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DATA ANALYSIS AND EVALUATION OF ROAD WEATHER INFORMATION SYSTEM INTEGRATED IN LITHUANIA

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Abstract. The Lithuanian climatic conditions set high requirements for road and street maintenance in winter. In our country, the air temperature is below zero for 3–4 months per year. The longest period of this temperature is in eastern Lithuania, and the shortest period is in the coastal area. On average, the first snow cover forms from the middle of November and remains until the middle of March. Moreover, in winter thaws are frequent in Lithuania and the temperature fluctuates around zero. There is also high probability of glazed frost, freezing rain and fog.

In most European countries road weather information systems have been established. The aim of these systems is to reduce the road maintenance costs in winter, to ensure good traffic safety, to inform drivers about poor traffic conditions. The following main components make up the integrated road weather information system: a) spatial analysis of the road microclimate to produce temperature graphs; b) road pavement and atmospheric characteristics' sensors providing information on the actual weather conditions on the roads; c) computer and information network.

The road engineer receives all information in a form which enables to use it quickly and take necessary actions. It also enables to collect external data on the weather conditions, which, upon its statistical analysis, can be used for road design, construction, repair and maintenance.

Keywords: climate, meteorological station, road weather information station.

1. Introduction

The climate of Lithuania as a certain geographical region is formed by global (area) climatic factors as well as local geographical conditions (ozone factors).

The most common features of the Lithuanian climate are influenced by the geographical location of the territory. Lithuania is situated in the northern part of the mean climatic zone, which affects the inflow of the general sun radiation: on average, Lithuania is exposed to 3,600 MJ/m^2 (85 kcal/cm^2) per year. The second global factor is the prevailing transfer of western air masses to the mean latitudes. This transfer occurs due to temperature and pressure contrasts between high and low latitudes [1, 2].

The most important seasonal factor forming the Lithuanian climate is the distribution of continents, oceans and seas. The water areas of the Baltic Sea and the Atlantic Ocean stretch to the west from Lithuania with only small land areas of the Scandinavian and Jutland peninsulas with islands.

The Euro-Asian Continent stretches several thousand kilometers to the east from Lithuania. Therefore, although Lithuania is a coastal land, its climate is not typically marine. Continental climate increases from the west to the east: its annual temperature and day amplitude rise; the weather becomes drier, and the amount of precipitation decreases.

The variation of temperature from the west to the east is the feature of meridian climate. The meridian climate is especially typical in the cold time of the year. Since then the air temperature depends more on the atmospheric circulation than during the warm period, ie on the amount of warm and humid Atlantic air penetrating into the continent. In summer, the most important climatic factor is the radiation warming the soil and atmosphere.

The average annual air temperature amplitude (according to the average monthly temperatures in Lithuania) varies from 19–20 °C on the coastal area up to 23–24 °C in the eastern part of the country.

The configuration of isolines to the east and the south from the Baltic sea is meridian. It speaks of the dominating advection of the heat in winter and the cool in summer. It is impacted by the Baltic sea.

The impact of comparatively shallow mid-continental Baltic sea is mostly of mezoclimatic type and is observed on the narrow 30–100 km wide coast section: the annual air temperature amplitude has decreased (the minimal temperature is higher and the maximum temperature is lower); in winter, the lower cloudiness, air humidity and the frequency of fogs increase; the snow cover forms 5–10 days later.

When the air mass reaches winter, the speed of the wind reduces by 1,4–1,7 times. Due to this, the area of converging air flows forms near the coastline; the convection centres form, the consequence of which is torrential precipitation and thunders in winter.

The Lithuanian climate is described as medium cold with a snowy winter. The amount of precipitation is rather big all the year round, and it is bigger in the cold period. The average temperature of the coldest month is below –3 °C, and the average temperature of the warmest month is not above +22 °C. The average temperature is higher than 10 °C for not less than four months. Such climate is typical of the middle part of Eastern Europe. The climate of the western part of Lithuania is described as medium warm since the average temperature of the coldest month is higher than –3 °C.

