A comprehensive Winter Maintenance Management System to increase Road Safety and Traffic Flow

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ABSTRACT

Major goals of road operations are safety, environmental protection, economics and the necessary optimisation of these issues in delivering quality winter maintenance services. For increasing road safety the needs are high quality prediction and sensor technologies as well as appropriate winter service treatments at the right time. Next to road safety mobility is an important factor in local economies; uninterrupted traffic is a basic requirement for the effective development of the economy and society. A significant increase in traffic volumes on roads has an effect on quality of traffic flow and safety. That means the aim of road management must be that a road user can drive a certain distance in a predictable time as safely and reliably in winter as in summer. Because of the complexness of meteorological, traffic and winter service processes, the persons in charge of winter maintenance need a comprehensive Winter Maintenance Management System.
This clearly shows the need for Maintenance Decision Support Systems (MDSS) to efficiently and safely manage infrastructure systems in wintertime. A solution to this is the Management System BORRMA-web MDSS inside. This system clearly displays all important elements in one view, such as dynamic maps, RWIS Stations, Fixed Automated Spray Technology (FAST), vehicle operation data and location of winter service vehicles, road conditions etc. for real-time, future, and past events. Especially useful is the combination of local measurements (RWIS-Stations) and weather forecasts allowing detailed predictions and alerts for each forecasted Road Weather Segment (road section with similar microclimatic conditions). This means that differentiated danger levels of road conditions can be shown on the dynamic map for a forecast time of up to 72 hours. Additionally, with the Vehicle Data Management tool with online data transmission, the operator has a clear overview of the actual location of all winter maintenance vehicles and their operation.
The collection, combination and visualisation of all this information and predictions of the Maintenance Decision Support System give the operator the possibility to make decisions efficiently and to manage dynamically, which increase road safety and improve traffic flow.

Keywords: MDSS; Winter Maintenance Management System; traffic safety; weather forecast; vehicle data management

1. INTRODUCTION

Wintry road surface conditions have a considerable impact on road safety and traffic flows. Speed levels fall, distances between cars increase along with a reduction in traffic quality and capacity. These conditions can result in reduced traction and reduced visibility when snowing (to the point of impassability). This in turn can result in a considerable cost to the economy due to winter-related accidents, as well as delays from reduced speeds and traffic congestions.
Winter maintenance is the combination of measures of the roads' operator for maintenance and easing of traffic as well as road safety during wintry conditions. There is no doubt that the highest priority is the guarantee of road safety. In addition, the maintenance of the traffic flow is also of great importance. This can be shown by the fact the mobility is now a key location factor and that free-flowing traffic is a key condition for the ongoing development of a functioning economy and society. There is also the increased demand for correct but economic road operation. These targets apply both to highways and urban roads.
Competent road condition and weather monitoring and the resulting qualified launching and control of winter maintenance deployments allow an optimised, high-quality winter maintenance. However, complex decision-making situations, such as those which occur in winter maintenance management, require support systems in order to employ the best possible measures according to the prevailing general conditions. A characteristic of

winter maintenance of road operations is that the winter maintenance service can usually only respond to the effects of the weather through timely winter maintenance measures; unlike as is with much of the summer maintenance management, carrying out preparatory work in a way which is flexible but takes adjusted requirements into account. Nevertheless, the influencing factors and interaction of these factors, which can lead to critical situations, can be analysed and can thus be processed in an intelligent management system in order to create detailed prognoses, with high probabilities, to support decision-making for efficient winter maintenance measures.

2. WINTER MAINTENANCE MANAGEMENT SYSTEM

It is here that a comprehensive Winter Maintenance Management System as the "BORRMA-web MDSS inside" management system can help, offering a web-based network solution with numerous functions for the management of roads and runways. "BORRMA" stands for "BOschung Road and Runway MAnagement". Special prognoses for the RWIS-station data and road conditions, along with a clear visualisation of all the key information support the winter maintenance manager in making decisions and controlling the winter maintenance deployments. "MDSS inside" (MDSS = Maintenance Decision Support System) can assist in making these decisions.

