INNOVATIONS IN WINTER MAINTENANCE MANAGEMENT IN LITHUANIA

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Abstract. Lithuania is a Baltic region country; therefore road maintenance in winter becomes a principal part of routine maintenance in this region. However, the economic crisis has impacted on the constrained budget in this area as well. This has resulted in the need to apply new attitude, methods, which could ensure effective implementation of road maintenance works even if there are significant losses of funding and lack of human resources.

Recently, the Lithuanian Road Administration has laid more attention on the efficiency of control of road maintenance. To achieve these goals, a number of researches are made and new measures have been implemented:

- In cooperation with Vilnius Gediminas Technical University, meteorological studies of all Lithuanian territory were carried out. As a result a climatic regionalization of country territory and new winter severity index was developed to index winter road maintenance funding, according to climatic winter conditions. Based on results of this study the Road Maintenance Manual and levels of maintenance were changed and adapted.
- The new mobile friction measurement devices RCM 411 were purchased. In cooperation with the state road testing laboratory "Problematika" tests with new mobile friction measurement devices were performed and friction measuring manual was created. According to this manual control and daily road inspections in state enterprises and coordination of road cleaning operations are carried out.
- The new Machinery Routes Monitoring Subsystem was developed and installed. It can observe real-time changes of weather and road condition and evaluate the performance of machinery by using data from GPS devices, RWIS stations and mobile friction measurement devices.
- The new Traffic Information Centre was expended and the traffic information mobile application for smartphones was established. It helps customers to get real-time information on traffic and weather conditions, to choose the optimal route and to report about accidents or other problems along the roadway.

Now positive results of these new measures are seen not only in the field of the road maintenance quality, efficiency and financing, but also in the satisfaction of road users. In this presentation the new winter maintenance management control attitude, measures and the results are described in detail.

Keywords. road maintenance, winter maintenance management, innovations, Lithuania.

Introduction

Lithuania lies in the northern part of temperate climate zone and the climate is described as moderately cold with snowy winter. The close neighborhood of the Baltic Sea and the Atlantic Ocean makes very significant impact on the climate. Cyclones from the Baltic Sea and the Atlantic Ocean determine the changes of temperature and rainfall in this region. These cyclones impact very high low-temperature fluctuations, which form perfect conditions for black ice. Approximately on November 15, at the earliest, the snow cover is formed in northern and eastern regions of Lithuania, while about 10 days later, at the latest, it is formed on the sea front. In snowy winters the thickest snow cover reaches even 90 cm. Generally, in the north eastern regions snow cover lasts 95–105 days, in the rest of the territory: 75–90 days. Cold period climatic conditions in Lithuania are very favourable for occurring dangerous meteorological phenomena, such as freezing rain.

Due to special climate, Lithuanian roads are operated in winter conditions up to 5 months per year. Therefore, winter road maintenance becomes the most principal part of routine maintenance in this region. However, the economic crisis has impacted this area as well. In the year 2008–2012 maintenance of the roads of national significance funding has decreased by 32 %. The evaluation of the price index shows that the current road maintenance funding is at the level of 2001. As a result, the state road maintenance companies have been forced to cut outlays. Limited budget forced to seek for new ways to improve the work efficiency and maintain the highest possible quality of road maintenance. Therefore, during the past few years, initiatives were taken to improve the management of state roads and road maintenance system and to expand the use of information technologies for work management, control and communication with the road users.

1. The Structure and financing of winter road maintenance

Lithuania roads are divided into roads of state significance, local and private roads. The Lithuanian Road Administration under the Ministry of Transport and Communications (LRA) is an institution that implements the public policies and programs of road maintenance and development, organizes the national road network development, modernization, operation and maintenance and also coordinates the funding of national roads (Fig. 1). All responsibility for local roads in Lithuania belongs to municipalities, they receive the funds from RMDP, which is administrated by LRA. Road Maintenance and Development Programme (RMDP) is funded by excise of fuel and gas and the road tax. The network of state significance roads consists of 21,242 km of roads, divided into groups according to relevance: main, national and regional roads (Table 1).

Table 1. Length of state significance roads, 2013

Groups of roads	Length, km	Total length, km
Main	1,746	21,242
National	4,929	
Regional	14,567	

Winter road maintenance in Lithuania is performed by 11 profit-seeking state-owned companies, which are awarded with one-year road maintenance contracts in the non-tender manner. Contracts with 10 state-owned companies are based on the territorial principle, boundaries of which coincide with county boundaries, and 1 state-owned company maintains exclusively only highways. The length of maintained roads for each company vary from 415 km (SE 'Automagistralė') to 2,790 km (SE 'Šiaulių regiono keliai') depending on the contracting territory (Fig. 1).

