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THE USE OF ROAD WEATHER INFORMATION SYSTEM DATA FOR THE FORECASTS OF CLIMATIC CONDITIONS

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Abstract. The article studies possibility by using the data of the Road Weather Information Systems to forecast the beginning of precipitation on the roads maintained by the state road maintenance enterprises. The article discusses the importance of forecasts both to the road users as well as road maintenance enterprises, especially in a cold period of the year. The hazards caused by meteorological phenomena specific of winter season are presented. Research methodology is described which is based on the speed of movement of clouds carrying precipitation. To calculate speed the theoretical background is given assisting in selection of certain parameters for the determination of this value. Knowing the speed of movement of clouds the forecasts have been made. Results of the forecasts are compared to the real parameters and it is determined in what radius the forecasts are advisable to be made.

Keywords: Intelligent Transport System (ITS), Lithuanian Hydrometeorological Service, Road Weather Information System (RWIS), precipitation forecast, winter road maintenance.

1. Introduction

Condition of roads in winter must ensure safe traffic throughout the cold period of the year. The roads of Lithuania are up to 6 months operating under winter conditions. Road maintenance operations in winter depend on winter duration, snow cover thickness, peculiarities of snowstorm regime, wind direction, air temperature, etc. (Ratkevičius *et al.* 2013a; 2013b; Ružinskas, Sivilevičius 2014).

The most general features of the Lithuania's climate are determined by its geographical location. Lithuania is situated in the northern part of the temperate climate zone characterized by a large amount of precipitation and requiring large resources to ensure a proper road maintenance in winter. The Republic of Lithuania lies on the eastern coast of the Baltic Sea (Fig. 1).

The variation in accident rate depends on various technical parameters and performance of vehicles, different properties and characteristics of road elements and pavement, behaviour of road users, types of freight, climate and weather conditions, traffic flows and other factors (Podvezko, Sivilevičius 2013).

Meteorological conditions have a large effect on road safety, whereas, meteorological information helps to ensure safety of roads. Seeking to reduce a negative impact of weather conditions on roads the modern technologies have been implemented in many countries making it possible to reasonably assess the existing meteorological conditions of roads and to transfer information about them to road maintenance services and the drivers travelling on the road (Trinks *et al.* 2012). The most relevant information is that obtained during the journey since it helps the drivers to choose safe speed as it describes weather conditions that influence vehicle control. Knowing that speed is the main reason of road accidents, this type of driver information reduces the number of accidents and, thus, helps to improve road safety (Novikienė 2009).

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "*Towards a European Road Safety Area. Policy Orientations of Road Safety 2011–2020*" also acknowledges that "ITS have the potential to play a considerable role for the improvement of traffic safety, for example through the adoption of systems to detect incidents and supervise traffic that are able to provide information to road users in real time".

A positive effect of timely information is also assented by Danilo Valerio and his colleagues (Valerio *et al.* 2010). His study mentions that only with the help of Intelligent

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Transport Systems (ITS) a real-time information can be given from vehicle to vehicle or from infrastructure to vehicle. And this is treated as a preventive measure aimed at reducing the number of accidents, people killed or injured (Valerio *et al.* 2010).

Timely information is important not only to the drivers but also to the road maintenance services, especially in a cold period of the year. However, a more relevant information for the maintenance services is not that of a real-time but the forecasted data based on which they would be able to plan road maintenance operations.

Winter maintenance of roads of national significance shall ensure their traffic conditions according to the attributed maintenance level, and also their road safety. For the implementation of certain requirements the maintenance services use even 50% of their total annual financing. However, the problem is that the road maintenance process is a multi-objective issue that depends on many factors, such as country development level, labour costs, user-delay costs, vehicle operation costs, traffic level and vehicle type distribution, climate conditions, present road conditions, construction quality, local experience, etc. (Zofka *et al.* 2014). One of the means to cut down winter maintenance costs without decreasing the quality of operations is the use of ITS.

Winter road maintenance in the countries of average and northward climate, characteristic of a large amount of precipitation, requires huge resources. Therefore, the aim of each road maintenance company is to minimize the costs of routine winter maintenance and at the same time to implement the standards of road maintenance.

This could be achieved only by improving the existing and creating the new technologies which, having got the investments, would reduce road maintenance costs and the number of road accidents, would evenly distribute the workload in winter. In this field the various multi-criteria assessment methods could be also used. The designed multi-criteria assessment model promotes accessibility of users to the technologies, new product, a part of the product and a technological process (Kildienė *et al.* 2014).