"BORRMA-web MDSS inside" is the central component of the complete Surface Condition Management (SCM) concept, which can offer communities, towns, road construction authorities and airports the option of integrating and networking all of their stationary and mobile systems to provide efficient co-ordination and control of their summer and winter maintenance programmes.

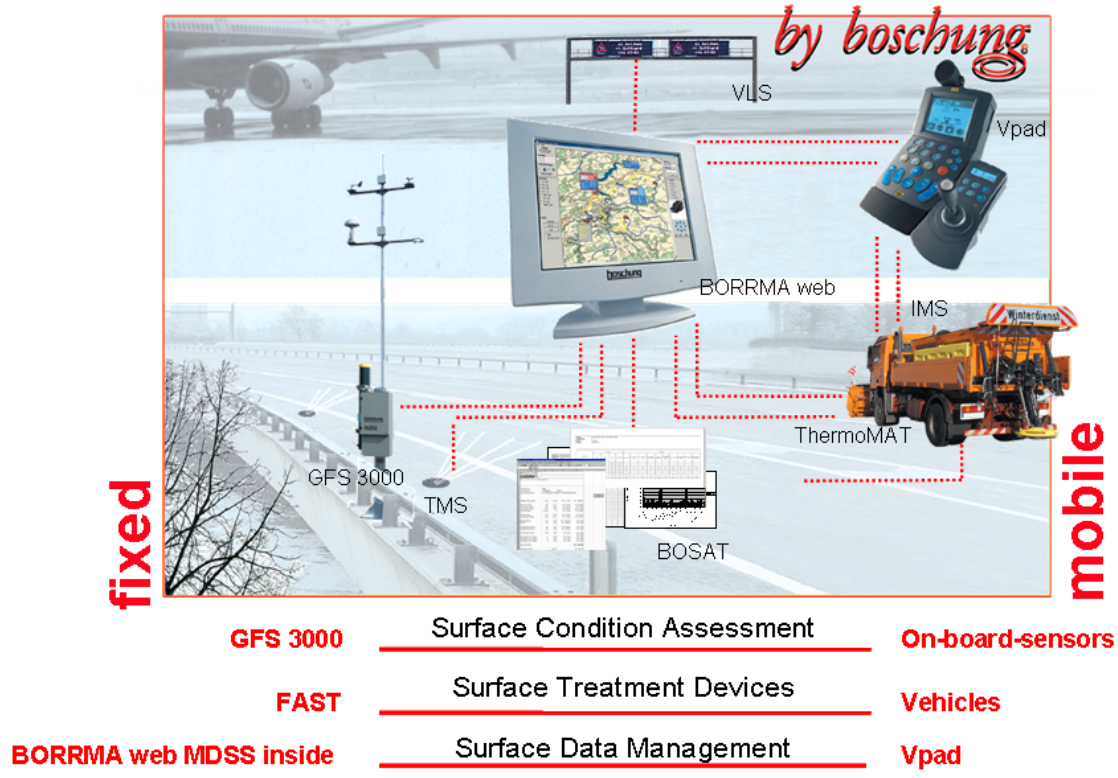

Fig. 1. Surface Condition Management (SCM)

"BORRMA-web MDSS inside" is a comprehensive winter maintenance management system to monitor the current and expected road conditions, to control deployments and for automatic recording and display of all the data and reports (proof of the road safety obligation and performance data recording of the deployment vehicles for balances and invoicing). The new features of this software are, on the one hand, the intelligent linking of weather information and periodic road condition data and prognoses from RWIS stations (GFS 3000) taking local general conditions into account, giving road condition predictions not just for local points but for whole roads sections, so-called Road Weather Segments. On the other hand, a management system has been created, from which the user receives a large volume of information presented clearly, e.g. RWIS station data, visualised road condition prognoses, RWIS reports, status of the Fixed Automated Spray Technology (FAST), location and activities of winter service vehicles, on one user desktop.