Fig. 1. Road maintenance contracting territories (the green bold line shows the contract of motorways).

In Lithuania, road maintenance is funded from the state budget under the Road Maintenance and Development Programme (RMDP), which is approved annually by the government. In the year 2013, 73 million Euros, i.e. 24 % of the total budget of RMDP, was given to the national road maintenance (this amount does not include funds for surface dressing). This year 36 million Euros was appointed for winter road maintenance, it is 50 % of all Lithuanian road maintenance budget, including routine and small-scale periodic road maintenance works. Unfortunately, since 2008, direct funding for winter road maintenance decreased by almost 15% (Fig. 2). Funding for 1 km of roads is distributed very unevenly, depending on the road group and supervisory levels. 1 km of the maintenance level I of main roads have nearly 10 times more funding than 1 km regional road with asphalt surface.

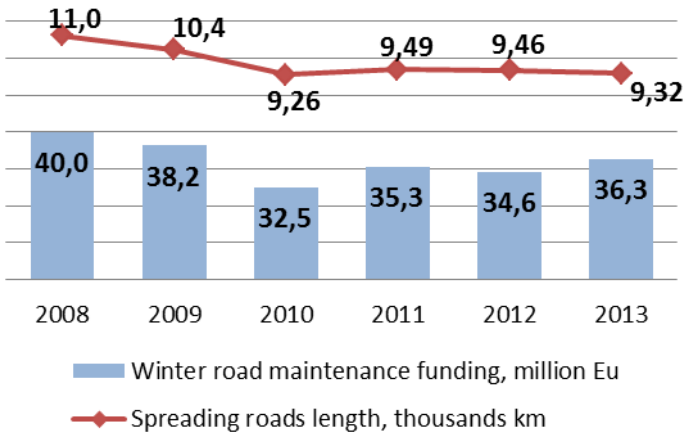

Fig. 2. Dynamics of Winter Road Maintenance funding and Spreading Road lengths 2008-2013

2. Organization of winter road maintenance

Winter road maintenance organization, execution and monitoring are carried out according to the Road Maintenance Manual, which was approved by the Lithuanian Road Administration in 2008. The Road Maintenance Manual is a set of normative documents, which regulates the quality of road maintenance works and its value. In order to ensure the most efficient use of funds, each year the Lithuanian Road Administration, with reference to financing and importance of a road, selects the maintenance level for each state significance road and accommodates the cleaning and spreading charts and rankings. The road list with maintenance levels and the work schedule are integral parts of the road maintenance contract.

Maintenance levels describe the key performance criteria based on the maximum efficiency and cost-effectiveness, so this system allows using available resources effectively. As a result, the losses of the road users are minimized. Each road group (main, national, regional) can be maintained in one of three levels: high (I), moderate (II), low (III) (Fig. 3).

Fig. 3. Map of winter road maintenance according to maintenance levels

Currently, Via Baltica and the highway Vilnius - Kaunas are maintained according to maintenance level I of main roads. Road maintenance service in these roads is on duty for 24 hours a day. The remaining main roads are maintained according to maintenance level II of main roads.

On these roads the road maintenance service is cleaning and spreading slip-reducing materials from 4 to 22 hours. National roads are maintained according to maintenance level II of national roads and Regional roads – to the maintenance level III of regional roads. Regional roads with traffic volume greater than 1,000 veh./day (about 1,000 km of roads), maintained according to maintenance level I of regional roads. At extreme weather conditions approved hourly charts are invalid. In this case, work is rearranged depending on the situation to ensure optimum driving conditions on major roads. Requirements for winter road maintenance according to maintenance levels for each road group are shown in Table 2.