2. Importance and the use of Intelligent Transport Systems in Lithuania

This article studies ITS having been implemented in Lithuania and their effect on seeking to optimize winter road maintenance works and to ensure traffic safety on roads.

One of the possibilities to reduce winter maintenance costs without affecting the quality of works is the use of ITS. These systems are often comprehended as the application of information and communication technologies seeking to solve various transport problems (Paulauskas *et al.* 2011).

Today, during winter maintenance the road specialists use information from traffic information systems as well as Lithuanian Hydrometeorological Service. Seeking for the effective and optimal winter road maintenance the forecasting of road pavement condition must be automated with the help of a digital forecasting model which should be integrated into the Road Weather Information System (RWIS) and other applications and should participate in traffic information systems when forming recommendations and warnings concerning road maintenance.

In Lithuania, like in other countries, the RWIS is one of the ITS which helps to ensure safe and continuous traffic during any season of the year.

Road Weather Information System consists of:

- measuring stations located on the main and national roads of national significance;
- GSM (Global Standart for Mobile Communications) subsystem between the measuring stations and the main computer;
- the main computer which collects information from the measuring stations;
- regional working stations where user-necessary information is available earlier processed and presented by the main computer;
- varying road signs controlled by the State Enterprise "Automagistralė" (road maintenance

Fig. 1. Location of Lithuania in the world map (Laurinavičius *et al.* 2014)

enterprises) or the main computer (for the meantime, only on the main road A1).

The RWIS is able to expand the network of Lithuanian meteorological stations. The users, for example, the Lithuanian Hydrometeorological Service or other interested institutions, can use this data to more accurately assess the former meteorological situation and to easier make the necessary decisions (Šidlauskaitė, Kažys 2012).

The primary information source is the field stations (with or without cameras). They record data which is transferred to the RWIS control centre, i.e. to the main computer, situated in the premises of Lithuanian Road Administration under the Ministry of Transport and Communications, and to the hydrometeorological services.

Hydrometeorological services and Lithuanian Road Administration under the Ministry of Transport and Communications are in close co-operation and share the additionally obtained information. Therefore, the hydrometeorological services transfer to the main computer the views from satellites, radars, and other forecasts.

A close co-operation is sustained not only with the Lithuanian Hydrometeorological Service but also with the Traffic Police and other services. The RWIS information about road weather conditions in the Baltic Sea region could be found on a common website of Finland, Estonia, Latvia and Lithuania.

The main principle of system operation is a rapid dissemination of information and a timely reaction of certain services to the existing situations what helps to save time, to reduce transportation costs, also winter road maintenance costs and the number of accidents.

Probably the largest negative effect on road safety, is made by precipitation: snow and snow storm (Eisenberg 2004). It has been determined that the most dangerous traffic conditions occur during snowstorm, freezing rain, sleet, and with the first snow (Kažys 2005). One of the preventive measures is timely information of the drivers. Namely the ITS is able to ensure the spread of the timely information for both the drivers and the road maintenance services. Timely information of drivers and appropriate services about dangerous meteorological phenomena enables to avoid part of road accidents and to reduce the number of road victims, also to save a large amount of funds allocated to road maintenance, health care, etc.

Important fact is that the types of timely information for the drivers and the road maintenance services are different. The drivers are interested in traffic conditions in the real time, whereas, for the representatives of road maintenance services the weather forecasts are more important in order to plan maintenance operations. The need of forecasts when using ITS is very large and has been growing significantly. With the use of reliable weather information and short-range weather forecasts the road winter maintenance staff can make more reasonable decisions on treatment procedures concerning the amount of salt applied, as well as the right place and the right time. Such optimization will result in reducing the road salt and therefore harmful impacts on the environment.

In this research the task on a basis of Vilnius region was solved. The research was implemented aiming to create conditions for more detailed and more reasonable organization of works in a process of winter road maintenance. The aim of the study is to determine if it is possible to predict the beginning of precipitation on the roads of the Vilnius zone by using data from the road weather (RW) stations situated at a 200 km radius round the Vilnius County and to find out the accuracy of the forecasts made.

