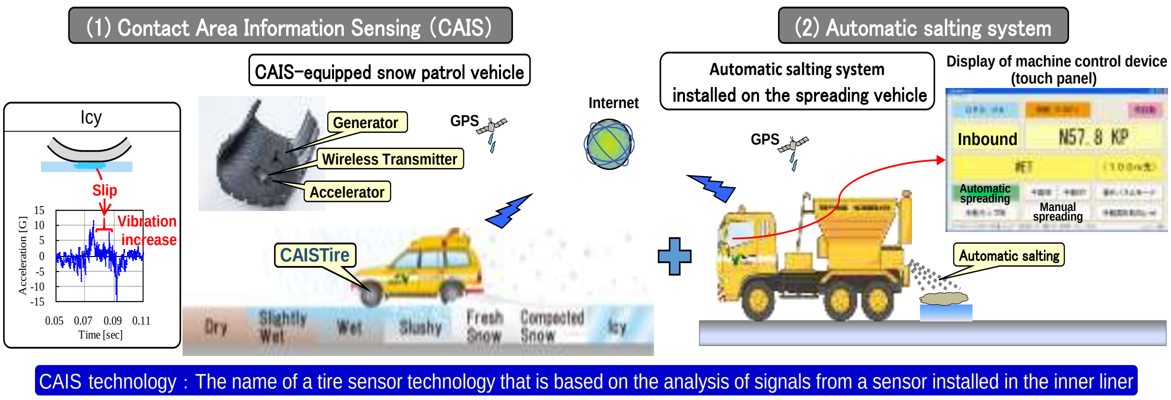

Figure 1 – Intelligent salting control optimization system

7.4. Future prospects

NEXCO EAST is improving road surface condition judgment function to increase the adequacy of operations using ISCOS. The first is the development of a whole-area road surface condition judgment system that supplements the current surface condition judgment system based only on the running paths of one CAIS tire, adding camera images and computerized image recognition. The second is the development of a surface prediction system to supplement changes in the surface conditions due to the time lag between the time of patrol and the time of spreader operation. These improvements have reduced the involvement of patrol workers and road administrators in the surface condition judgment. In the future, NEXCO EAST tries to develop the complete automatization of deicer application using ISCOS and promote a further reduction of the spreading salt.

7.5. Conclusion

- NEXCO EAST developed the Intelligent Salting Control Optimization System (ISCOS), which automatically optimizes and quantifies each operation by linking a tire sensor (CAIS) that automatically detects the road surface conditions with an automatic salting control device for deicer application.

- ISCOS consists of four systems – CAIS (winter road patrol vehicle), supplementary system (winter road patrol vehicle and regional command control desk), optimum amount deicer loader (DD hopper) and automatic deicer spreading system (deicer spreader).

- Since ISCOS equips the spreading system based on the surface condition of each 100 meter section instead of the conventional way to decide application for each several-kilometer section, the application amount of deicer has been reduced by approximately 7%, resulting in improved durability of structures and reduced influence on the surrounding environment.

- With automatizing the surface condition judgment and machine operations, ISCOS has had diverse effects to improve the accuracy, efficiency and safety of snow and ice control works, such as the use of workers and operators without a wealth of experience, improved work accuracy and reduced workload.

- A whole-area surface condition judgment system that supplements the current surface condition judgment with camera images and a surface prediction system to supplement changes in surface conditions due to the time lag between the time of patrol and the time of spreader operation are currently being developed.

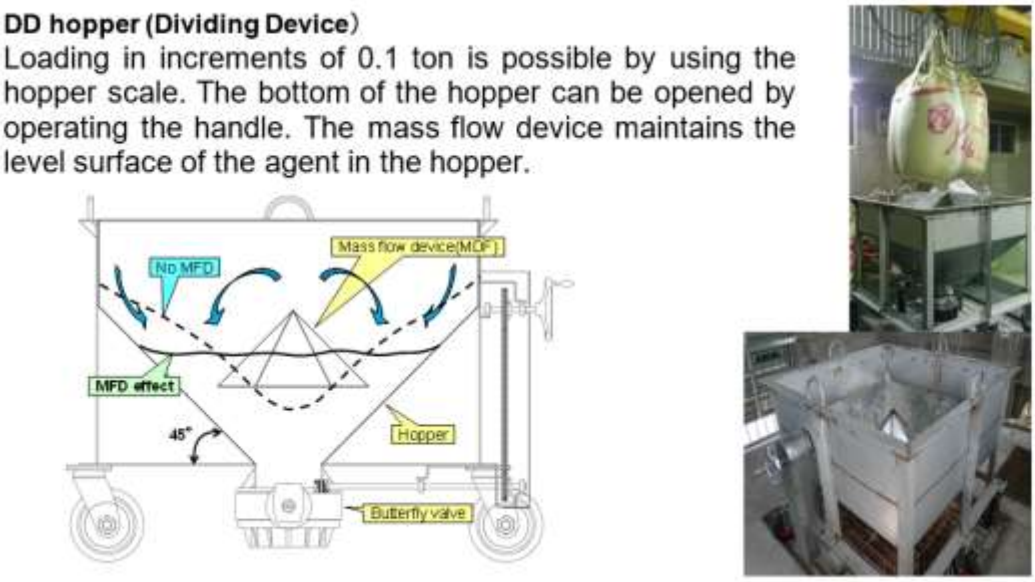

Figure 2 – DD hopper (deicer loader)

FY	2015	2016	2017	2018
Management length (km)	144.3	295.2	434.2	696.3
No. of snow and ice control bases	6	11	17	26
No. of winter road patrol vehicles	5	9	13	20
No. of deicer spreaders	11	21	29	44
A: No. of spreading operations using ISCOS	3830	7397	9192	10291
B: Spreading amount using ISCOS (results) (t)	9818.6	19126.6	23397.8	24531.8
C: Existing spreading amounts (estimated values) (t)	10503.6	20251.5	24734.5	26390.0
D: Reduction of deicer amount (t) (C−B)	685.0	1124.9	1336.7	**1858.2**
E: Deicer reduction rate (%) (D/B×100)	7.0	5.9	5.7	**7.6**