The following overview shows the functional principle of "BORRMA-web MDSS inside" together with the key input parameters and dataflow, which the system uses to prepare the appropriate prognoses, centralised databases and visualised information. In addition, Boschung uses Open Source components. The user does not need to install any special software, but can access the server functions directly. The system is also freely scalable, i.e. the hardware is adapted individually according to requirements and size (community, city, state). Hosting is also possible in various areas, for example the vehicle performance data recording, i.e. data is managed using a secure Internet portal and no system investments are required.

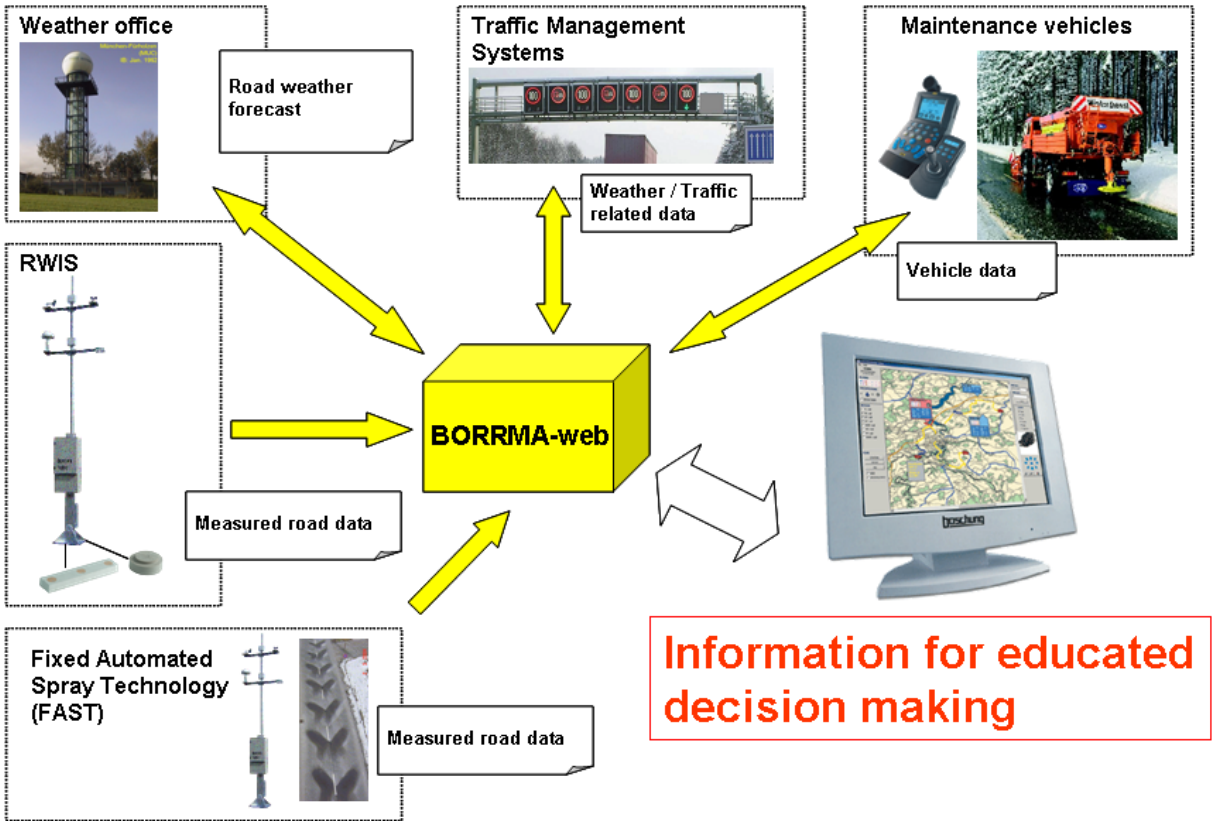

Fig. 2. Functional principle of BORRMA-web MDSS inside

3. LOCAL AND ROUTE-RELATED ROAD CONDITION PREDICTIONS

For the winter maintenance manager, it is important to know in advance when and what areas, in the road network under their control, are subject to wintry road conditions. Only with this information is it possible for them to co-ordinate the resources available and make decisions regarding the deployment time, treatment type and scope.