3. Research methodology

The research uses one of the ITS most widely spread in implementing winter road maintenance, i.e. the RWIS. The Road Weather Information System is a computerized system capable to automatically register physical parameters of road pavements, meteorological conditions of roads, visibility and traffic volume parameters. The main task of the system is to warn in advance about slippery road pavement. The main element of the system is the road weather stations the registered data of which is transferred to the users. Since RWIS operates not only in Lithuania but also in the neighbouring countries (Fig. 2), the forecasts also uses Polish road weather stations situated at a 200 km distance from the Vilnius County. They were included into the research due to abundancy of available information and due to the southern and south-western winds prevailing in winter and carrying rain and snow clouds towards Lithuania. Totally, data of 15 stations was used, of which 7 (Bialobrezgi, Kalinowo, Babrowniki, Grabówka, Choroszcz, Most nad Nnarwią, Jezewo) – installed on the Polish roads, 5 (Pabezninkai, Pivašiūnai, Kampai, Seirijai, Druskininkai) – in Alytus County (responsibility of State Enterprise "Alytaus regiono keliai") and 3 (Pirčiupiai, Aukštadvaris, Eišiškės) – under the responsibility of State Enterprise "Vilniaus regiono keliai" (Fig. 3).

The aim of the research was to find out if it is possible with the help of RW stations of the neighbouring countries, in this case the Polish stations, to determine a time interval in which precipitation will reach RW stations maintained

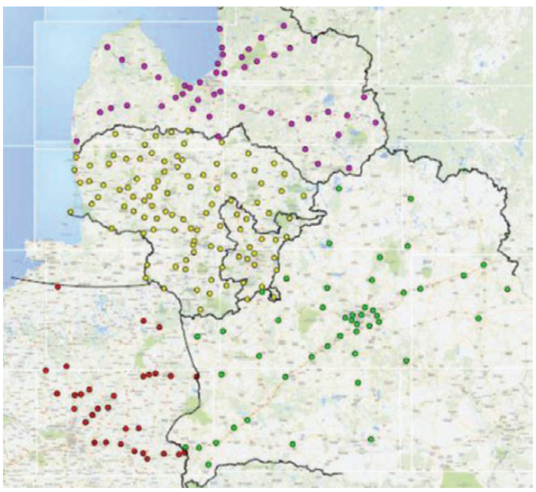


Fig. 2. Location of the weather stations in Lithuania

by State Enterprise "Vilniaus regiono keliai". The aim is to eliminate one of the most important disadvantages of RWIS – inability to make forecasts.

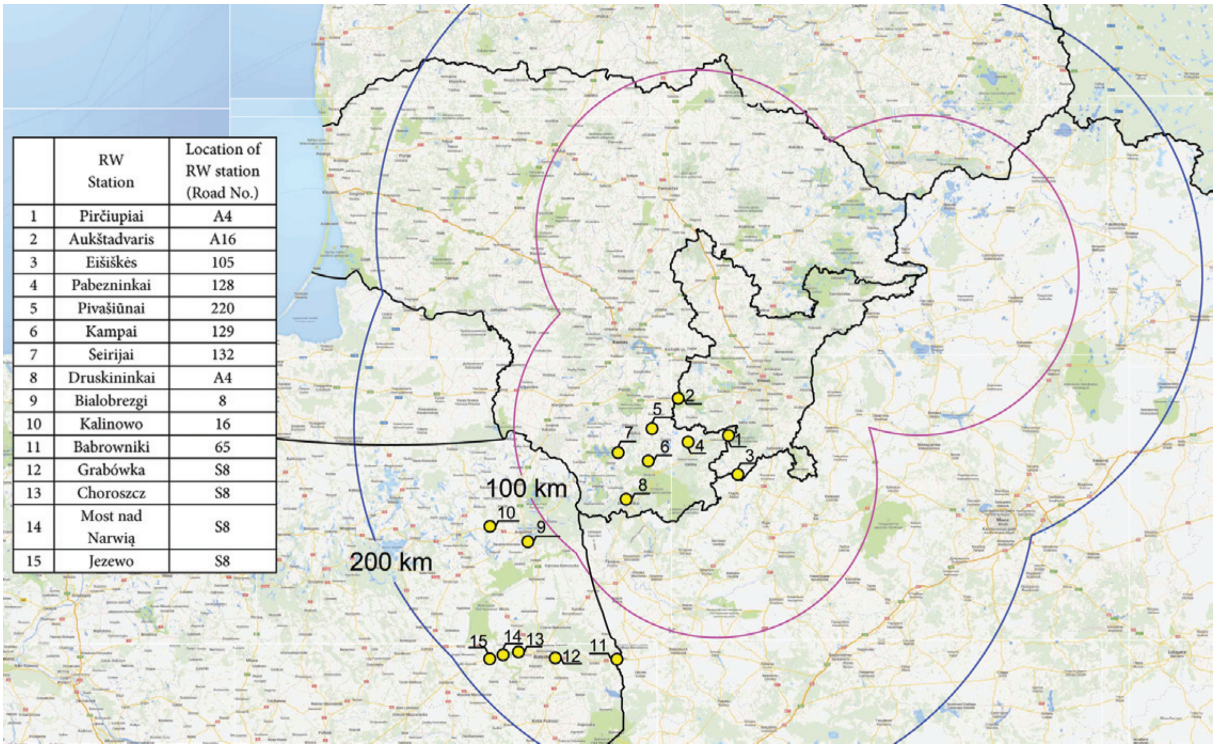
The research was carried out in February–March 2013. First of all the forecasts of Lithuanian Hydrometeorological Service were observed. Having noticed a coming precipitation front the publicly available data from the RW stations was recorded. Parameters provided by the Polish stations were recorded every two hours since the historic data of namely this period of time is presented to the simple users. Information of interest was obtained from the website of the General Directorate for National Roads and Highways of Poland. Data of RW stations installed in Lithuania was collected from the RWIS application freely accessible for the staff of State Enterprise "Vilniaus regiono keliai" where historic data is accessible at any time. The stations recorded the type of precipitation, the time of its beginning, duration and the time of its ending.