Road maintenance in winter mostly depends on the air and road surface temperature variation around 0 °C, ie its change from positive to negative and vice versa. The frequency of such changes in Lithuania is from 60 to 80 per year. This variation, especially in winter, which lasts up to five months, causes a lot of problems for road specialists. Modern technologies and road weather information systems shall be used to deal with these problems.

2. The Lithuanian road network

Today Lithuania has a relatively good road network even comparing it with western standards.

At the beginning of 2006, our country had 21 328,09 km of roads of national significance, out of which there were 1750,05 km main, 4947,90 km national and 14 630,14 km regional roads. There are six kilometers per one thousand inhabitants and 3,23 km of roads of national significance per one thousand square meters of the territory in Lithuania. The state road network contains 1530 bridges, out of which 1447 are reinforced concrete, 80 metal and 3 timber bridges. These roads and bridges which are managed by the Lithuanian Road Administration are used by 1,6 million vehicles registered in Lithuania as well as thousands of vehicles from foreign countries.

The road network of national significance of the Republic of Lithuania on 1 Jan 2006 is presented in Table 1. The number and length of bridges and viaducts is presented in Table 2.

3. Meteorological stations

The period of instrumental meteorological observation was started in Lithuania in 1770 when the Observatory of Vilnius University started to take air temperature. Since meteorological observations were started in other places of Lithuania much later, temperature fluctuations of the last two centuries in Lithuania have been studied according to the observations carried out and being carried out in Vilnius. The temperatures taken in other places of Lithuania closely correlate with the temperatures in Vilnius – 0,96–0,98.

The climatic information, based on which climatic parameters for road construction are calculated, and various quantitative indicators are obtained from different sources. Primary meteorological information is the data obtained during the observations of meteorological stations. At present, 21 meteorological stations and 32 posts are in operation in Lithuania, where standard observations are carried out according to the common programme: at 03, 06, 09, 12, 15, 18 and 21 h Greenwich Mean Time. Indicators of the air temperature and humidity, precipitation, cloudiness, atmospheric pressure, wind, sun radiation, at-

Table 1. The Lithuanian road network of national significance, km

Type of pavement	Roads			
	Main	National	Regional	In total
Asphalt	1665,3	4947,90	6203,98	12 817,18
Cement concrete	84,55	–	1,27	85,82
Gravel	–	–	8415,87	8415,87
Cobble-stone	0,20	–	9,02	9,22
In total	1750,05	4947,90	14 630,14	21 328,09

Table 2. Bridges and viaducts on state roads

	The number of bridges	Length, m
Metal	80	5008
Reinforced concrete	1447	45 789
Timber	3	266
In total	1530	51 063

mospheric phenomena, snow cover, soil temperature are observed. Data sheets of meteorological observations are drawn up, which is the basis of further processing of climatic information. Average day, month and year values of meteorological elements are calculated. The data from meteorological tables, monthly and annual journals reflect the first level of processing. The first data processing level is the base to calculate average perennial meteorological element values (norms). Five-year period norms are the second data processing stage, and the third level is the World Meteorology (WM) confirmed climatic norms in the period of 30 years. Average values of meteorological elements calculated in various countries in 1961–1990 may be compared.

4. The selection of places to install road weather information stations

Meteorological conditions in the mean climate zone make up an important part of information which is necessary to manage and control transport on high volume roads and transport nodes as well as to carry out good quality and timely road maintenance works in winter.

Close co-operation between road engineers and meteorologists has been existing for a long time, which is related to the winter road maintenance to ensure safer traffic conditions on the roads. The weather forecast of higher quality not only enables to save road maintenance costs. Forecasting systems of complicated weather conditions on the roads used in some European countries (eg Sweden, Finland, Great Britain etc) have had an effect of a catalyst when rationalising road maintenance procedures. These countries provide information on the weather conditions on the roads to the emergency and utility services as well as society at large.

The data from stationary meteorological stations (SMS here and after) on the side of the road make up only a fragmentary picture of the weather conditions. On the other hand, optimal location of SMS is possible only if microclimatic peculiarities of the road are very well-known.