Table 1 – ISCOS introduction status and reduction of deicer amounts

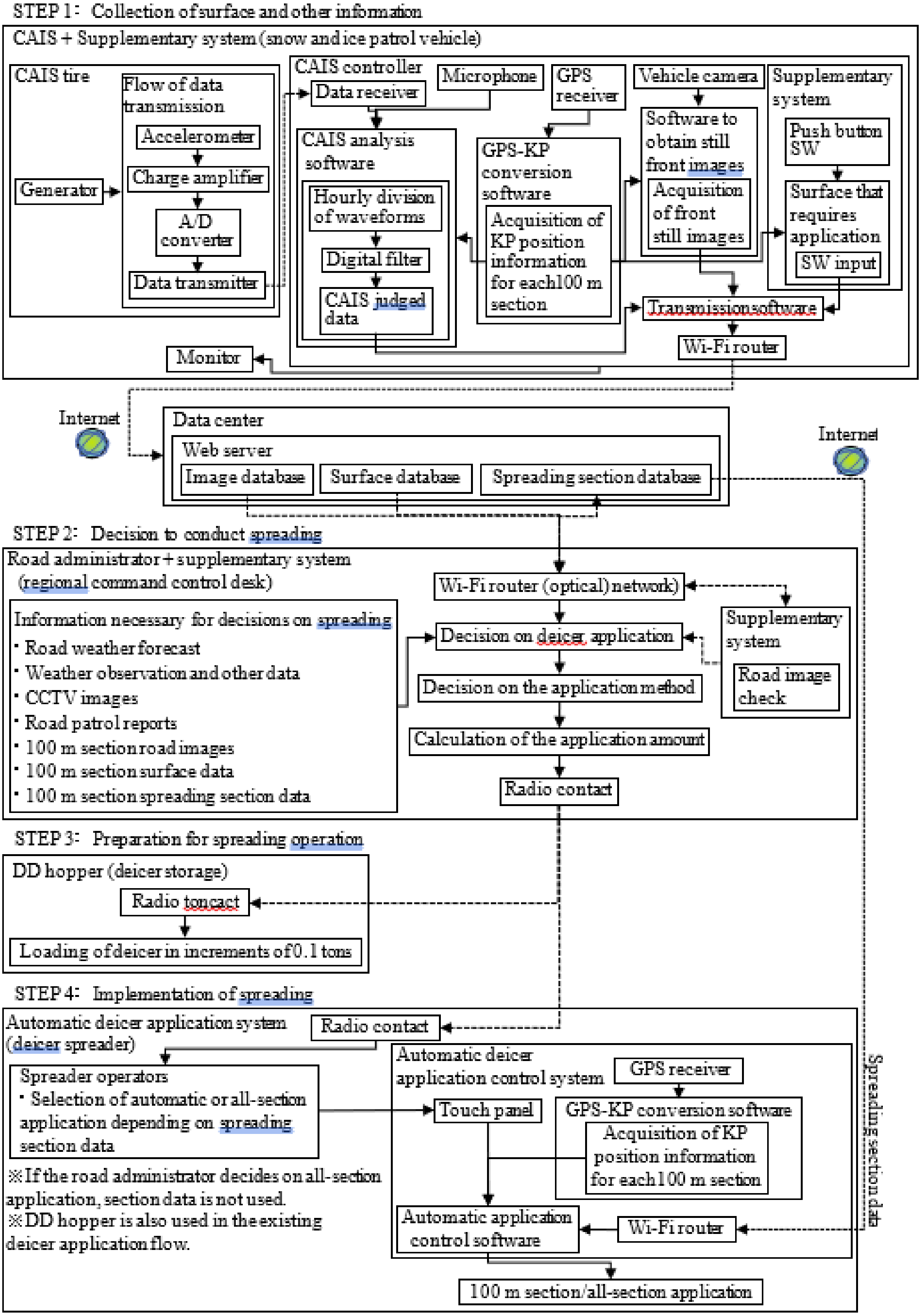

Figure 3 – Flow of deicer application using ISCOS

8. DEVELOPMENT OF A SNOW BLOWER OPERATION SUPPORT SYSTEM

Ryo Nakatani & Kazue Usui
East Nippon Expressway Co., Ltd. (NEXCO EAST), Japan
Hokkaido University, Japan
r.nakatani.ab@e-nexco.co.jp

8.1. Purpose and background of development

When performing snow blower operations on expressways, it is necessary to prevent contact with general vehicles and guardrails while securing a certain road width and flat road surface in a safe and accurate manner, even in poor visibility conditions at night and snowstorm (Fig. 1). Therefore, snow blower operators must be familiar with the location of bridges, guardrails, and other road structures and facilities that require special attention during operations, in addition to having operational skills to handle with accuracy of a centimetre class driving on slippery roads covered with snow and ice. Although operators have been invited from roadside farms and construction companies, there are concerns about the aging of skilled operators and a shortage of workers due to the recent decline in the birthrate. Therefore, NEXCO EAST has been researching technologies to support and automatize the driving and mechanical operations of various snow and ice control vehicles by utilizing ICT (Information and Communication Technology) that has been shown dramatic progress of technological innovation. As part of these activities, NEXCO EAST developed a snow blower that uses high-precision positioning information obtained from an artificial satellite.

8.2. Development and introduction of a snow blower operation support system

In Japan, a high-precision satellite positioning service using the *Michibiki* quasi-zenith satellite system was launched in November 2018 and enabled stable positioning with an accuracy of a few centimetres. In conjunction with it, NEXCO EAST developed a snow blower driving support system to conduct safe and accurate snow removal operations using positioning information obtained from a satellite even if visibility is poor during snowstorms and when it is difficult to determine the location of obstacles and lane marks because snow covers them.

This system was primarily developed for a snow blower that mainly remove snow that has accumulated on the road shoulders (outside the driving lanes) at a low speed. It combines signals from *Michibiki* and a high-precision map prepared beforehand, and the position of the snow blower, the extent to which it has crossed the side lines of driving lane, and the degree to which the vehicle has to change direction to prevent the body from colliding with the guardrail or other objects are displayed on the driver's guidance monitor. At the same time, it also issues sound alarms to warn about crossing lines and impending collisions, thus providing audiovisual assistance to the driving operator (Fig. 2).

Trial driving started along a 21 km long section of an expressway in Hokkaido in 2018. The difference between the position displayed on the guidance monitor and the actual one was less than ten-odd centimetres, which is smaller than the width of the road lane marks and is not considered as problematic for snow removal performance. The system's tolerance to the extreme cold temperature in winter, the vibration accompanying snow removal operations as well as the effect of adverse weather conditions such as snowstorm on the transmission system were also confirmed.

There are, however, transmission-blocking sections along the road like tunnels or over-bridges where satellite signals cannot be received. To interpolate for this issue, we are developing a receiver with an acceleration measurement function such as gyro sensor.

According to snow blower operators who used this system, the introduction of the system is equivalent to ten years of driving experience. The workload of driver's operation that has required high expertise and the work volume of assistant on board who confirms the safety and communication are greatly reduced, while the safety and efficiency of snow removal work are improved. It is expected that this system allows inexperienced operators to perform safe and accurate operations, and to reduce the number of workers (2 at present →1). In addition, this system can not only serve to assist operators who are dispatched from other areas in times of snowstorms or other emergencies but also meets the present Corona pandemic protocols requiring small numbers of workers.