Table 2. Requirements for winter road maintenance according to maintenance levels

Road Group	Maintenance level	Road maintenance service works	Road must be cleaned and spreaded*	Traffic may be interrupted
Main	I	24 h	within 2 h	not more than 2 h
	II	4 – 22 h	within 3 h	not more than 3 h
National	II	6 – 19 h	within 4 h	not more than 8 h
Regional	I	6 – 19 h	within 5 h	not more than 8 h
	III	9 – 18 h	only after main and national roads	not more than 48 h
* – State significance roads are cleaned and spreaded according to approved schedules and rankings. After the precipitation at the specified time cleaning and spreading must be completed in all roads of this group.				
Extreme weather conditions: - more than 6 hours of uninterrupted snow and /or blizzard, - more than 24 hours of snow and/or blizzard with intervals, - frozen road is covered with ice after rain or freezing rain, - frozen road is covered with ice more than twice in 24 hours, - daytime temperature does not rise above 8ºC.				

At present, the review and revision of road maintenance normative documents and creation of new version are in process. The current situation of the Lithuanian road maintenance system was examined and as a result the new version of Road Maintenance Manual will be prepared, according to the last developments in the road system, new information and technological capabilities, changes in laws, economic regulations, types and groups of works. In this package of road maintenance standards maintenance levels (including some parts for winter road maintenance) will be reviewed and adjusted as well. It is planned that in 2014 a new Road Maintenance Manual version will be formally approved and put into use in the field of winter road maintenance.

In Lithuania several kinds of chemical materials are used for road spreading, such as NaCl, $CaCl_2$ and the red salt. $CaCl_2$ is used in a mixture with a $NaCl_2$ (in the proportion of 88:12), because it is an effective agent at low temperatures (<-8 ºC). For main and national road spreading the 'pre-wetted salt' method is used. Under extreme weather conditions (strong freezing rain, low weather temperature) roads can be spread with sand and salt. It improves the skid resistance.

During winter season (November – April) spreading of state significance roads requires about 80-85 thousand tons of salt, up to 10% of this amount is $CaCl_2$. Depending on the temperature and the current state of the road, during one spreading cycle normally 20–40 g/m^2 of salt is spreaded on the road surface, it is about 2 kg/m^2 for all winter season. Although the NaCl is the cheapest spreading material, according to its performance, but it causes a number of negative effects, such as corrosion of vehicles and reinforced concrete structures of transport buildings and negative impact on the environment. Therefore, LRA is looking for new alternatives to replace NaCl. Currently, the Study of Effective Winter Road Maintenance in Lithuania is being prepared. After laboratory testing, analysis and evaluation of environmental impacts, friction and chemical materials most suitable for winter road maintenance in Lithuania will be selected.

3. Winter road maintenance cost indexing

Since winter is not the same in different regions of Lithuania (the amount of precipitation, air temperature fluctuations and duration varies); therefore, in order to differentiate road maintenance costs and to use funds more flexibly, in 2012 the Lithuanian Road Administration has developed an indexing project of winter maintenance funding, for which Winter Severity Index (ŽSI) is used. Winter severity index describes an influence of the climatic conditions on winter road maintenance cost, according to the variation of selected climatic factors, which have the maximum impact for cost of maintenance works, compared with the existing average perennial climatic factors. The index considers the following factors: precipitation, snowstorms, air temperature transitions over 0 ºC and the number of days with freezing rain.

Winter Severity Index is calculated by the following formula:

$$\check{Z}SI = a\,\frac{K_{fakt.}}{K_{vid.}} + b\,\frac{P_{fakt}}{P_{vid.}} + c\,\frac{T_{0\,fakt}}{T_{0\,vid.}} + d\,\frac{L_{fakt.}}{L_{vid.}} \quad (1)$$

$\mathbf{K_{fakt.}}$- factual values of precipitation over the period, mm;
$\mathbf{K_{vid}}$- average perennial values of precipitation over the period, mm;
$\mathbf{P_{fakt.}}$- factual number of days with snowstorms and drifting snow over the period, days;
$\mathbf{P_{vid.}}$- average perennial number of days with snowstorms and drifting snow over the period, days;
$\mathbf{T_{0\,fakt.}}$- factual number of days with air temperatūre conversations over 0 ºC, days;
$\mathbf{T_{0\,vid.}}$- average perennial number of days with air temperatūre conversations over 0 ºC, days;
$\mathbf{L_{fakt.}}$- factual number of days with freezing rain, days;
$\mathbf{L_{vid.}}$- average perennial number of days with freezing rain, days;
a,b,c,d,e- weight factor.

Weight factors describe the impact of separate variables of winter severity index formula to the overall cost of winter road maintenance works. The highest weight factors are set to days with snowstorms and freezing rains, because on these days the highest increase of road maintenance cost is being noticed.