In cold winter nights, when bright or almost cloudless and windless weather prevails, road surface temperature on a small several-ten-square-kilometer area may vary more within the range of 10 °C. It means that certain road sections may not freeze when the surface temperature in most road sections has fallen below zero. Weather people may produce the forecast on how long and how many degrees below zero the road surface may freeze on average in the whole region. However, such forecasts do not show the differences in road pavement temperature in concrete road sections. Therefore, the limited areas where the road surface temperature may fall below zero for one or more hours is a more important problem than of the road section where the surface temperature is much below zero. As we know, the most slippery ice is at the temperature of 0 °C.

When looking for suitable places for SMS, first of all, such road spots shall be found where unfavourable meteorological conditions occur. Thus, mobile meteorological equipment (MME) is used to analyse meteorological parameters (air and road surface temperature and relative humidity) from different perspectives lengthwise the track of the road [3, 4].

Temperature graphs is graphical and digital information describing the variation of the road surface temperature lengthwise the measured road section in the nights of the cold time of the year.

These graphs help locate SMS optimally and, therefore, to reduce the price of the whole system. Road temperature parameters between SMS are found by interpolation of temperature graphs. The temperature graphs supplement the information provided by SMS; these graphs may also show thermal parameters from any point of the track as well as to construct analytic road temperature condition models in winter. Temperature graphs show only the relative differences of minimal road pavement temperatures on various road sections. They are most useful where minimal air temperatures are close to 0 °C in winter.

When developing the stationary network of meteorological stations, depending on the road density and microclimatic differences in the region, an SMS is usually installed on the area of approx 250 km^2.

It would be purposeful to install SMS on the spots with various microclimate to avoid too optimistic or too pessimistic results. For example, if SMS are located only on cold spots, a pessimistic picture of road weather conditions in the region is created.

5. Road Weather Information System

In 1999, the Road Weather Information System (RWIS here and after) was implemented in Lithuania. RWIS collects and stores data on extreme changes of the weather conditions on the state road spots mostly impacted by the climate in Lithuania [5].

This data base collects and processes data on the climate and road condition constantly measured by the Lithuanian Road Administration under the Ministry of Transport and Communications. Measurements have been carried out since 21 May 1999. The current number of meteorological stations is 39 (Fig 1) [6].

In the future, the number of these stations should be approx 100. In the cold period from 1 Nov to 31 March, the data are registered every 30 min, and in the warm period, ie from 1 Apr to 31 Oct every 12 minutes. The measurements are carried out automatically, through the use of GMS. All parameters are measured every 0,5 seconds, and the average value of this parameter (most parameters) during this time period is registered at every selected time interval.

Only momentary values of the wind are registered. The data base is supplemented with the data obtained from RWIS several times per year.