8.3. Future prospects

The companies manufacturing the satellite signal receiver, interpolation instrument such as gyro sensor and high-precision map that are included in this system are at present busy to improve the system's performance and reduce the price. According to these development, NEXCO East plans to extend the range to which the system is applied.

NEXCO EAST is also developing an autonomous snow blower by linking positioning and guidance information obtained from this system with the driving mechanism of the snow blower. The special snow blower was manufactured in 2020 and its autonomous driving capability has been confirmed. Complete automatization of the snow blower, including the snow removal function, is under development (Fig. 3).

8.4. Conclusion

- A snow blower operation support system (guidance monitor) was developed by utilizing high-precision positioning information from an artificial satellite.
- The accuracy of the system is within ten-odd centimetres, which satisfies the performance required of snow removal operations.
- By introducing the system, it became possible to handle such issues as the aging of experienced operators, shortage of workers, dispatch of support workers, and decreased manpower due to the COVID 19 pandemic.
- To expand the application of the system, improvement of receiver performance, interpolation positioning technologies in signal dead zone and high-precision maps are necessary.
- An autonomic snow blower is currently being developed based on this system.

Figure 1 – Snow blower

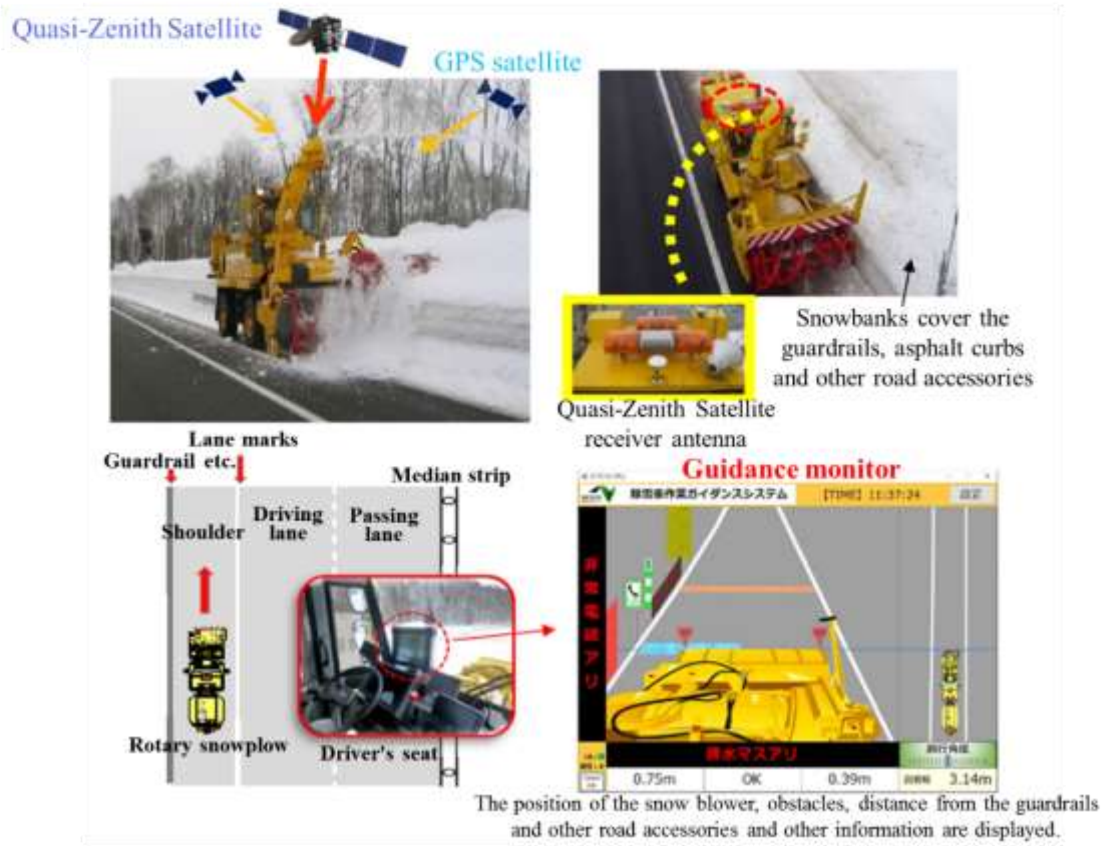

Figure 2 – Snow blower operation support system

Figure 3 – Autonomous snow blower trial run

9. GIS IN ROAD MANAGEMENT

Julius Janeba
STRABAG, Czech Republic
julius.janeba@strabag.com

9.1. INTRODUCTION

Geographic information systems (GIS) are playing an increasingly important role in many industries. Wherever information can become an attribute to a geographical location, and it is important to monitor and analyse it in this way. Road managers are no exception. Using GIS systems, road network data is stored with further details like surface condition, road management system, completed and planned reconstructions and more. Up-to-date information on traffic, closures and other restrictions is commonly available and is also reflected in the navigation systems.