In the description of winter road maintenance funds indexing is set, that funds are indexed twice a year: once for January–April, and the second time for November- December. Only the direct cost for road cleaning and spreading is indexed. Due to the possibility that funding may be reduced, every month 10% of funds are retained.

Factual and average perennial meteorological data for the calculation of winter severity index are taken from the Lithuanian Hydrometeorological Service. Index is counted for every road maintenance state-owned company. Currently simulations with the latest meteorological data and analysis of the results are being carried out.

In the Study of Effective Winter Road Maintenance in Lithuania, which was already mentioned in the previous chapter, the improvement of this winter severity will be made. Also in this study the territory of Lithuania will be divided into climatic zones according to the climatic impact for the roads. This will let improve the winter severity index and to calculate the total cost of winter maintenance system, to perform detailed cost / benefit calculations, to assess the cost-effectiveness of the existing systems or to calculate a cost of specific road maintenance area.

4 Measurements of road surface friction

Technical control system of winter road maintenance works consists of three steps: internal control (self-control), carried out by the contractor, control carried out by hired inspectors and special inspection and by the LRA specialists. During inspections, inspectors observe whether road maintenance works are in compliance to the maintenance level, slipperiness of road surface and if the contractor’s performance meets to the contract requirements.

So far in Lithuania, as well as in many other European countries, road slipperiness is measured in daily inspections visually or by using a short-stop method. The only difference is that

in Lithuania no device has been used for friction measurement, except the stationary optical meters in RWIS stations. It was only road master's/inspector's professionalism and experience that were trusted.

In order to improve the control of road maintenance works, from 2012 mobile friction meters RCM 411 and μTec (manufacturer Teconer Oy) were purchased and begun to use in daily road maintenance inspections (Fig 4). RCM 411 meter is one of the best devices of its type on the market. This principle of operation is based on determination of the road condition by using close infrared spectroscopy into the road surface. It determines the road surface condition, thickness of water or pure ice and friction value according to the measured content of snow or ice on the road surface. This is a very practical device that can be attached on the trailer hitch of any vehicle, it takes up a little space and it is quick and easy to learn.

Fig. 4. Mobil optical friction measurement device RCM 411 (on the left) and user's interface (on the right)

μTec is an application for mobile phone that uses the accelerometer for calculations of road surface friction. The main advantage of this application is adaptability i.e. the phone position in the car can be easily changed, while the other applications do not provide this possibility. This application could be customized for each vehicle separately using the calibration mode. Accuracy and reliability of μTec, when the higher class mobile phone is used, are the same as "Gripman" meter, which are officially approved and used in Finland (Problematika, 2012).

μTec is used for accurate measurement of friction in a chosen place on the road and can be used to assess the quality of road maintenance, while RCM411 can provide information about the road surface condition and the friction value throughout the measured section of a road. Data from both measurement devices can be stored in one phone, which is very convenient and practical, so the best results are obtained when both devices are used together. They are easily calibrated, sufficiently accurate and can be used for adaptation of winter road maintenance works. Data from the measurement devices are sent to the central server of the Traffic Information System, identified and displayed in real time on the map.

The State Road Testing Laboratory 'Problematika' has performed tests with new mobile friction measurement devices. During the test, road surface friction measurements were carried out under different road conditions (the surface is covered with snow or water membrane), and the results were compared with the data from RWIS stations. Classification of friction values and recommendations, based on the test results, were proposed. It was concluded that the package of friction measurement tools is suitable not only for the estimation of road maintenance quality during winter period, but also for planning road maintenance operations. Road masters with measurement equipment can objectively evaluate the road condition and record friction value. Road masters, according to the data from RWIS stations, video cameras and friction measurement devices, have an ability to decide what road sections and what quantities of salt should be spreaded, as well as to perform other maintenance tasks.

Currently, new mobile friction measurement devices are used intensively in winter road services of two state-owned companies SE ‘Alytaus regiono keliai’ and SE ‘Vilniaus regiono keliai’ and in special inspections performed by LRA specialists. However, in order to optimize organization and control of road maintenance works, it is essential that all contractors should have measurement devices of their own. For this reason, the LRA have realised the Manual of Friction Measurements with mobile non-contact devices and Winter Service Road Master Guide, in which there is a provision for road masters to assess road condition and surface slipperiness not only visually, but also with a help of specialized devices. It is expected that this would encourage other road maintenance companies to purchase these measurement tools.