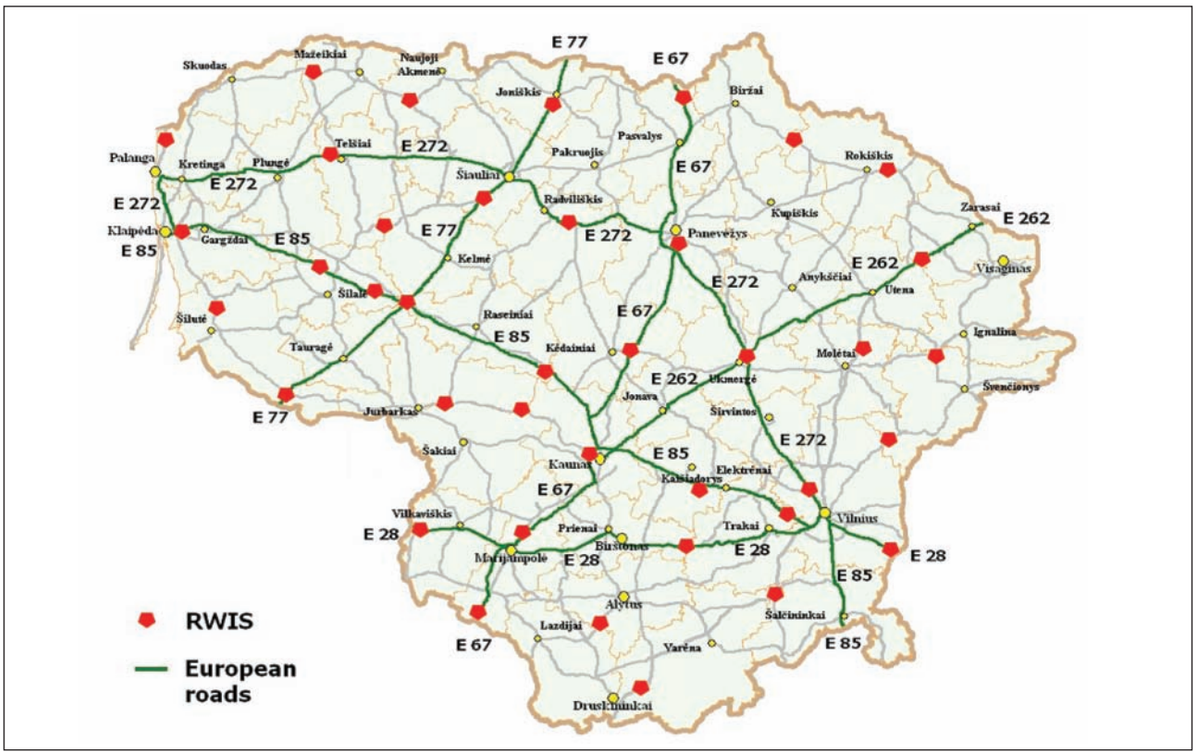
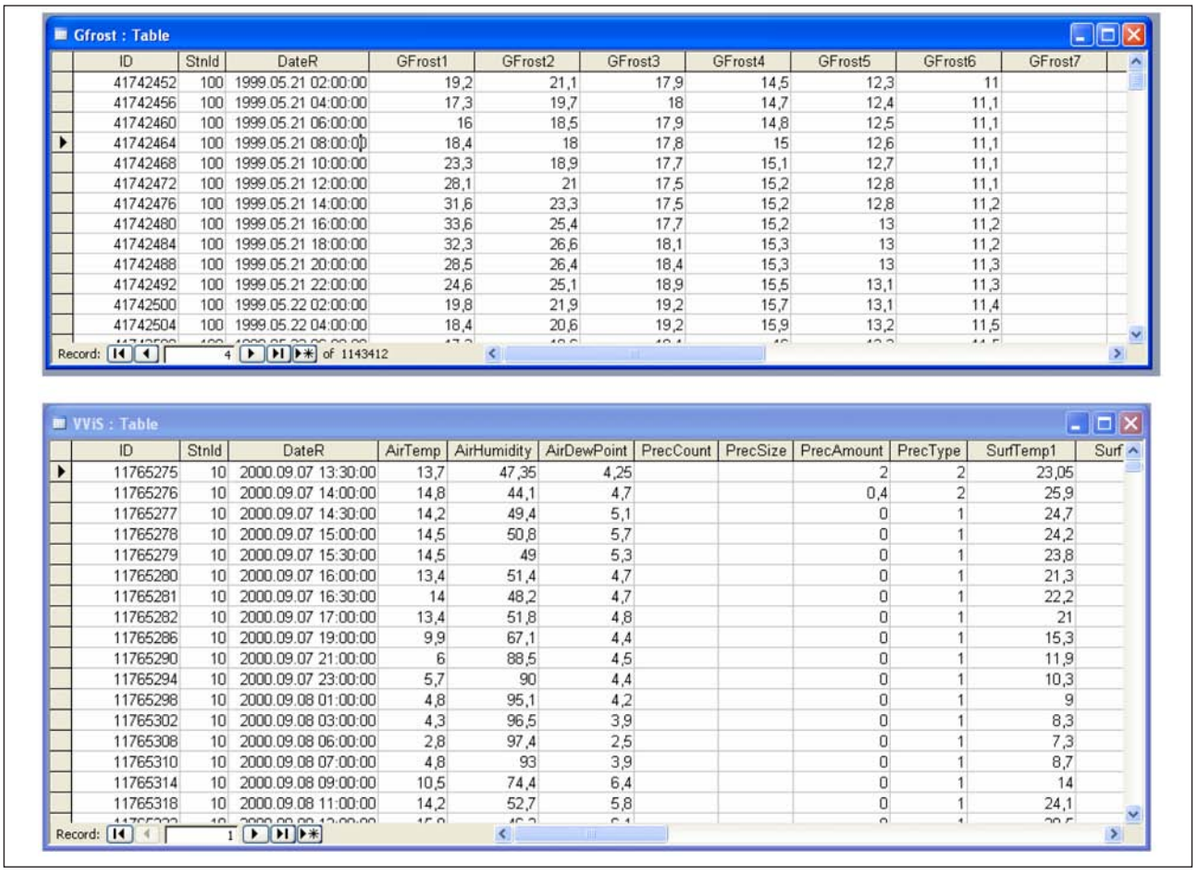