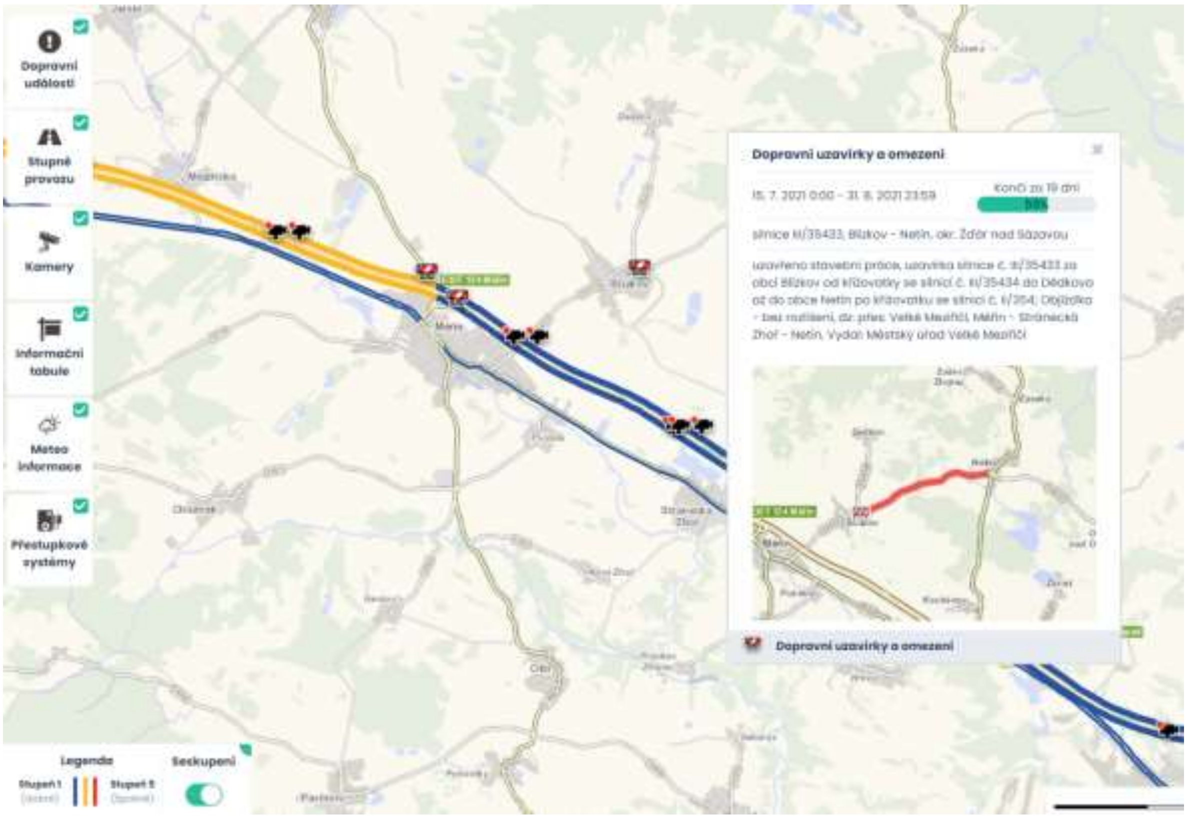

Figure 1 – Current traffic situation, detail of a closed section

9.2. UNIFIED EVALUATION OF WINTER MAINTENANCE

With a renewed regional arrangement after the year 2000, the roads class II. and III. were transferred to the property and administration of these regions. Motorways and class I. roads remained the property of the state and administered by the state organization Road and Motorway Directorate. The original district enterprises of road administration and maintenance were newly integrated into regional structures, their subsequent development with a total of 13 + Prague was no longer controlled and there was a significant differentiation from gradual privatization to efforts to keep their own maintenance capacity, including machinery. Different regional administrations also approach the fleet management in a different way, they are equipped with various types of GPS units, and they use several software providers for tracking the position of vehicles.

In 2017, ŘSD announced a large public tender for the maintenance of class I. roads for the next eight years in 14 areas (the Central Bohemian Region is divided into two areas), in which partly the original regional road administrations and partly private companies succeeded. The unifying condition for the candidates in this competition was to ensure a certain level of data sent from the GPS units so that it could be further evaluated in terms of the adequacy of the performed services and other parameters. Standards have been defined for GPS modules on vehicles and for data transmission.

In addition to the location of vehicles, their activity is also monitored, it means operating parameters at each location such as weight, width and directional setting of the spread or the position of the snow plough. Furthermore, information on the distance travelled (according to the tachometer) and the consumption of spreading materials is taken over from the vehicles.

Figure 2 – All vehicles and their bodies must be equipped with the appropriate equipment

9.2.1. Technical requirements for vehicles

Vehicles deployed in winter service (as well as inspection activities) must be equipped with a GPS system that meets the following criteria:

- Real-time position monitoring, adjustable recording interval according to:
  - time (minimum adjustable interval 1 s),
  - distance travelled (minimum adjustable interval 10 m),
  - change of direction (minimum adjustable interval 1 °),
- Deviation of the GPS receiver for locating the mechanisms: max. 10 m. From the position records obtained, it must be possible to reconstruct the vehicle route, i.e. the distance travelled. The longest storage interval must not exceed 10 s. A shorter interval

must be used in places where the direction of travel changes more frequently. The provider is obliged to ensure faultless operation of the GPS system throughout the maintenance.

The requirements for the vehicle unit are as follows. The unit must:

- include GPS module and GSM communicator with GPRS communication support,
- enable data to be stored in the internal memory ("black box" function – data must be retained even when the power supply is disconnected),
- enable connection to the control electronics of the spreader and plough and connection of other peripherals (temperature sensor, etc.),
- provide the required information according to the specified communication protocol,
- record the change in dosage,
- record the faults or pass them on to the dispatching office.

The vehicle unit must be connected to the display and control unit, which must be located within reach of the driver. On this unit, the driver sets the spreading and ploughing parameters while driving. The provider's obligation is to provide uncorrected data from vehicle units for all vehicles performing maintenance in real time (i.e. immediately after storage in the provider's database, or directly from vehicles) to the customer's central database using a binding XML protocol specified by the customer. Sending XML files to the customer is realized through a web service specified by the customer. Exemptions from the obligation to monitor the operation of vehicles using the GPS system may be used by tractors destined exclusively to assist in ploughing. Data must be sent during the journey, or no later than after the end of a specific journey / intervention.

The vehicle unit must enable data backup and subsequent sending to the customer's database even in the event of a long-term failure of the mobile connection (communication signal). The system must have the capacity to store at least 1 month of vehicle operation. The system must allow an alternative way of transmitting (downloading) data from the vehicle in case of failure of the standard method of sending data. Complete records of vehicle operation must be transferred to the customer's database immediately (without undue delay) after the end of the partial intervention. Such termination means the return of the vehicle to the vehicle base (garage), or to the starting point of the vehicle, where the vehicle will be parked, or to prepare the vehicle for possible further intervention (exit of the vehicle back to the intervention circuit). The term “partial intervention” is meant one pass of the intervention circuit.

The maintenance system of class I. roads is further supplemented by meteorological support of dispatchers, i.e., updated data from individual weather stations with evaluation of important parameters – air temperature, humidity, road surface temperature, dew point temperature and more. It also includes a forecast for the next period, the system independently evaluates the risks in terms of the winter service intervention and sends warnings. If the vehicle is equipped with an appropriate meteorological sensor, the air temperature and the temperature of the road surface can also be monitored while driving, or the condition of the road surface and the so-called slipperiness factor.

9.3. WEB APPLICATIONS FOR OWN NEEDS

For most of winter service suppliers, this compulsory evidence brought new challenges. It was not always easy to adapt, especially for elderly workers. Many initial failures of GPS modules, spreader units or data transmission occurred and had to be solved. However, after certain time it was accepted.

The web application itself contains a map section for the analysis of vehicle operation and tools for reporting and evaluation. First, the traffic data is used by the winter service dispatch centre. Responsible workers find out where all monitored vehicles are currently located and what type of job they are currently doing. Also, they can see which sections of roads have been treated, time horizon, dosages used and other necessary information that can help in deciding on the next maintenance procedure. There is a map application where it is possible to monitor in detail movement of selected vehicles, including operating parameters in a selected moment. The trajectory of the vehicle on the map can be distinguished, for example, by the type of service and the visualization is complemented by interactive graphs, where you can monitor, for example, the course of the spreading material used or the surface temperature while driving.