5. Traffic information system

The Lithuanian Road Administration pays great attention to the expansion and improvement of traffic information system. Over the past year, RWIS (Road Weather Information System) network has been updated and expanded to 103 stations. It is planned to have nearly 300 video cameras in key points of state significance roads network before the end of the year. So far, the Traffic Information System has allowed observe only the emergence of extreme weather conditions and changes of road condition at a point where RWIS stations are installed. However, the installation of GPS devices in all road maintenance mechanisms (more than 800 machines) and the introduction of road maintenance machinery routes application have resulted in a significant increase of road maintenance work organization and control (Fig. 5). Contractors have the right to freely use these data and in this way they can control their employees, keep fuel records and organize works more effectively.

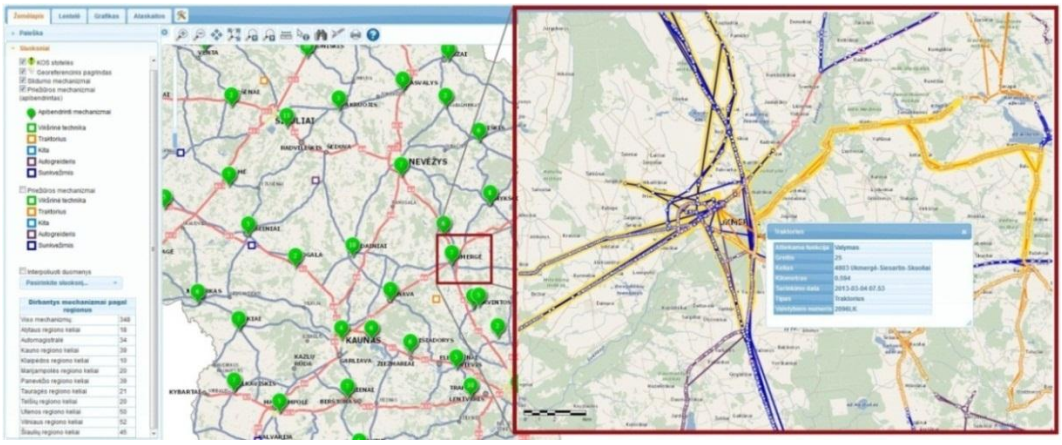

Fig. 5. The screen shot of road maintenance machinery routes application

Application allows to supervise real-time data from RWIS stations on the map (road surface temperature, air temperature and relative humidity, dew point, wind direction, speed and gusts, precipitation intensity and type, visibility, road conditions, road construction, frost depth, etc.), records of video cameras and road maintenance machinery movement (Fig. 6). If necessary, a user can easily look at the data at any time by selecting an appropriate calendar date. In this way it is possible to control how the contractor carries out road maintenance manual requirements: the emergence of dangerous weather events was addressed, when the road was cleaned and spreaded, whether performed actions achieved any results.

This system is very functional and it is designed so that users can easily adjust the information according to the current needs – determine what parameters will be shown on the map, set the alarm for the appearance of extreme weather conditions (surface slipperiness, heavy rainfall, etc.), select road maintenance mechanisms, define parameters of mechanisms which will be displayed (speed, direction of movement, etc.), form graphs and reports. This information helps to determine easily whether the response to the slipperiness on the road was made on time.