Besides the weather reports and the RWIS prognoses, the data and predictions of the RWIS stations are of high importance for the launching and control of winter maintenance activities. On the dynamic map, the winter maintenance manager can, for example, see all the RWIS stations as flags, and is informed of expected dangers by a tiered alarming notification/.

Several steps must be run through for a route-related road condition process. The network under observation is divided into sections according meteorological criteria, so that similar microclimatic conditions can be found within these segments. Within "BORRMA-web MDSS inside" these sections are called Road Weather Segments.

Using the measurements of the local RWIS stations, detailed weather forecasts and precipitation forecasts (precipitation radar), local forecasts (these local forecasts usually relate to the RWIS stations) are calculated in a nowcasting module. This nowcasting prognoses is calculated for the next two hours and is updated regularly. When controlling winter maintenance activities, it is these two / three hours which are critical for the correct selection and scope of winter maintenance deployments. The measured and expected parameters for the RWIS stations can be viewed in a separate window.

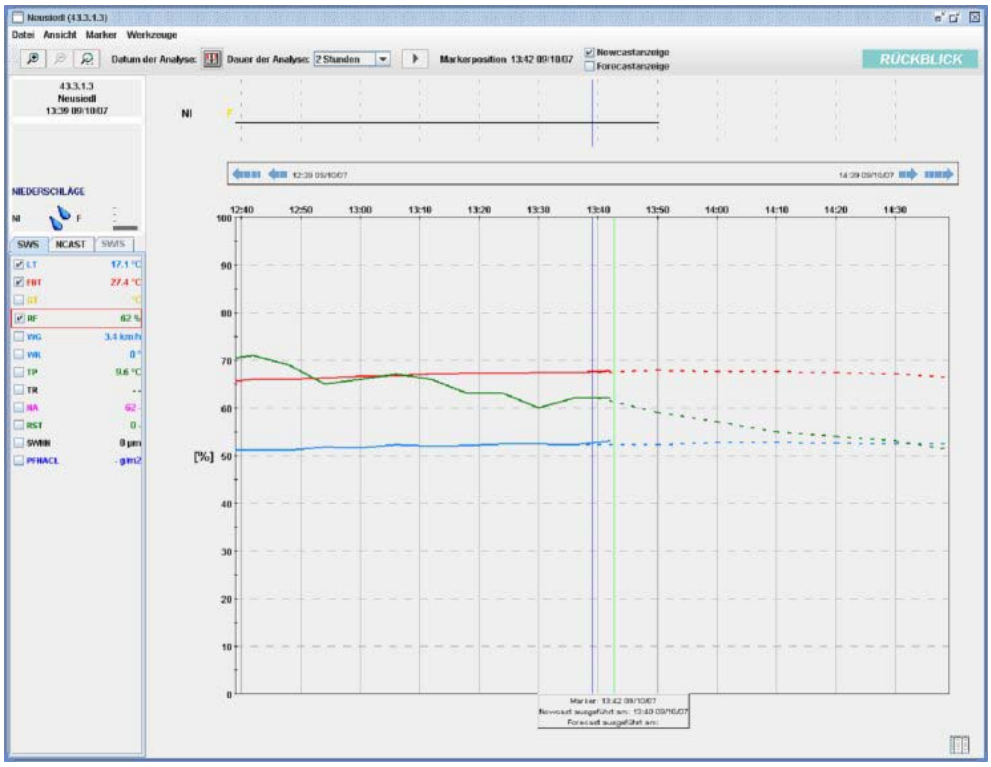

Fig. 3. Measured and forecast data for an RWIS station

In the area of measuring points, the user can now use specific parameters to detect exactly when, for example, this area can expect ice. The reliability of the measuring point prognoses for road conditions is increased even further by active sensor technologies. In this technology, a road surface sensor is cooled in stages at regular intervals until ice formation is determined on the sensor surface. This means that a freezing point temperature is not calculated from resistance measurements but is measured (increased accuracy). This active technology is particularly advantageous for forecasting frost.