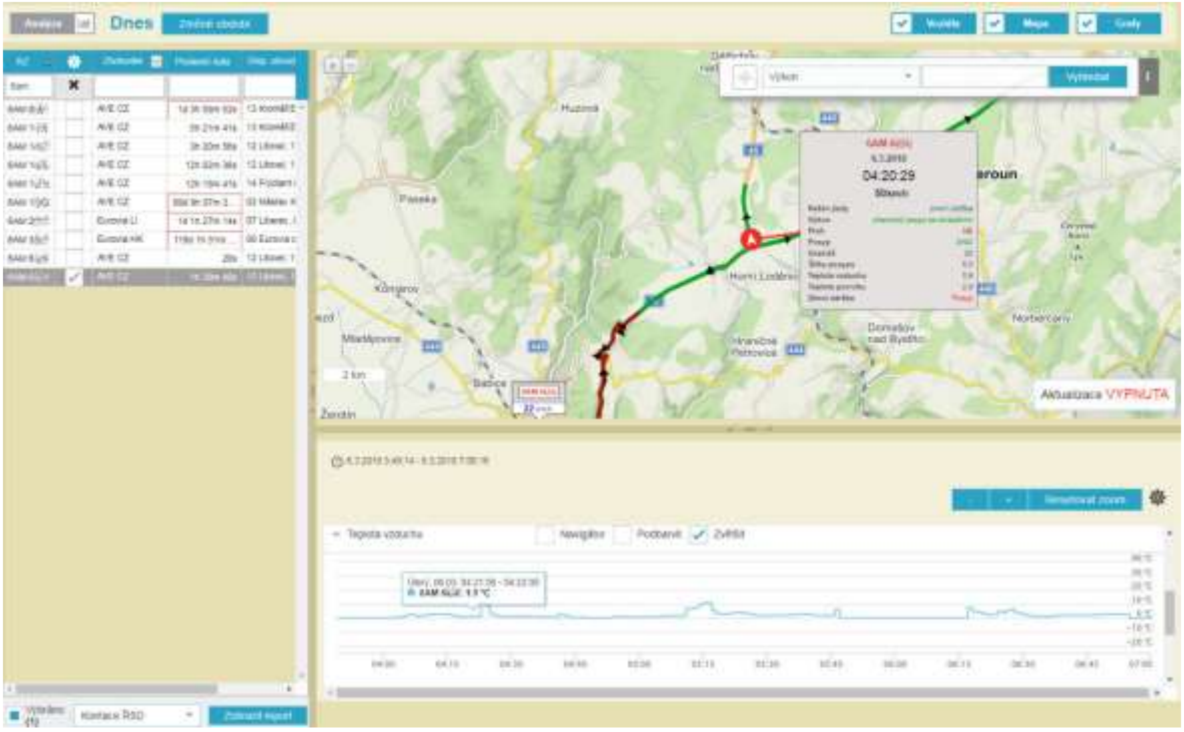

Figure 3 – Vehicle trajectory and all driving data in the METIS system

Compared to previous handwritten vehicle operation documents, this tracking system is a ground-breaking tool in supporting winter road maintenance, as it can very accurately record the course of maintenance in line for each individual section of the road network.

Secondly, the data on vehicle performance is used by the maintenance manager when reporting and documenting the work done. Jobs are monitored for individual vehicles and reported for defined maintenance areas (dispatching circuits) and calendar days. The data from the vehicle tracking system are a convincing basis for billing the services to the maintenance client, i.e. Road and Motorway Directorate.

Last but not least, the outputs of the system serve road administrators in case of retrospective checks. This has been even supported with mounting on-board cameras on selected vehicles. Firstly, the records can help solve disputes about adequacy of the journey. They can be also used in case of a traffic accident.

9.3.1. Vysočina region application

One of the administrators – the Regional Administration and Maintenance of Vysočina Roads - came up with a request for another application that would allow tracking the position of vehicles in a different type of display based on data sent from GPS units, and especially with a short-term history of their movement. Therefore, the input was to set the colour resolution depending on these times from green (intervention no later than 30 minutes) to red (intervention no later than 12 hours). In cooperation with the GIS department of the Vysočina Region and with the company ARCDATA PRAHA (technology of the American company Esri), a simple application was created, which displays the current position of individual vehicles in points.

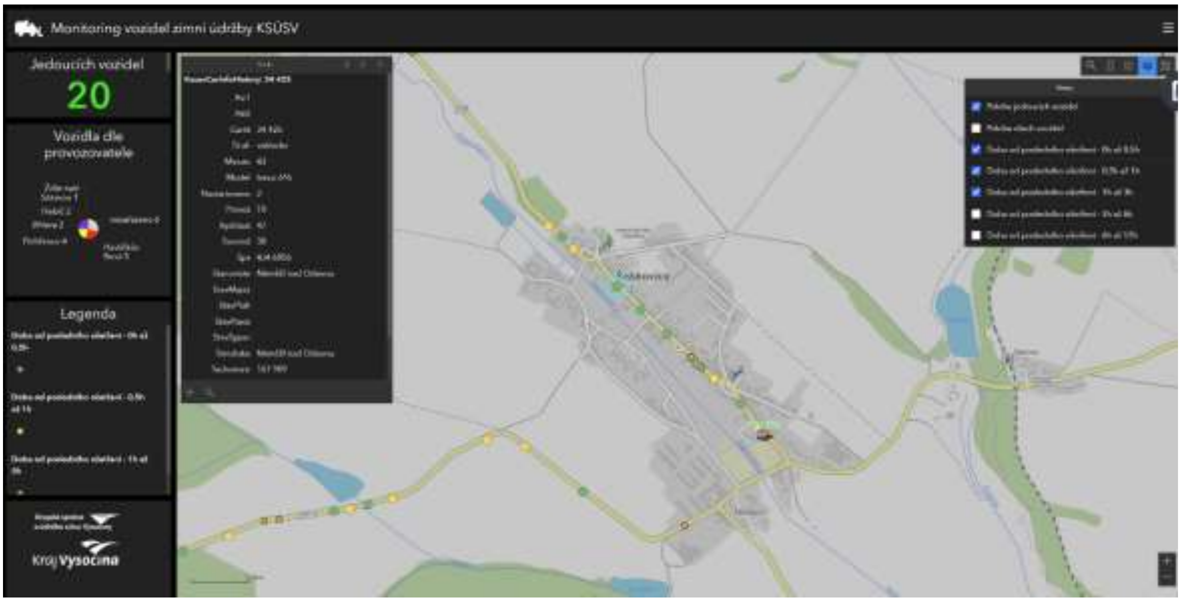

Figure 4 – KSÚSV vehicle tracking system; source: gis.kr-vysocina.cz, hidden access

When you zoom out on the map preview, the points merge into a curve showing the car's past movement, including the colour resolution of the history. For users, the task is fulfilled to clearly display the movement of all cars, at the same time has the opportunity to find out all the details of its activities – speed, spreading, ploughing, vehicle detail, maintenance technology and more. A layer of traffic information, winter maintenance circuits, technologies performed and importance classes on a given section of road can also be added to the display, as determined by the officially approved Winter Maintenance Plan. The system is not only used in the winter months, but also in the summer, for example in the transport of the coated mixture to the paver finishers when laying new roads. Another key advantage is the trouble-free use of the mobile version with responsive display.