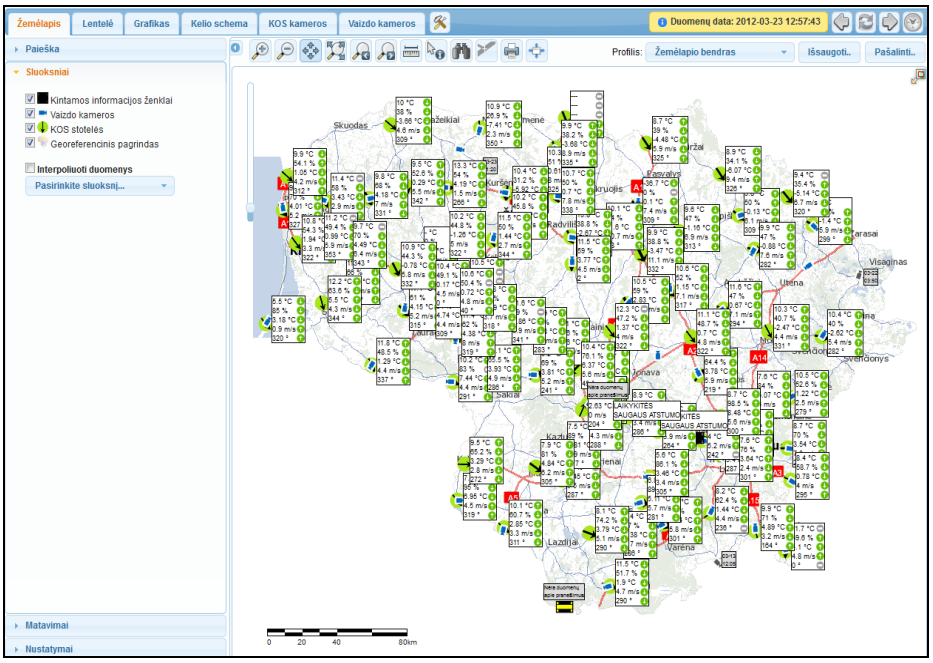

Fig. 6. Screen shot of traffic information system (green tables on the map show road condition and weather indicators from RWIS stations)

Currently, every suspect case must be verified by a system user, and this takes a long time. Therefore in the near future it is planned to introduce an algorithm that automatically would follow the road surface condition and weather changes from RWIS stations, and in case of dangerous events (slippery road surfaces, etc.), automatic timer would be activated, which counts a time until the road section would is cleaned. If within the prescribed period of time (depending on the level of road maintenance) cleaning mechanism does not pass through the station, the program will automatically activate an alarm. This should significantly increase the work efficiency and control effectiveness.

The goal of LRA is to turn the Traffic Information System not only the tool for inspections, but also a comprehensive system for organization and management of road maintenance works, enabling to make important decisions centralized, to adjust works and quantities of spreading materials, depending on the rapidly changing weather and road conditions.

This requires a further improvement of the information technology base and the training of operators, road masters and other related personnel how to work effectively with this system. LRA plans to launch a series of trainings where employees from road maintenance companies who are directly associated with the organization of winter road maintenance works, will be introduced with innovations of the Traffic Information System and will get a deeper knowledge how to adapt it in everyday road maintenance tasks. It is also expected from the end of this year to start the development of thermal mapping.

6. Cooperation with road users

No matter how good road maintenance is, only close collaboration between the client, the contractor and the road user can ensure user's satisfaction with the provided services. Recognizing this challenge the Lithuanian Road Administration is trying to implement measures that would allow the road user to get more detailed information about road conditions, respond promptly to complaints, and to ensure comfortable and safe travel on the roads of state significance.

In 2011 the Traffic Information Centre was established, which aims to collect, organize and provide information about traffic conditions on the roads of state significance and to coordinate the road maintenance activities. In Traffic Information Centre operators work 24 h a day in shifts. They collect information about the situation on the roads, road and weather conditions from RWIS

stations, the Emergency Response Centre, police, road maintenance companies, sum up the given information and place it to the www. eismoinfo.lt web site (Fig. 7). On this site the user can find out about road repairs, their duration, detours, as well as the volume of traffic, alerts about traffic disruptions, restrictions on the roads and to choose the best travel route. Information is presented in an easily understandable text and audible form of an interactive map; the user can also look at the video cameras recordings.