Using the local prognosis, the forecast function is used to calculate a long term (three-day), route related prediction. This forecast is based on the combined results of the nowcasting, long term weather forecasts and additional general conditions. Risk levels are determined for time periods for each road weather segment using innovative decision-making methods. These risk levels are then displayed on the dynamic map for each road weather segment, according to time. Each time a road weather segment is clicked, the individual risk levels (no risk, risk level 1 to 4) are displayed at the bottom right of the user desktop along with the time of predicted occurrence. This gives the road maintenance manager an overview of the current status of their entire road network and, using a time slider, of the forecast road surface states. Besides the road surface conditions, it is also possible to display the air temperature or road surface temperature for all the road weather segments on the map.

This gives the winter maintenance manager a tool, with which they can control the winter maintenance deployments efficiently and plan the optimum personnel and vehicle requirements for a longer period of time.

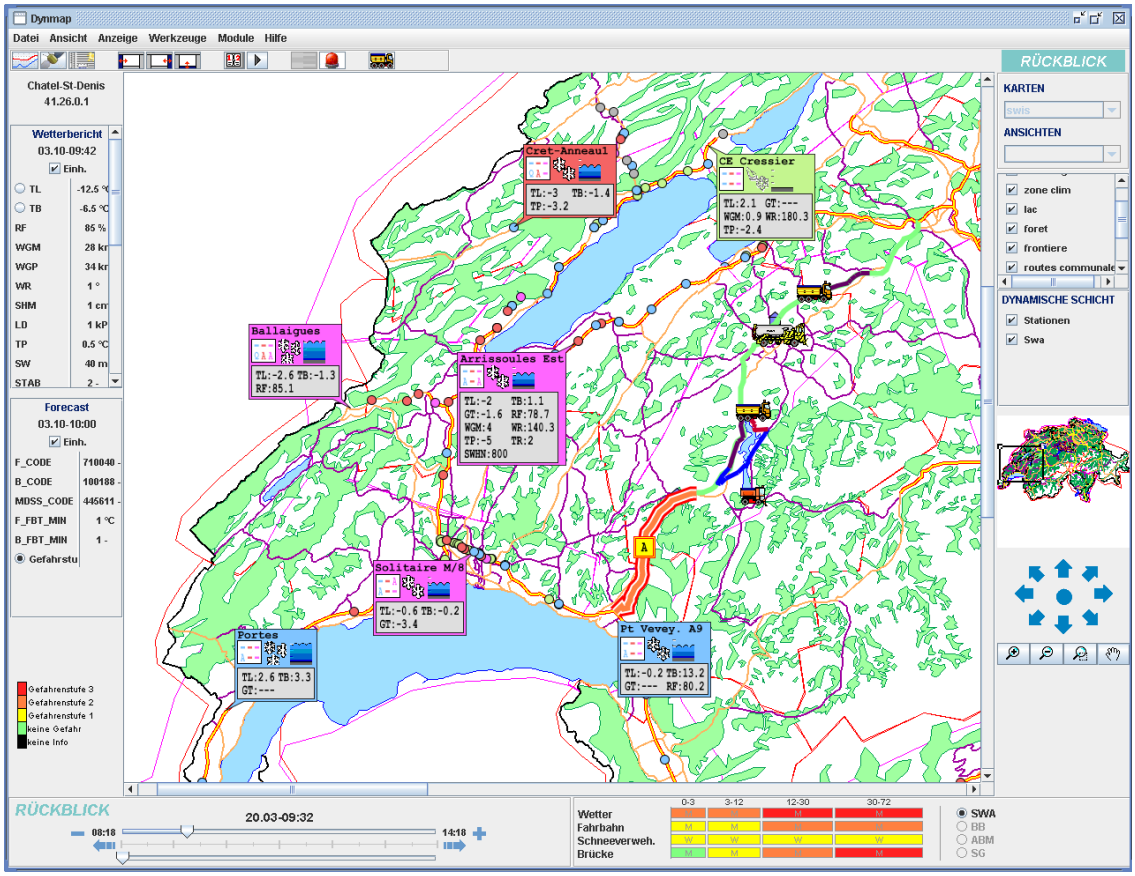

Fig. 4. BORRMA-web MDSS inside desktop

4. DYNAMIC MAP

When planning and controlling winter maintenance activities, the winter maintenance manager has to observe numerous general conditions and influencing parameters, such as legal regulations and requirements, meteorological parameters and weather developments, current and future road conditions, traffic factors, resources, etc., and include them in the decision-making process. In particular, in the case of winter events such as heavy snowfalls or rapid icing, it is essential that the winter maintenance manager is supported by a visualisation of the deployment-relevant information, prognoses and alerts, due to the complexity of the operation.

The dynamic map consists of a static background, calibrated according to GPS co-ordinates (vectorial map, satellite images, etc.) and various dynamic information layers (Road Weather Segments, RWIS-stations, vehicles, Fixed Automated Spray Technology (FAST), etc.) which are superimposed upon it. RWIS stations are shown as small flags, in which the parameters can be configured individually. The dynamic segment is continually updated, to show the latest data. Alerts from the RWIS stations or expected risks on the road weather segments are clearly shown on the dynamic map, by the appropriate road or measuring point flag changing colour.

Fig. 5. Example of the display of a measuring point flag and deployment vehicle with current data on the dynamic map

Installed Fixed Automated Spray Technology (FAST) can also be monitored and controlled from the dynamic map using a special de-icer spraying synoptic. In so doing, the user can follow the course of the spraying programme (control of the individual valves, spraying operation of the individual spraying profiles, flow measurements, tank levels, etc.) in detail on the screen. System alarms are indicated to the user by a change in screen colours.