9.4. Applications with public access

With the development of internal tools and especially "user friendly" applications came the idea of publishing some data also to the public in the form of public access. Software companies develop and offer this as part of their services, either on the basis of OSM (Open Street Maps) or Esri ArcGIS. It is a relatively dynamic field that is constantly evolving and improving.

Data for the public is provided in two forms – as static data (plain html text, .pdf files) or online updated data.

Static data

- maps displaying technology used and spreading material
- maps displaying order of road importance (necessary time of intervention)
- maps of obligatory snow chains or other equipment sections
- explanation of terms, legal framework
- contact information

Figure 5 – Winter maintenance technology of the Liberec region - static .pdf map;

9.4.1. Dynamic (online) data

• vehicle movement map with history

In order to streamline the data provided, maintenance is presented using color-coded operator intervals. In addition, thanks to this, information on the real movement of vehicles managing regional roads cannot be misused. Each vehicle position record is compared based on a complex algorithm to the road network, and if all requirements are met, the section is evaluated as serviced. The served roads are displayed above the background map, where the individual sections are color-coded according to the last maintenance performed (up to 30 minutes, 30 to 60 minutes, 1–3 hours and 3–12 hours). Unattended sections or sections served less than 12 hours ago are not highlighted in colour on the map. Specifically, the sections where, according to the operational plan, winter maintenance is not to be done, are also colour-coded, and displayed. The overall output is then visualized in a special section on the public website of the regional administration. The site is also adapted for viewing on mobile devices. Everything works fully automatically and in real time.

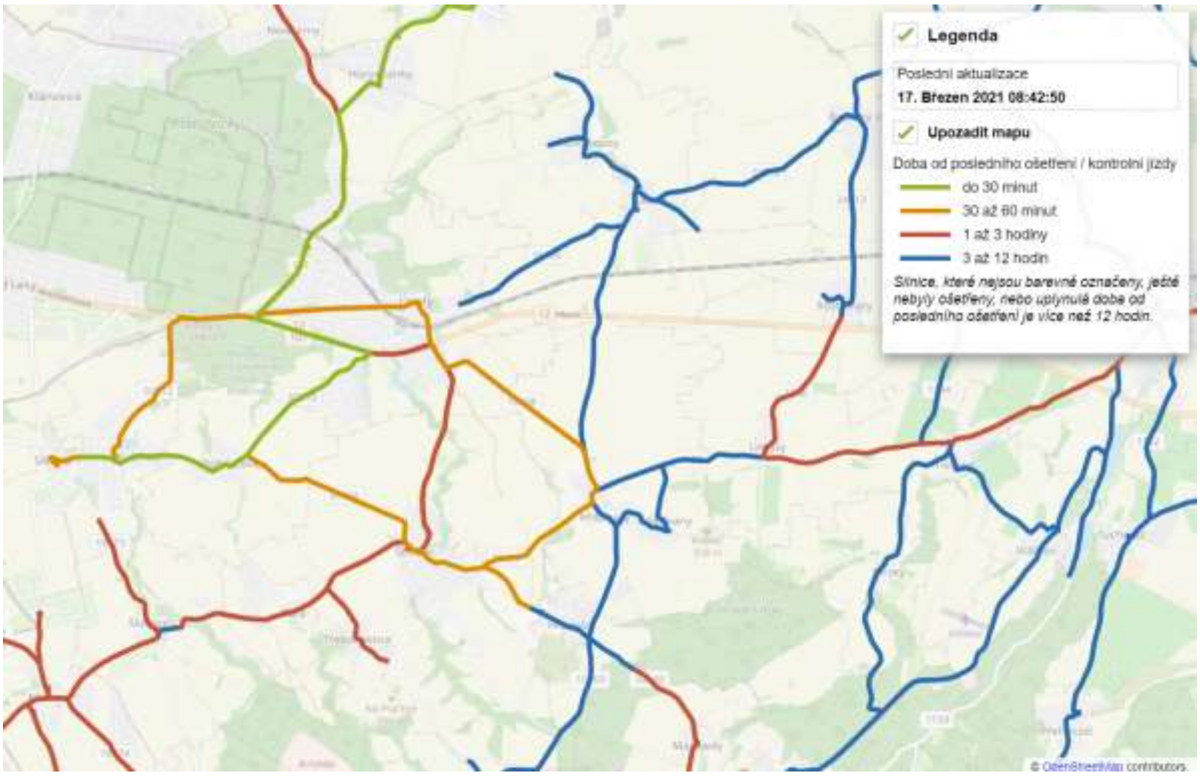

Figure 6 – Movement of winter maintenance vehicles of the Central Bohemian Region

9.5. Conclusion

A description of the operation and evaluation of winter maintenance and other possibilities of using data from GPS units of vehicles and their additional devices was given. It is clear that vehicle motion control systems and GIS technology in general will become increasingly important for road managers in the future. The digitization of traffic flow management and the pursuit of maximum efficiency will certainly place higher demands on road maintenance managers as well. This is also related to the posting of selected data to the public, which will be probably asked more and more in the future. The question of risks in enabling free access must be only well answered.

REFERENCES

- GIS.KR-VYSOCINA.CZ, HIDDEN ACCESS
- KSUS.CZ, OPEN ACCESS
- KSSLK.CZ, OPEN ACCESS
- DOPRAVNI INFO.CZ, OPEN ACCESS
- CROSS.CZ

10. CONVERSION FROM ABRASIVES TO DE-ICING MATERIALS

Julius Janeba
STRABAG, Czech Republic
julius.janeba@strabag.com

10.1. Introduction

The length of the road network in the Czech Republic is approximately 56 thousand kilometres. The substantial majority (87%) is represented by 2nd and 3rd class roads. According to the Roads Act, 2nd class roads use for transport between district towns, 3rd class roads are intended to connect municipalities to each other or connect them to other roadways. In the English equivalent, these roads are referred to as "regional" or "rural”. 1st class roads are owned by the state, lower-class roads were transferred to individual regions as a part of the renewed self-governing arrangement. After the delimitation of the former district agencies into regional structures after 2000, the organization of road maintenance is developing differently in different parts of the country. While the majority of regions still keep their own capacities for carrying out routine and winter maintenance, in some these activities are already outsourced almost exclusively to suppliers.