Due to time difference and data renewal frequency, the parameters recorded by the stations of both countries were unified and moved into a single summary table. Information of the table was mapped and the maps show a gradual movement of precipitation fund.

Fig. 4 gives the steps of research.

The collected data was used for forecasting. Calculations have assumed that the wind direction in all cases is south-western, and the wind speed in eastern and south-eastern regions of Lithuania in a cold period of the year is 3–5 m/s (at a 10 m height).

In order to determine the speed of movement of clouds the wind speed was calculated at the height of clouds carrying precipitation. Actual distance above the Earth's surface varies from 0.1 km to 5 km depending on the type of the cloud. For calculations the height was selected depending on the type of precipitation (Table 1).



	RW Station	Location of RW station (Road No.)
1	Pirčiupiai	A4
2	Aukštadvaris	A16
3	Eišiškės	105
4	Pabezninkai	128
5	Pivašiūnai	220
6	Kampai	129
7	Seirijai	132
8	Druskininkai	A4
9	Bialobrezgi	8
10	Kalinowo	16
11	Babrowniki	65
12	Grabówka	S8
13	Choroszcz	S8
14	Most nad Narwią	S8
15	Jezewo	S8

Fig. 3. The study road weather stations

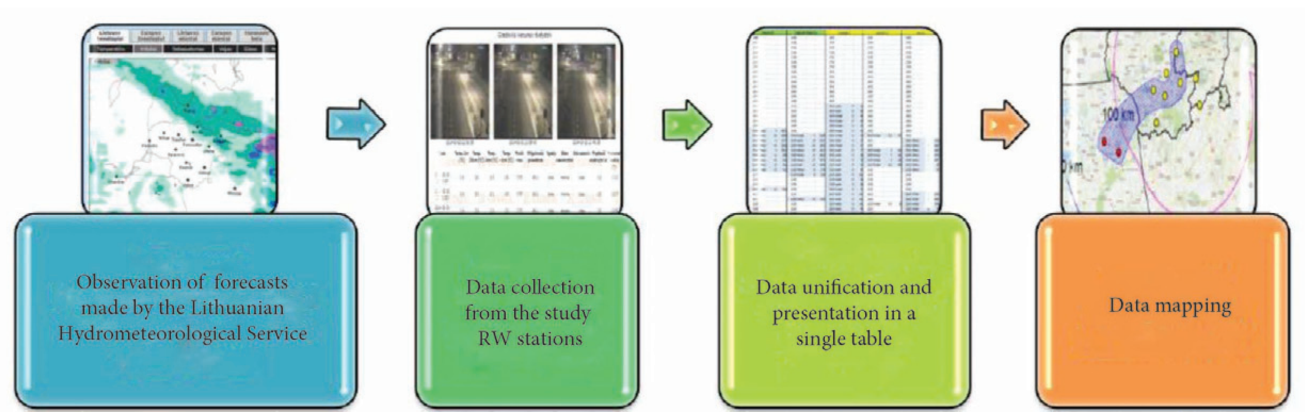


Fig. 4. The steps of research

Table 1. The height of movement of clouds carrying precipitation and the type of precipitation (Rimkus 2005)