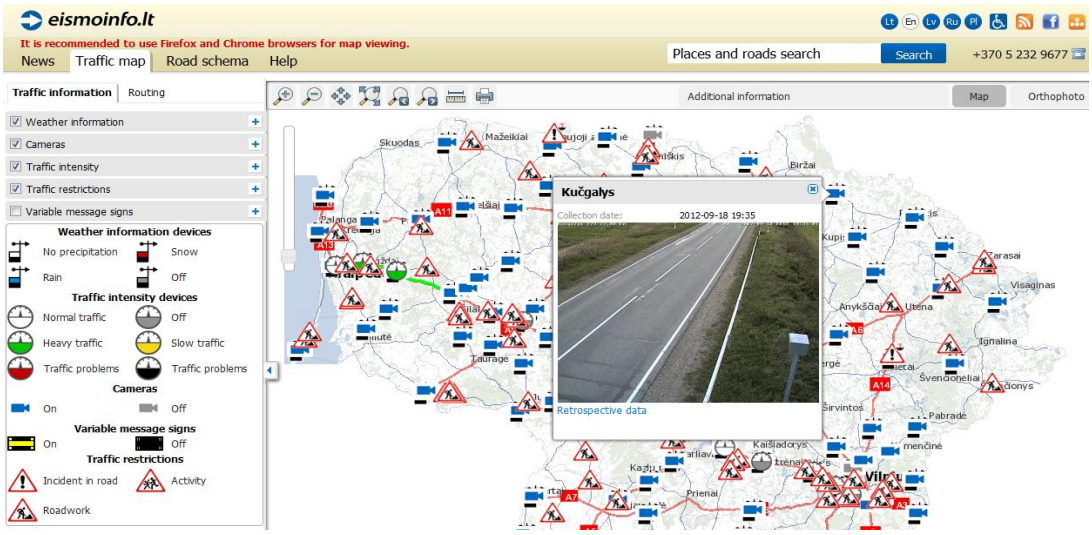

Fig. 7. Screen shot of eismoinfo.lt webpage

On the end of the last year free application 'Traffic Info' was presented for smartphones, which provides with information about traffic and weather conditions, road barrier and traffic restrictions on the selected route. It is also possible to report sightings of the events along the way. More than 10,000 users have already downloaded this application (Fig. 8).

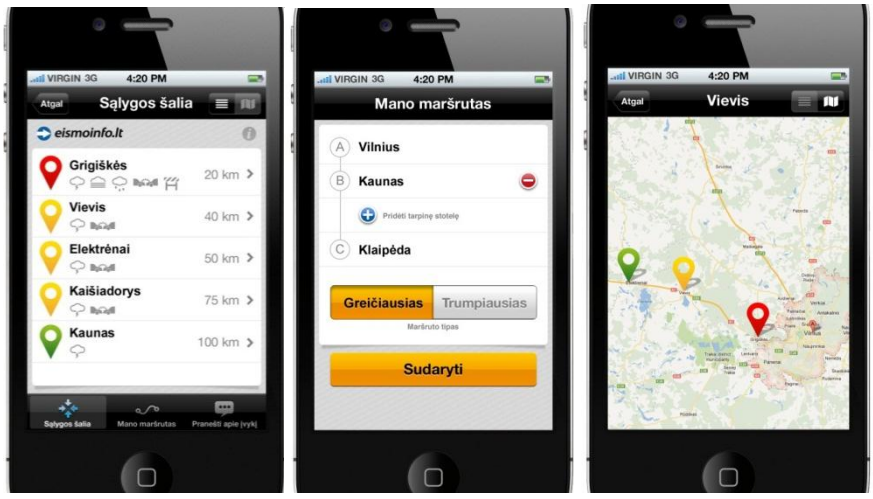

Fig. 8. Screen shots of Traffic info application for smartphones

Conclusions

1. Since 2008 direct funding for winter road maintenance decreased by almost 15%. The lack of funds and growing prices of work and materials encouraged to take steps to keep the winter road maintenance quality and to ensure traffic safety.
2. Over the past few years in the field of road maintenance information technology has reached a breakthrough: RWIS station network was expanded; in the end of this year there will be installed

nearly 300 video cameras near roads; GPS devices have been installed into cleaning mechanisms, allowing to track the movement of every single unit, to coordinate works more expeditiously and to estimate fuel consumption; Traffic information system was developed, allowing to observe the weather conditions, dangerous weather phenomena and changes in road conditions, and to react respectively to the formed situation; new mobile friction measurement devices were purchased, which facilitate the implementation of road inspection. These measures help to ensure more operative and efficient execution of maintenance activities and to save funds.

3. In order to expand the traffic information system and to have information about the roads condition from all road network, It is planed from the end of this year to start the development of Thermal mapping.

4. In order to differentiate road maintenance costs and to use funds more flexible, in 2012 the Lithuanian Road Administration has developed an indexing project of winter maintenance funding, Winter Severity Index describes an influence of the climatic conditions on the winter road maintenance cost, according to the variation of selected climatic factors, which have the maximum impact for cost of maintenance works, compared with the existing average perennial climatic factors.

5. The great work is done in the development of information system for road users. Now anyone can easily check traffic and weather conditions on the road, road status, to create an optimal travel route. They just have to connect to eismoinfo.lt or download an application for smartphones. Learning about weather and road conditions help people to objectively assess the situation, avoid unexpected road hazards and improve traffic safety.

6. It is necessary to improve the information technology base and to integrate more deeply into the road maintenance system, to train operators, road masters and other related personnel and to promote contractors to use IT in the wider area of road maintenance works.

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