10.2. Use of spreading materials in the Czech Republic

The legislative framework for winter road maintenance is established by Executive Decree No. 104/97 Coll. Each road must be assigned an order of importance in the winter maintenance plan and at the same time the implementation technology. Only a minority of the network is maintained by plowing alone.

a) I. order – the entire width and length of the roadway is covered with ice, and the remaining layer of snow after plowing with a thickness of less than 3 cm is removed by spreading deicing materials, if chemical deicing materials are ineffective, it is roughened using abrasive materials,

b) II. order – the same technology as in order I, with the fact that, if necessary, layers of snow are left on the roads, which are roughened by spreading abrasive materials. Spreading may only be carried out in places where the traffic technical condition of the road requires it (intersections, large inclines, sharp bends, regular passenger transport stops),

c) III. order - they are maintained only after the treatment of roads I. and II. in order of importance, basically with plowing, and in places where the traffic technical condition of the road requires, spreading roughening materials is carried out.

The text of the decree is still relatively benevolent for road administrators in an international comparison, especially the possibility of only plowing and the 12-hour time limit for driving on roads in the III. order. Furthermore, the high proportion of regional roads maintained with roughening materials (abrasives or grit) remains a specific feature of the Czech Republic, despite the fact that the ratio of the applied salt compared to abrasives has been gradually increasing over the last two decades. For the calendar year 2002, the 2nd and 3rd class roads consumed three times more abrasives compared to salt, in 2021 only 1.15 times more.

Figure 1 – Example of a section with abrasive treatment

With the roughening technology, straight sections of roads are spreaded with a dose of approx. 70 to 100 g/m^2, places where the traffic technical condition of the road require, with a dose of approx. 300 g/m^2.

The minimum, technologically sufficient dose for the deicing type of spreading is 20 g/m^2. When removing thicker layers of ice, it is usually necessary to use higher doses, but the total consumption of salts should not exceed 60 g/m^2 on one intervention day. Spreaders, which are equipped with a pre-wetted device, should enable the ratio of dry material to brine to be maintained at 7:3 at a dosage of 5 – 20 g/m^2.

The Regional Road Agency the Vysocina Region (KSUSV) provided the data for a specific analysis of the actual kilometers driven and the materials consumed. All winter maintenance records have been collected in the sophisticated internal application "Winter Maintenance Log" since the 2006/7 season. Obviously, older records suffer from some inaccuracies in mileage and amount of spreading materials. With the development of GPS technology and other sensors on superstructures, the numbers have become more precise in the last decade. In addition to general technological progress, newly introduced rules for evaluating performance "adequacy" contributed to the right data collection.

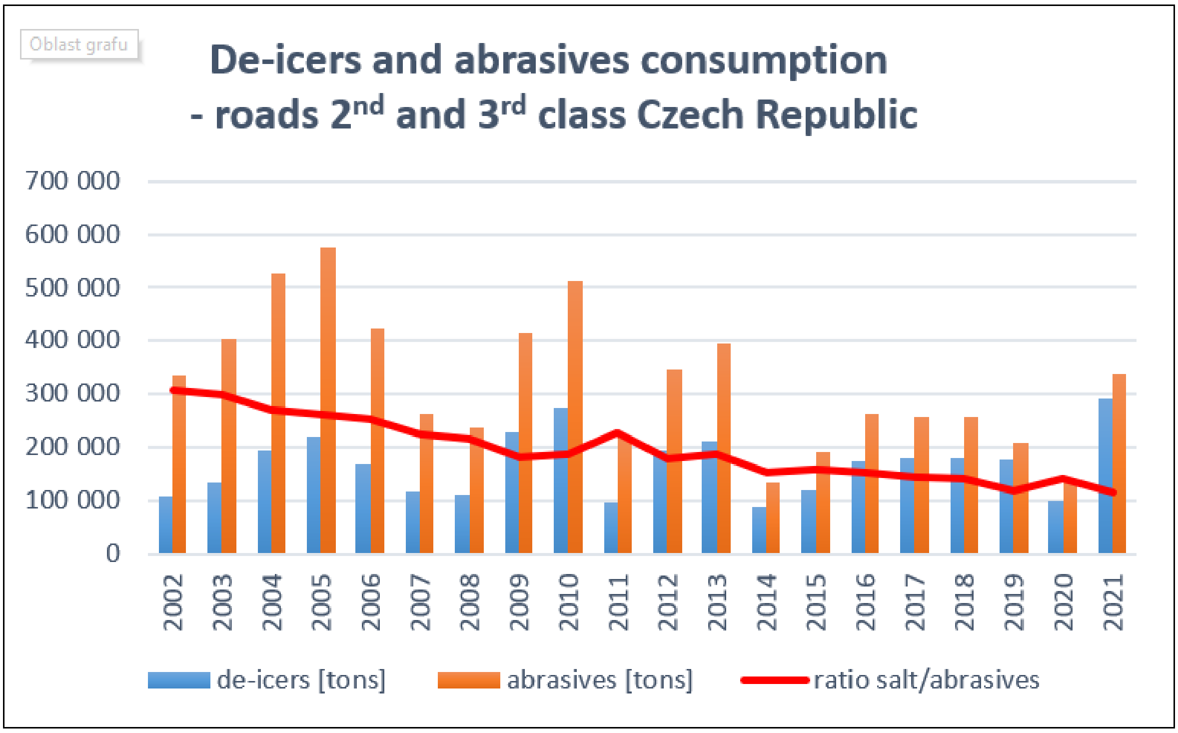

Figure 2 – Use of spreading materials on 2nd and 3rd class roads in the Czech Republic since 2002

For further comparison, we are again based on the paragraphs of Decree No. 104/97 Coll.:

KSUSV statistics copy the national average in the long-term development. The ratio of consumed abrasives and salt decreased from 7.1 to below 4.0. Overall, there is a noticeable decrease in winter service operation due to climate change, the strong winters of the first decade of the 21st century are a matter of the past. For comparison, an indicative share of the total kilometres driven and the spreading material used can be calculated. The considered spread width is 4.0 m. Of course, this statistic is affected by forced crossings and other factors. Even so, the figures show that the efficiency of spreading in relation to the kilometres driven. Abrasive spreaders are driven almost half of the routes without dosing started. The average value of around 50 g/m2 does not change in the long term.