Classification of clouds according to the outer view	Height of the lower line of clouds, km	Type of precipitation
High stratus (As)	3–5	In winter – snow, in summer – precipitation random reaches the surface
Nimbostratus (Ns)	0.1–0.7	Continuous rain or snow, sleet
Stratocumulus (Sc)	0.6–1.5	Very rare low intensity and thin precipitation
Stratus (St)	0.1–0.7	Very rare low intensity and thin precipitation, drizzle
Cumulus (Cu)	0.8–1.5	Very rare low intensity and thin precipitation, short-term rain
Cumulonimbus (Cb)	0.4–1.0	Torrential rain or snow

Table 2. The values of Roughness Coefficient (Lithuanian Hydrometeorological Service)

Surface type	β
Water surface	0.010
Fully open location with even surface, e.g. roads, airports, pastures, etc.	0.077
Open agricultural location surrounded with infrequent hills, without fences or trees, with rare buildings	0.120
Rural location intruded into the fields, with houses and gardens, occupying an approximate area of 0.125 km^2	0.145
Rural location intruded into the fields, with houses and gardens, occupying an approximate area of 0.25 km^2	0.160
Rural location intruded into the fields, with houses and gardens, occupying an approximate area of 1 km^2	0.200
Rural settlements, small towns, gardens and forests	0.280
Large cities with high buildings	0.375
Large cities with high buildings and skyscrapers	0.460

Knowing all the variables the wind speed at the selected height was calculated by the formula:

$$v = v_1 \left(\frac{H}{H_1} \right)^{\beta}, \quad (1)$$

where v_1 – the known wind speed (3–5 m/s) at height H_1 (10 m); H – height, where wind speed is calculated, m; β – Roughness Coefficient depending on the Earth's surface (Table 2). The values of Roughness Coefficient is calculated Lithuanian Hydrometeorological Service.

Roughness Coefficient was selected for each segment between the stations depending on the local surface (Table 3).

Having calculated the speed of movement of clouds by the above given formula and knowing a distance between the stations in south-eastern direction, the time was calculated during which precipitation clouds will reach another station.

$$t = \frac{S}{v}, \quad (2)$$

where S – distance between the adjacent RW stations, m; v – speed of movement of a cloud or wind, m/s.

Having calculated all the times between each pair of stations the results were summed up to calculate the total time during which precipitation will reach the considered station situated in Vilnius County.

When making forecast the obtained results were constantly compared to the actually recorded times. Upon noticing that precipitation moves slower or faster than it was forecasted, calculations were corrected by changing the height of considered clouds and, thus, by increasing or decreasing the forecasted speed of movement of clouds.

Table 3. Roughness Coefficient in each segment between the RW stations

RW stations	Roughness coefficient	Roughness coefficient between the RW stations
Kalinowo	0.145	
Bialobrezgi		0.28
Druskininkai	0.280	
Seirijai		0.77
Kampai	0.280	
Pivašiūnai		0.77
Pabezninkai	0.280	
Eišiškės		0.28
Aukštadvaris	0.280	
Pirčiupiai		

During the research the forecasting errors were determined, the RW stations were identified data of which are advisable and non-advisable to be analysed and it was found out what is the longest time period for which the forecast can be made. For the final research two stations in Poland were selected, i.e., situated in Kalinowo and Bialobrezgi, that are located at a 150 km distance from the Vilnius County.

4. Research results, their analysis and assessment

In February 2014 the forecasted cyclone was investigated bringing precipitation from Poland towards Lithuania. The beginning of the first precipitation is recorded at 18:20 h in Bialobrezgi station. Type of precipitation – continuous. Based on collected data the first station of Vilnius County Aukštadvaris was reached by the front at 21:05 h. Using research methodology the time was calculated during which the cyclone bringing precipitation will reach Aukštadvaris station from each of preceding stations. It was assumed in the research that the height of clouds is 700 m, since, depending on the type of precipitation in all cases the clouds were of nimbostratus type. The obtained forecasting results were compared to the real and to the calculated minutes of error (Table 4). During the research 8 continuous approaches of precipitation front to the Vilnius County were detected. Unfortunately, none of 8 continuous approaches involved all the study RW stations.