Fig 1. Location of RWIS stations [10]



Gfrost : Table

ID	StnId	DateR	GFrost1	GFrost2	GFrost3	GFrost4	GFrost5	GFrost6	GFrost7
41742452	100	1999.05.21 02:00:00	19,2	21,1	17,9	14,5	12,3	11	
41742456	100	1999.05.21 04:00:00	17,3	19,7	18	14,7	12,4	11,1	
41742460	100	1999.05.21 06:00:00	16	18,5	17,9	14,8	12,5	11,1	
41742464	100	1999.05.21 08:00:00	18,4	18	17,8	15	12,6	11,1	
41742468	100	1999.05.21 10:00:00	23,3	18,9	17,7	15,1	12,7	11,1	
41742472	100	1999.05.21 12:00:00	28,1	21	17,5	15,2	12,8	11,1	
41742476	100	1999.05.21 14:00:00	31,6	23,3	17,5	15,2	12,8	11,2	
41742480	100	1999.05.21 16:00:00	33,6	25,4	17,7	15,2	13	11,2	
41742484	100	1999.05.21 18:00:00	32,3	26,6	18,1	15,3	13	11,2	
41742488	100	1999.05.21 20:00:00	28,5	26,4	18,4	15,3	13	11,3	
41742492	100	1999.05.21 22:00:00	24,6	25,1	18,9	15,5	13,1	11,3	
41742500	100	1999.05.22 02:00:00	19,8	21,9	19,2	15,7	13,1	11,4	
41742504	100	1999.05.22 04:00:00	18,4	20,6	19,2	15,9	13,2	11,5	

Record: 4 of 1143412

VViS : Table

ID	StnId	DateR	AirTemp	AirHumidity	AirDewPoint	PrecCount	PrecSize	PrecAmount	PrecType	SurfTemp1	Surf
11765275	10	2000.09.07 13:30:00	13,7	47,35	4,25			2	2	23,05	
11765276	10	2000.09.07 14:00:00	14,8	44,1	4,7			0,4	2	25,9	
11765277	10	2000.09.07 14:30:00	14,2	49,4	5,1			0	1	24,7	
11765278	10	2000.09.07 15:00:00	14,5	50,8	5,7			0	1	24,2	
11765279	10	2000.09.07 15:30:00	14,5	49	5,3			0	1	23,8	
11765280	10	2000.09.07 16:00:00	13,4	51,4	4,7			0	1	21,3	
11765281	10	2000.09.07 16:30:00	14	48,2	4,7			0	1	22,2	
11765282	10	2000.09.07 17:00:00	13,4	51,8	4,8			0	1	21	
11765286	10	2000.09.07 19:00:00	9,9	67,1	4,4			0	1	15,3	
11765290	10	2000.09.07 21:00:00	6	88,5	4,5			0	1	11,9	
11765294	10	2000.09.07 23:00:00	5,7	90	4,4			0	1	10,3	
11765298	10	2000.09.08 01:00:00	4,8	95,1	4,2			0	1	9	
11765302	10	2000.09.08 03:00:00	4,3	96,5	3,9			0	1	8,3	
11765308	10	2000.09.08 06:00:00	2,8	97,4	2,5			0	1	7,3	
11765310	10	2000.09.08 07:00:00	4,8	93	3,9			0	1	8,7	
11765314	10	2000.09.08 09:00:00	10,5	74,4	6,4			0	1	14	
11765318	10	2000.09.08 11:00:00	14,2	52,7	5,8			0	1	24,1	

Record: 1

Fig 2. Main tables of data (VViS, GFrost and #Station)

6. Data collection and analysis

Due to a huge number of data, the only real way to process them is to use some data base management systems (DBMS here and after). MS Access was selected for this purpose due to its popularity, availability and convenience. The aim of developing this data base is to have a possibility to carry out the analysis of big quantity of data and thereby to identify statistical characteristics of various parameters or their combinations, certain regularities, tendencies and dependences. Values of different parameters of specific station in special time represented in samples of inqueries and graphics (Figs 2–4). In first table (Fig 2) are road pavement structure temperatures at the depth of 7, 20, 50, 80, 110 and 130 cm.