- inert material 54.19 g/m2
- salt 15.92 g/m2
- brine 3.84 ml/m2

In the long-term average, the share of brine is 19.5% of the total volume of deicers used, the trend of recent years is to increase this ratio. In the 2006/7 season, the share was 11.2%, in the 2019/20 season it has already more than doubled to 24.2%. The Directorate of Roads and Highways, and in recent years also the Regional Administrators, are going further and acquiring superstructures with the same volume of solid salt and brine, whereas the experience appears to be very positive.

Figure 3 – Spreader with Epoke Sirius Combi AST body in Boskovice

10.3. Change of Road Technology II/360

The 2nd class road II/360 is an example of a positive technology transition even in the conditions of the environmentally protected area. The road passes through the hilly terrain in the section Nové Město na Moravě – Jimramov. Due to its location, the road is also widely used for freight transport, it is an important north-south link of the two regions. According to the results of the last nationwide traffic census, 443 heavy vehicles passed through the section on weekdays.

In addition to the relatively high altitude, reaching up to 755 m above sea level, the road II/360 has a profile with significant curves and steep hills. The main climb takes a length of 1 km and a longitudinal gradient reaches 12%. With the increasing intensity of traffic, accidents and traffic jams occurred more and more frequently in winter season. The section was maintained by plowing and spreading roughening materials (abrasives). Already in 2006, the district road administration in Žďár nad Sázavou managed to negotiate an exception to the use of deicing materials. However, it only concerned the listed sections and calamitous conditions. In practice, this turned out to be difficult to implement also due to the absence of a proper salt storage facility, a part of the hall was set aside for salt at the landfill in Jimramov, which did not comply with building or ecological rules. The dispatcher's office continued to be frequently contacted by drivers of blocked trucks and cars stuck in convoys. The exceptional daily comsumptions reached 100 tons of abrasives on only one spreader’s circuit.

After another wave of complaints from drivers, residents and municipalities, in 2015 the road agency renewed negotiations with the administration of the environmentally protected area on a permanent exception for the use of deicing agents on the entire section. The paradox is that the views of the municipalities were still not unified at that time. The representatives of the Jimramov township defended the layers of snow as a romantic part of the foothills and defended themselves against the slushy slurry when using salt. The representatives of CHKO finally agreed to the transition to chemical maintenance of the entire section, subject to clearly stated conditions:

• chemical treatment will be carried out after previous mechanical removal of the snow layer;

• sodium chloride dosage does not exceed 20 g/m^2, in extreme cases 40 g/m^2;

• solid sodium chloride will be applied with a 25% brine of magnesium chloride;

• monitoring of groundwater, soil and botanical monitoring will be carried out at regular intervals within the specified scope and period.

Circuit No. CH503V was modified to include the affected Nové Město – Jimramov section in its route. Temporary bags were first installed in the Bystřice nas Pernštejnem Road Administration facility, and later stable tanks for the magnesium chloride solution. A 30% solution from the cistern is pumped into one tank. The possibility of further diluting the solution with clean water in the second tank was empirically verified, the resulting ratio has still sufficient defrosting ability.

Figure 4 – Tanks for magnesium chloride in the road administrator's facility Bystřice n/P

The impact of deicers on nature has been verified regularly. In the first three years, the values did not change fundamentally (see table no. 4). When comparing the values measured in 2016 – 2018 and 2018 – 2022, the agency notes an increase in the average values of Cl- from 35.9 mg/l to 55 .7 mg/l (Roženecké Paseky) and from 26.8 mg/l to 34.2 mg/l (Věcov). Conversely, in the wells near Zubří, the values decreased from 10.4 mg/l to 7.3 mg/l. The limit value for chlorides is 100 mg/l. Mg+ values do not change at all in a long-term comparison. Likewise, soil monitoring shows no significant changes.

Datum odběru	Místo odběru	pH	Cl⁻ mg/l	Mg mg/l	Na mg/l
26.5.2016	Zubří OM ZJ	5,9	7,4	1,9	6,88
15.9.2016	Zubří OM ZP	6,1	6,4	1,58	6,11
27.4.2017	Zubří OM ZJ	5,9	19,5	2,41	7,23
21.9.2017	Zubří OM ZP	7,2	7,1	1,77	5,12
15.5.2018	Zubří OM ZJ	6,1	11,7	2,33	7,76
minimum		5,9	6,4	1,58	5,12
maximum		7,2	19,5	2,41	7,76
průměr		6,24	10,4	2,00	6,62

Figure 5 – Results of groundwater monitoring

It follows from the botanical report that no plant species has started to disappear from the adjacent meadows, on the contrary, an increasing involvement of vegetation and an increasing proportion of ruderal and nutrient-demanding plants were recorded in the monitored transects more species. On the selected transects, the occurrence of Puccinellia distans was recorded. It is a salt-loving species naturally occurring in inland salt marshes and salt meadows on the sea coast. Thanks to the salting of roads in winter, it is now widely distributed in secondary habitats along roads, where it forms typical 20-30 cm wide strips of gray-green colour. In the extension of the decision on exemption until the winter season 2027/28, issued by AOPK on 29 November 2022, there is no longer an obligation to take soil samples. Groundwater analysis and botanical analysis will continue to be carried out by road workers.

In terms of road traffic, there has been a positive change. Above all, the flow of freight traffic even in winter contributes to the generally calmer traffic situation, which is acknowledged by local citizens and representatives of local governments. The proof is the development of accidents in winter conditions - according to the condition of the road surface parameter.

From the regular evaluation report for the 2021/22 season, the following values are recorded on the 14 km long section II/360 Nové Město – Jimramov: 106 intervention days, 190.35 tons of road salt and 67,978 liters of $MgCl_2$ brine. The brine ratio therefore corresponds to approximately 26%. In conditions of freezing precipitation, condensed water vapor at temperatures close to 0°C, it would be advisable to apply an even higher proportion of the liquid component compared to solid salt, up to 50% or more. In the future, it may therefore involve the acquisition of a superstructure with a higher proportion of liquid tanks and ensuring sufficient capacity of the brine tanks.

11. CONCLUSION

For further development, we always need to define current conditions, weak sides and opportunities. Quality of winter road maintenance, as all other public services, depend on system settings and willingness to keep it improving. Individual's enthusiasm and patience to follow the progress is necessary. In the case studies, we could see some examples of positive advance, no matter if a significant change or a minor innovation is considered. It is important, the goals aim at safer and user-friendly roads, better efficiency for operators regarding environmental issues.

World Road Association (PIARC)

La Grande Arche, Paroi Sud, 5e étage, F-92055 La Défense cedex