CLIMATIC REGIONING OF LITHUANIA FROM THE POINT OF VIEW OF WINTER ROAD MAINTENANCE

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ABSTRACT

Geographers and climatologists divide Lithuania into 5 geographical regions. The regions and their characteristics (amount and duration of precipitation (snow), amount of glazed frosts and snowstorms) describe the specific features of road maintenance in winter.

The main indicator describing winter severity is winter severity index. It shows the main characteristics of road climate within the zone and is related to the required maintenance.

Determination of climatic coefficient for each zone of Lithuania by combining different climatic factors makes it possible to determine winter severity in a specific zone and to compare the climate of different years or seasons. Climatic coefficient would help to calculate in more detail the Winter Index which shows the main climatic characteristics of the zone related to road maintenance.

1. INTRODUCTION

Climatic conditions are the amplitude and speed of temperature variation, maximum and minimum temperature, precipitation and vaporization processes, direction and speed of wind, thickness of snow cover, depth of frozen ground, and mist.

The climate of Lithuania, as of a certain geographical region, is formed under the effect of global and local climatic factors.

The most general features of the Lithuania‘s climate are determined by its geographical position. Lithuania is situated in the northern part of the temperate climate zone. Distance from the equator (6100 km) and North Pole (3900 km) causes the inflow of solar radiation: annually Lithuania gets 3600 MJ/m^2 of solar radiation on average (equator region – 6000–8000 MJ/m^2). The Republic of Lithuania lies on the eastern coast of the Baltic Sea. The country borders on Latvia, Belarus, Poland and Kaliningrad Region of the Russian Federation (Figure 1).

Another global factor – the prevailing western carry of air masses in the middle latitudes. Differences in the air temperature of Lithuania due to geographical latitude and solar radiation are not large, since the country takes a relatively small area situated between 53°34′ and 56°27′ north latitude and 20°56′ and 26°51′ east longitude. The largest effect on the air temperature and its distribution in Lithuania is made by the Atlantic Ocean and by the distance from the sea. The climate of Lithuania is described as moderately cold, with snowy winter. Annual amount of precipitation is 800–950 mm, it is more abundant in a warm period. The average temperature of the coldest month is less than –3°C, of the

warmest month – does not exceed 22°C. An important climatic factor is the air temperature variation per day. The lowest air temperature is observed at sunrise, whereas, the highest about 2–4 p.m. After the sunrise the temperature speedily grows up, though 3–4 hours before the temperature maximum, the growth slows down. Having reached the highest point the temperature is dropping slowly down for 2–3 hours, and then drops down intensively. At night, when the temperature minimum approaches, temperature variation slows down again. The average daily amplitude of air temperature variation at the seaside is 1.5 times less than that in the eastern Lithuania.

Figure 1 – Location of Lithuania in the world map

There are many and different principles of climatic regioning in the world. Climatic regions are identified not only by particular meteorological elements but also by their complexes. (Laurinavičius *et al.* 2008). General theoretical climatographical schemes are developed, also the climatic regioning of applied nature is carried out. Geographers and climatologists divide Lithuania into 5 geographical regions. The regions and their characteristics (amount and duration of precipitation (snow), amount of glazed frosts and snowstorms) describe the specific features of road maintenance in winter.

Even in a small area (65.2 thous. km^2) it is very important, depending on the climate zone, to choose safe and good driving conditions, as well as environmentally-friendly and cost-effective road maintenance materials and technologies.

When analysing probability for the occurrence of meteorological factors having the largest effect on road users, first of all, it is necessary to determine the time of winter season when bad and extremely bad traffic conditions could be caused by the following factors – blizzard, glazed ice, snow, fog, wind, low temperature and large air humidity or their combinations (Васильев, Сиденко 1990).

The main indicator describing winter severity is winter severity index. It shows the main characteristics of road climate within the zone and is related to the required maintenance. Index calculations, when comparing different climate parameters, help to determine winter

severity in a specific zone or to compare the climate of different years or seasons. Winter severity index is also used for another purposes and needs, e.g. to calculate the total cost efficiency of RWIS and other currently-used systems, or to determine maintenance costs of roads situated in a certain climate zone.

2. CLIMATIC REGIONING OF LITHUANIA

Climatic regioning is a determination of climatic-graphical units with a consideration of applied needs. The climate is described by average multi-year, extreme and probability values of climatic elements and their complexes: solar radiation, energy balance, atmospheric pressure, cloudiness, air and soil temperature and humidity, precipitation, snow cover, wind direction and speed, atmospheric phenomena (fog, frost, blizzards, freezing rain, etc.).

Uneven distribution of air temperature in the territory of Lithuania is determined by the local geographical latitude, solar radiation, atmospheric circulation and interaction of these factors with the terrene. The largest effect on the air temperature and its distribution in Lithuania is made by the Atlantic Ocean and distance from the sea. Due to a heating effect of sea, winters on the coast of Lithuania are significantly warmer and springs are cooler. The effect of the Atlantic Ocean could be felt all over Lithuania where the climate is significantly warmer than that in the continental regions of the same geographic latitudes (Laurinavičius *et al.* 2011).