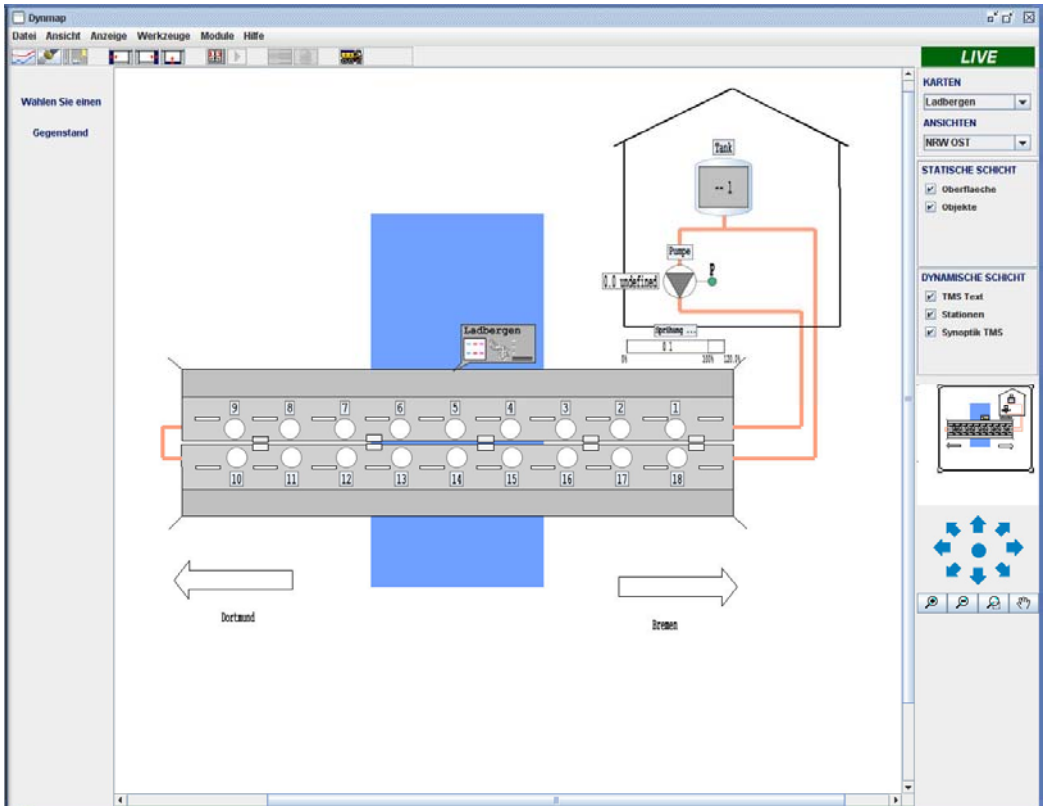

Fig. 6. Example of de-icer spraying synoptic to control and monitor a FAST system

5. VEHICLE DATA MANAGEMENT

Due to the obligation to prove regular analyses and evaluation and also for invoicing purposes, all the winter maintenance activities must be documented fully and clearly. Currently ,drivers of the winter maintenance vehicles (along with others) create winter service reports which contain the ploughing and salting route, with times, the type of deployment, if necessary making distinctions of route areas, the quantities of salt usage and loading, as well as the environment conditions (weather, road surface conditions, etc.). This is done in order to prove the correct fulfilment of the duties and to counter any liability claims. Often, the winter maintenance operators must provide reports, i.e. road and motorway maintenance authorities must report to the state operators or municipal operators must report to local government.
Automatic data recording of the winter maintenance deployments as part of vehicle management can be used to create complete this comprehensive documentation without any manual effort. This is even more important in order to meet the growing requirements for fast, functioning and economic winter maintenance as part of a comprehensive winter maintenance management system.

Fig. 7. Winter maintenance vehicle on highway

The performance data recording makes a distinction between summer and winter maintenance. The deployment data is recorded for a range of units with GPS locations in the Vpad. The Vpad is a control panel for the winter maintenance vehicle and is also used to record and transmit data. Data transmission takes place online via SMS or as a file via GPRS during the deployment in defined time periods (e.g. 60 secs., two minutes) or offline, after the deployment, in the database of "BORRMA-web MDSS inside". The master data must be entered or simply confirmed on starting the trip, and data transmission takes place without any manual input. With the online communication, the deployment data and vehicle positions can be followed on the dynamic map during the course of the deployment, which provides benefits for dynamic route planning, changing of deployment focus, etc.

Fig. 8 Control panel to control spreaders and snow plows with integrated data recording and route guidance

Once acquired, the data in the database can be evaluated easily, in order to prove the fulfilment of the obligation to road safety, invoice contractors, create balances and statistics, which, amongst other things, considerably reduces the amount of administrative work. The summary and detailed reports are openly configurable. This means that event lists, deployment lists and deployment reports can be created for any time period. The deployment reports can also be sorted by road name, road category, zone or task. Figure 9 shows an example of an event list report. All the reports and logs can be exported into various formats (PDF, XML, HTML, CSV) for further processing. This also provides the option of automated invoice generation.