Not all precipitation, registered during the research, reached the Vilnius County. Fig. 5 gives the distribution of probability of precipitation to reach the Vilnius County. The probability value has been determined only for those stations where the movement of continuous precipitation front was registered.

Such results are determined by a distance between the study stations, since the higher this value the lower probability of precipitation to reach the study stations situated on the roads maintained by the State Enterprise "Vilniaus regiono keliai". The results are also influenced by the station locality itself. This proposition is justified by the locality of Babrovniki station. It is the most south-easterly station of the Vilnius County and therefore the wind of south-eastern direction carries precipitation not to Lithuania but to Belarus.

Reliability of forecasts was also influenced by a distance between the stations or simply the density of the network of RW stations. Results of reliability analysis are given in Fig. 6.

From all three graphs the largest error was obtained when making forecasts from the Bialobrezgi station situated at a 121.6 km distance from the Eišiškės station, at a

Table 4. Results of research made on 10 February

RW stations	Forecast	Reality	Error	
			min	%
Kalinowo	2 h 56 min	3 h	9	4.83
Bialobrezgi	2 h 38 min	2 h 45 min	7	4.24
Druskininkai	1 h 34 min	1 h 30 min	4	4.44
Seirijai	1 h 18 min	1 h 15 min	3	4.00
Kampai	55 min	45 min	10	22.22
Pivašiūnai	39 min	30 min	9	30.00
Pabezninkai	15 min	0 min	15	53.29
Eišiškės	8 min	0 min	8	33.34