Based on climatic peculiarities the following climatic regions are distinguished: Coastal, Samogitian, Middle Lowlands and South-eastern Highlands, as well as the sub-regions of Curonian Spit, Seashore, Coastal Lowlands, Samogitian Highlands, Venta Midstream Lowlands, Mūša – Nevėžis, the Lower Reaches of Nemunas, Sudovia, Dzūkija and Higher Lithuania (Figure 2) (Klimato rajonavimas 2013).

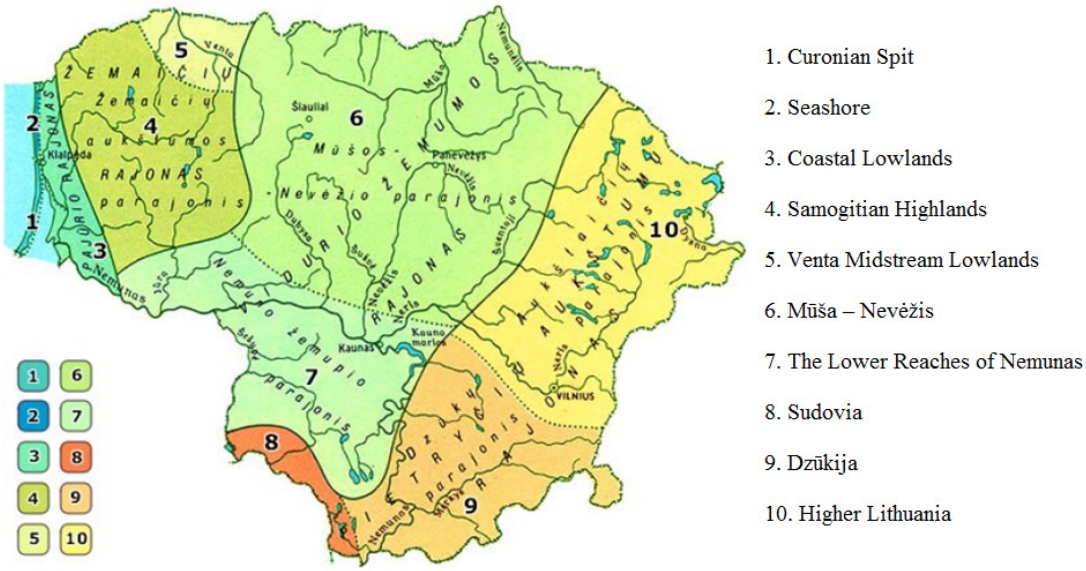

Figure 2 – The map of climatic regioning of Lithuania (Climatic regioning 2013)

The largest difference from the general territorial climatic conditions is represented by the Baltic Coast region. Distinct features of oceanic climate here are analogical to Latvian, Kaliningrad region and Polish coasts. Other climatic regions have also their analogues

outside the borders of the territory of Lithuania. Climatic conditions of the Middle Lowlands region are similar to those of the Middle Latvia, especially of Semigallia Lowlands. The climate of South-eastern Highlands region is also characteristic to the adjacent Belarus provinces.

The climate of Lithuania is described as averagely cold with a snowy winter. Amount of precipitation is sufficient in all seasons, more abundant in a warmer period. The average temperature of the coldest month is lower than –3°C, and of the warmest – does not exceed 22°C. The average temperature of at least four months is higher than 10°C. The climate of the western part of Lithuania is described as averagely warm, since the average temperature of the coldest month is higher than –3°C (Lithuanian Climate Guide. Air Temperature 1992).

Already in the second half of November the first snow cover is formed which keeps until the mid-March (Lithuanian Climate Guide. Precipitation. 1991). In winter Lithuania faces frequent thaws, the daily temperature varies around 0°C and there is a high probability of freezing rain, glazed frost and fog.

When designing, building and maintaining roads it is important to take into consideration the local landscape, hydro-geological peculiarities, climatic and weather conditions. Already in a design stage it is necessary to study peculiarities of environmental and weather conditions of the planned structure in a particular location: for example, wind direction and strength, air temperature variations, air humidity, amount of precipitation, depth of frozen ground, etc.