Event list

Intervention	20.03.2007 06:53:54	**Agent**	[illegible]	**Vehicle**	320 Vogel	[illegible]	Salt
Intervention	20.03.2007 09:10:14			**Vehicle plate**	LU974		
Duration	2:16:20			**Center**	Kt. Luzern	[illegible]	

Tools 320 Salzstreuer
Sensors

Vehicle and tools			
	Time / Number	**Distance**	
320 Vogel	2:16:20	71.73	[km]
320 Salzstreuer	1:18:29	49.92	[km]

Spreading				
	Quantity		**Distance**	
Salt	1'751.16	[kg]	49.90	[km]

Event	**Status**	**Hour**	**Dist. [km]**	**Road**	**Road category**	**PK**	**Speed [km/h]**	**Spreading**					
								Width [m]	**Density Subproduct1 [g/m²]**	**Dist. Subproduct1 [km]**	**Quantity Subproduct1 [kg]**	**Asimmetry**	**Spread program**
[illegible]	+	06:53:54	0		0	0.0	0						
JOB2468	+	06:53:54	0		0	0.0	0						
320 Salzstreuer	+	06:54:25	0.00		0	0.0	2	3	10	0	0	0.0	0
		06:55:25	0.00		0	0.0	2	3	10	0.02	0.78	0.0	0
Streustrecke 320	*	06:55:29	0.03		2	0.0	1						
[illegible]	*	06:55:29	0.03		2	0.0	1						
[illegible]	*	06:55:59	0.10	Streustrecke 320	2	-1.0	11						
		07:02:16	3.76	Streustrecke 320	2	-1.0	51	4	10	3.79	113.84	0.0	0
		07:02:17	3.79	Streustrecke 320	2	-1.0	102	4.5	10	3.80	114.28	0.0	0
		07:02:18	3.82	Streustrecke 320	2	-1.0	0	5.5	10	3.82	115.16	0.0	0
		07:02:19	3.82	Streustrecke 320	2	-1.0	0	6.5	10	3.83	115.88	0.0	0
[illegible]	*	07:02:23	3.82	Streustrecke 320	2	-1.0	0						
		07:02:41	4.11	Streustrecke 320	2	-1.0	43	6	10	4.12	134.86	0.0	0
		07:02:42	4.14	Streustrecke 320	2	-1.0	11	5	10	4.14	135.66	0.0	0
		07:02:43	4.14	Streustrecke 320	2	-1.0	5	4.5	10	4.14	136.11	0.0	0
		07:02:44	4.14	Streustrecke 320	2	-1.0	5	3.5	10	4.16	136.83	0.0	0
[illegible]	*	07:04:17	5.27	Streustrecke 320	2	-1.0	58						
		07:05:10	5.55	Streustrecke 320	2	-1.0	56	4.5	10	5.55	185.48	0.0	0
		07:05:11	5.57	Streustrecke 320	2	-1.0	74	5	10	5.55	185.48	0.0	0
		07:05:21	5.68	Streustrecke 320	2	-1.0	43	4	10	5.69	192.43	0.0	0
		07:05:22	5.70	Streustrecke 320	2	-1.0	65	3.5	10	5.71	192.99	0.0	0
		07:06:22	6.45	Streustrecke 320	2	-1.0	43	4.5	10	6.47	219.64	0.0	0
[illegible]	*	07:06:23	6.48	Streustrecke 320	2	-1.0	86	5	10	6.47	219.82	0.0	0
		07:06:25	6.49	Streustrecke 320	2	-1.0	10	5.5	10	6.50	221.17	0.0	0
		07:06:26	6.49	Streustrecke 320	2	-1.0	9	6	10	6.51	221.72	0.0	0

Fig. 9. Example of a report - Event list

8. CONCLUSION

Complex decision-making situations, such as those which occur in winter maintenance management, require supporting systems to detect dangerous road conditions and winter events early enough to plan and control road maintenance properly. But a differentiated knowledge about traffic flows and capacities under wintry road conditions and prediction of weather events and road conditions are necessary to organize an efficient, fast winter service. In the field of winter maintenance, BORRMA-web MDSS inside is a comprehensive management system to monitor the weather and road conditions and control and log the winter maintenance measures.