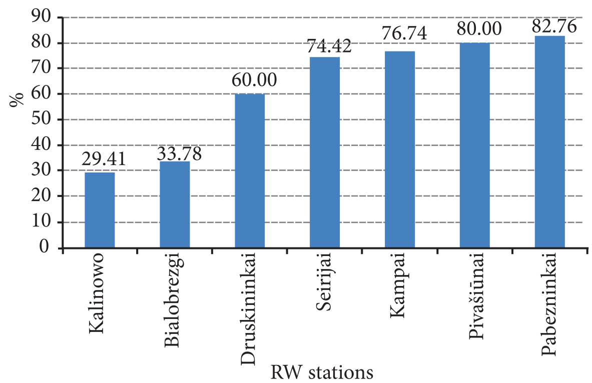


Fig. 5. Probability of precipitation in the final point

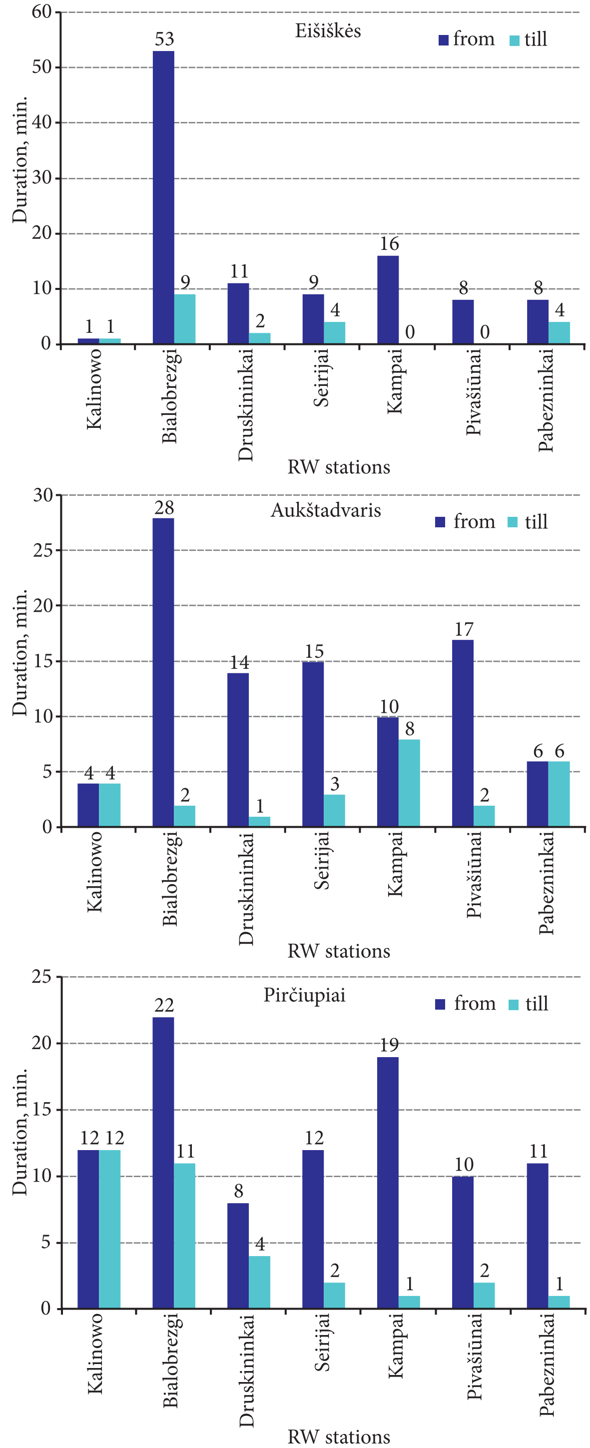


Fig. 6. Forecasting errors up to the RW stations

128.7 km distance from the Aukštadvaris station and at a 134 km distance from the Pirčiupiai station. With the decreasing distance to the RW stations the error decreases. The lowest errors in minutes were determined when making forecasts from the stations of Kampai, Pivašiūnai and Pabezninkai. Since data of Kalinowo station was used for forecasting only once, the obtained error was not assessed.

Knowledge of the beginning of precipitation makes it possible to timely and reasonably organize road maintenance works, such as:

– preventive spreading of the carriageway;

– advance organization of works for the morning shifts;

– use of personnel and machinery of the neighbouring road maintenance services in extreme weather conditions.

Preventive spreading of the carriageway is carried out even before precipitation starts. De-icing materials, spread in advance, prevent the icing of precipitation after it reaches pavement surface and the formation of ice layer. It also helps to avoid ruts, elimination of which needs not one but two spreadings. However, when using this method one must necessarily take into consideration the wind speed and direction along the ground, as well as the road environment.

The contract of obligatory road maintenance works (operations) specifies the time period during which the roads must be cleaned and spread according to the attributed maintenance level of roads of national significance. In cases when the beginning of precipitation is predicted after the end of maintenance hours the consequences of weather conditions will be eliminated in the morning. In order to do this as soon as possible and to ensure as early as possible safe traffic of vehicles the personnel of evening shifts can prepare machinery and de-icing mixes in advance.

When extreme weather conditions are forecasted and when machinery and human resources of winter maintenance service are not enough for implementing requirements set in the road maintenance contract, it is possible to use the help of adjacent maintenance services where this type of weather conditions was not forecasted. Cooperation of available machinery and personnel creates possibility to more efficiently fight against the consequences of weather conditions and to faster ensure proper road rideability.

5. Conclusions

1. Forecasting of meteorological conditions is especially important, relevant and essential for the road maintenance services, thus, creating possibility to timely and reasonably organize road maintenance works, such as: preventive spreading of the carriageway; advance organization of works for the morning shifts; the use of personnel and machinery of the neighbouring road services in extreme weather conditions.

2. Having the aim to determine if it is possible to predict the beginning of precipitation in the Vilnius County based on the data of only the road weather stations the research was made. Data from 8 stations situated in Lithuania and 7 stations situated in Poland was used for the research. What concerns the reliability of forecasts it was determined that the movement of precipitation shall be observed from Kalinowo station situated in the south-eastern part of Poland at a distance of 132 km from the Vilnius County, whereas, the forecasting should be made from the station Druskininkai. The latter station is run by the State Enterprise "Alytaus regiono keliai" and is located at a 60 km distance from the Vilnius County.

3. The research has determined that the reliability of forecasts depends on the density of the network of RW stations and on the locality of the station. When the forecasting results were compared to the really recorded data it was determined that the longest time period for which a forecast can be calculated is 1 hour and 30 min (with an error of 15 min). Based on the results obtained and conclusions presented it is suggested to make analogical calculations in various directions from the Vilnius County. This would make it possible to forecast the beginning of precipitation in all RW stations situated on the roads maintained by the State Enterprise "Vilniaus regiono keliai". It is also suggested to more actively cooperate with hydrometeorological services seeking to get from them as accurate forecasts as possible for each region.

4. The suggested methodology for forecasting meteorological conditions allows to make forecasts also in other cities of Lithuania.

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