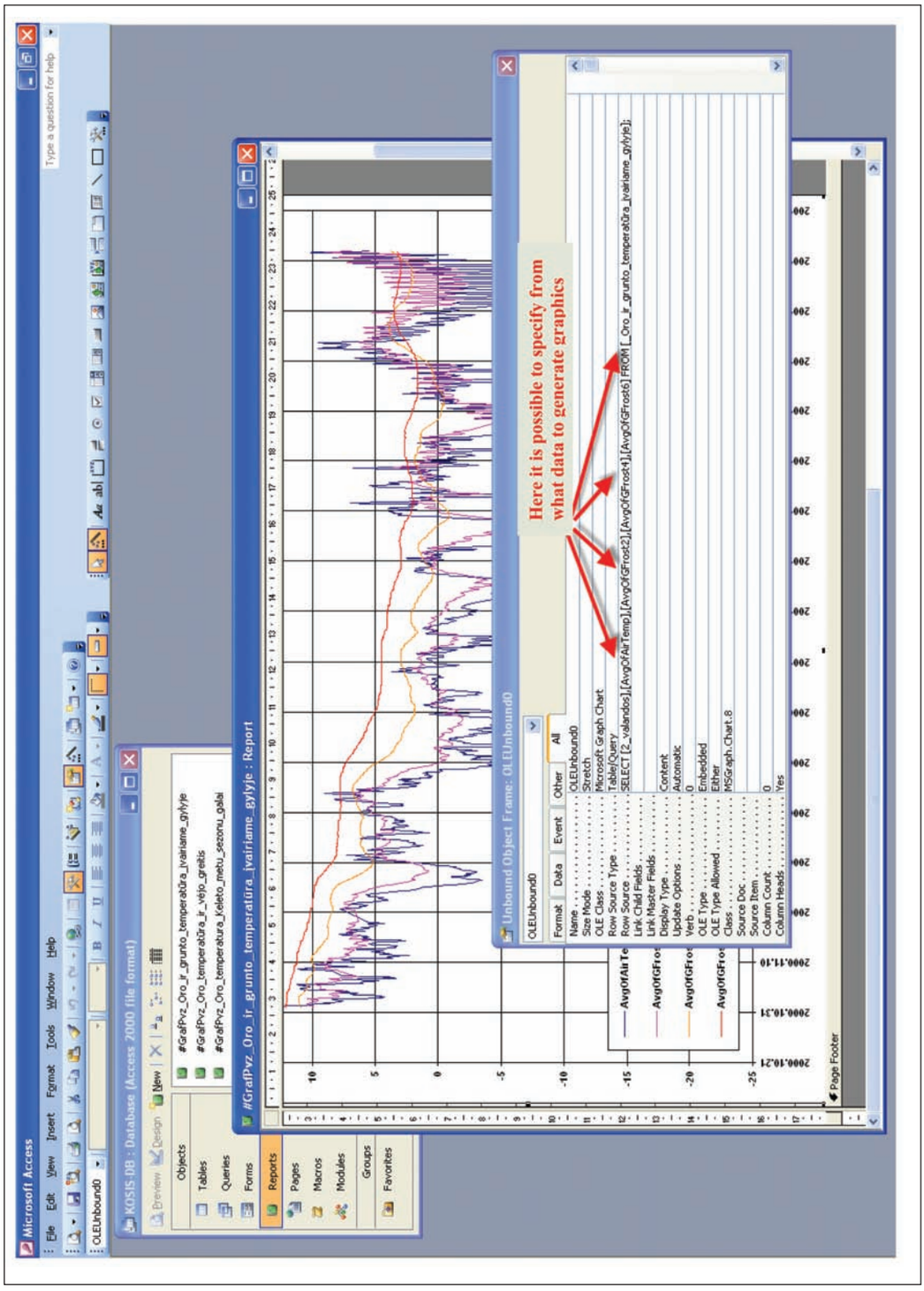


Fig 3. Edits of references to graphics data

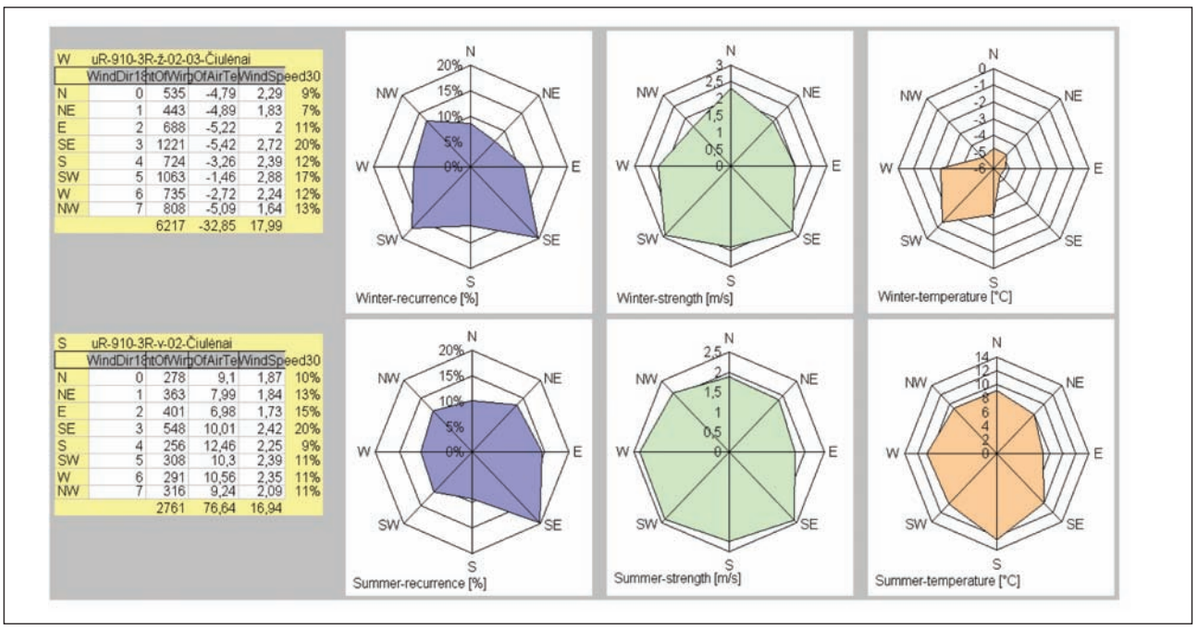


Fig 4. The sample of wind roses graph, which is made using queries "Summer wind rose" and "Winter wind rose" (N – north, NE – northeast, E – east, SE – southeast, S – south, SW – southwest, W – west, NW – northwest)

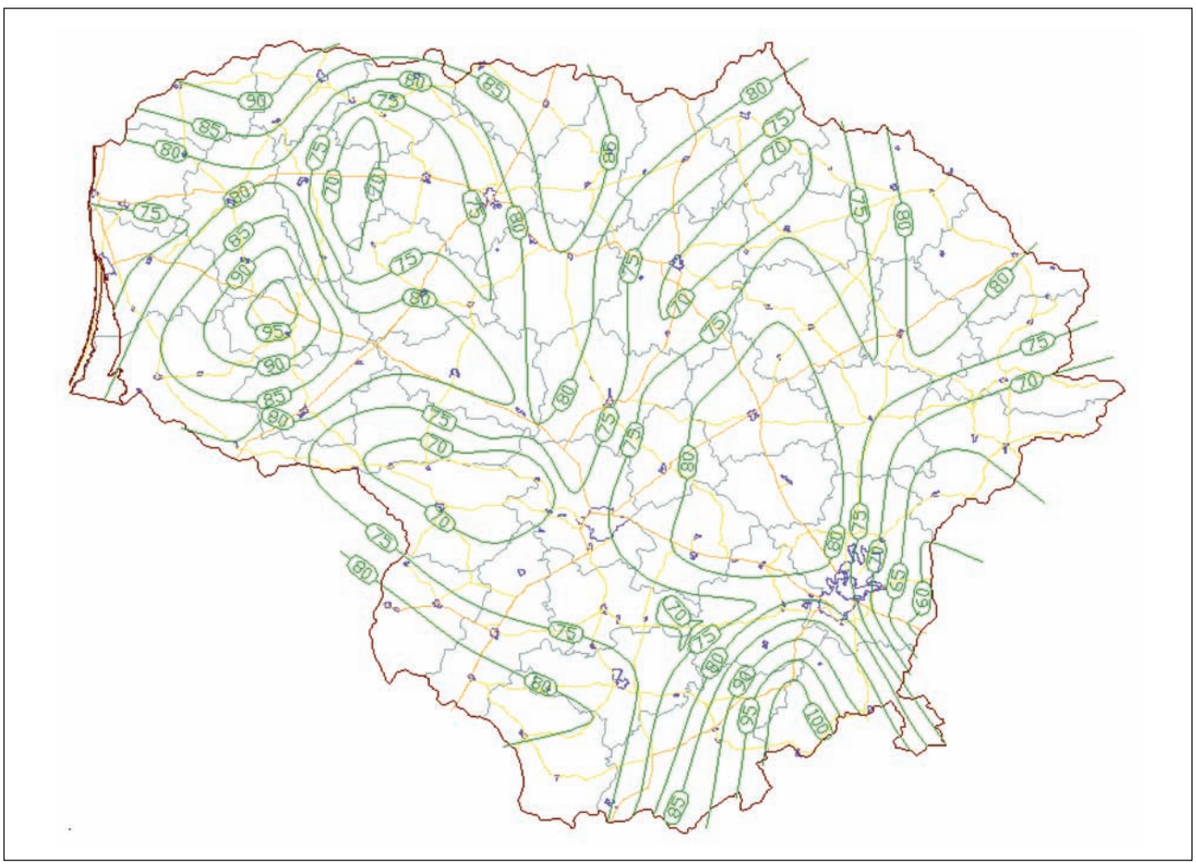


Fig 5. Map on the freezing cycles number of the road surface which is made by Autodesk Land Desktop 3, using averaged data of 1999–2005 years cold seasons, which is gotten additionally processing data of RWIS-DB inquerie "Stations_Seasons_ Shifts_ Of _0_Crosstab"

These samples can be modified easily if there is a need to get data and graphics of other stations, on different time and/or parameters. It is recommend to make copies of inqueries and graphics before. It is possible to draw up the thematic maps when it is drawn up a map on average of numbers on freezing cycles of road surface (network of showing parameter isolines is making with separate program, this is not a function of this DBMS) (Fig 5).

Therefore, the established data base enables to analyse the weather conditions' parameters registered by RWIS from various perspectives and apply them in designing, constructing, repairing and maintaining roads [7–9].

7. Conclusions

1. The RWIS is an inseparable part of good road maintenance in Lithuania in winter. It enables to forecast the variation of the weather conditions in various parts of the country: to use road winter maintenance measures timely and appropriately, to inform road users about the condition of roads and to ensure safe traffic on the roads.

2. The parameters registered by the RWIS are of utmost practical importance when designing, constructing, repairing, and maintaining roads in Lithuania. The most important parameters are as follows: air temperature, road surface temperature, pavement structure temperatures at the depth of 7, 20, 50, 80, 110 and 130 cm, wind direction and speed, type and quantity of precipitation. It is very important to know the derivative characteristics of these parameters: the number of cycles of the road pavement structure temperature variation around 0 °C at various depths and the total freezing depth.

3. The air and road pavement temperatures registered by special sensors are important for the technological process of road pavement construction and maintenance in winter; the wind direction and speed for road maintenance in winter (protection from snow), the freezing depth for designing pavement structures, and the number of cycles of temperature variation around 0 °C for the prognosis of defects occurring in the pavement structures etc.

4. The developed special data base registered by RWIS enables to analyse the collected data and to use them for road design, construction, repair and maintenance.

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