3. DETERMINATION OF THE COMPLEX CLIMATIC ROAD MAINTENANCE INDICES FOR DIFFERENT CLIMATIC ZONES IN LITHUANIA

From geographical point of view Lithuania is divided into regions according to the most characteristic weather conditions where regions are not related by one or another climatic index. However, winter road maintenance should take into consideration not only the average climatic indices of the whole Lithuania but also to study in detail the LHS and RWIS data mostly close to the certain road. Condition of roads in winter must be such as to 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. In organizational respect winter road maintenance is determined by the date of the occurrence and disappearance of permanent snow cover. To protect road from climatic factors or in a very short period to remove snow and ice layer from the road pavement is a complicated task, however, there are not a few real possibilities by using modern cleaning and spreading machines to accomplish the main requirements to winter road maintenance. Therefore, road maintenance services get ready for the winter season in advance, the plan of maintenance operations is drawn up. The plan is prepared very thoroughly taking into consideration the experience of former winter seasons and the revealed drawbacks. The need for the necessary materials and machinery is calculated and financial resources are planned. The largest maintenance funds are allocated to winter maintenance services and here it is very important to distribute them as rational as possible (Eriksson, Lindqvist 2001). For this purpose many countries (Denmark (Kirk 1998), Norway (Mahle and Rogstad 2002), Sweden, Switzerland, Great Britain, USA (Goodwin 2003)) are using or make an attempt to

introduce the Winter Index (WI) (NCHR...2004) which shows what optimum amount of salt/sand according to winter severity shall be given to a particular zone, region, county, and other. In Lithuania, before each winter season the project *of Indexation of Funds Allocated to Permanent Winter Road Maintenance* is drawn up where calculations of Winter Severity Index (WSI) are carried out by combining different climatic factors representing winter severity in a specific zone and giving a possibility to compare the climate of different years or seasons. Winter Severity Index shows the main climatic characteristics of the zone and is related to road maintenance. It can be used for several purposes and aims: for example, to calculate the total profitability of winter maintenance system, to make more detail cost-benefit estimations, to assess cost efficiency of existing systems, and also to more rationally and in more detail calculate maintenance costs of the certain zone.

According to the project of *Indexation of Funds Allocated to Permanent Winter Road Maintenance,* prepared by the Lithuanian Road Administration under the Ministry of Transport and Communications, the necessary financing of winter road maintenance is planned based on the Winter Severity Index (WSI) which takes into consideration the following factors:

- Precipitation in a form of snow or water;
- Blizzards, number of days with blizzards and blowing snow;
- Number of days with air temperature transitions over 0°C;
- Number of days with freezing rain.

$$WSI = a\frac{K_{fakt.}}{K_{aver.}} + b\frac{P_{fakt.}}{P_{aver.}} + c\frac{T_{0fakt.}}{T_{0aver.}} + d\frac{L_{fakt.}}{L_{aver.}}, \quad (1)$$

where $K_{fact.}$ – factual amount of precipitation in a considered period, mm; $K_{aver.}$ – average multi-year amount of precipitation in a considered period, mm; $P_{fact.}$ – factual number of days with blizzards and blowing snow in a considered period; $P_{aver.}$ – average multi-year number of days with blizzards and blowing snow in a considered period; $T_{0fact.}$ – factual number of days with air temperature transitions over 0°C in a considered period; $T_{0aver.}$ – average multi-year number of days with air temperature transitions over 0°C in a considered period; $L_{fact.}$ – factual number of days with freezing rain in a considered period; $L_{aver.}$ – average multi-year number of days with freezing rain in a considered period; a, b, c, d – weighing coefficients.

The value of weighing coefficients a, b, c, d depends on its impact on the total cost of winter road maintenance. The following weighing coefficients are determined: a = 0.25; b = 0.30; c = 0.15; d = 0.30.

The Winter Severity Index could be improved by introducing additional climatic factors that also affect organization of winter road maintenance, i.e. air humidity and road surface temperature ≤ 0°C since the transitions of air temperature over 0°C, when there is no certain humidity and precipitation, create no larger problems for road traffic. Besides, this would increase the number of weighing coefficients and the WSI calculation would be more accurate.

For this purpose the analysis of LHS and RWIS data was carried out in order to attribute to each region of Lithuania the climatic coefficient k_i which would allow to determine the quantity of maintenance works and to revise funds allocated to a winter service. This coefficient would depend on snow cover thickness, duration of freezing rain and blizzards. The coefficient is calculated by the formula:

$$k_i = \frac{a_i}{a_v}, \tag{2}$$

where a_v – the average value of the characteristic to be determined; a_i – the value of the characteristic to be determined in particular region (zone).

The average value a_v of each characteristic to be determined is found:

$$a_v = \frac{\sum_{i=1}^{n} a_i}{n}, \tag{3}$$

where n – number of regions (zones) considered.

The values of this climatic coefficient can be lower or higher than 1. The coefficients would help to assess in more detail the funds allocated: for example, if the climatic coefficient in the region is higher than 1 the traffic conditions are more difficult and it is suggested to allocate a larger amount of funds. According to the same system the coefficient of those characteristics is determined:

- number of snowfall cases;
- snowfall duration, in hours;
- number of freezing rain cases;
- freezing rain duration, in hours;
- number of blizzard cases;
- blizzard duration, in hours.

Having calculated coefficients of snowfall cases and duration, freezing rain cases and duration and blizzard cases and their duration in the territory of Lithuania the general climatic coefficient of all characteristics is derived (Figure 3).

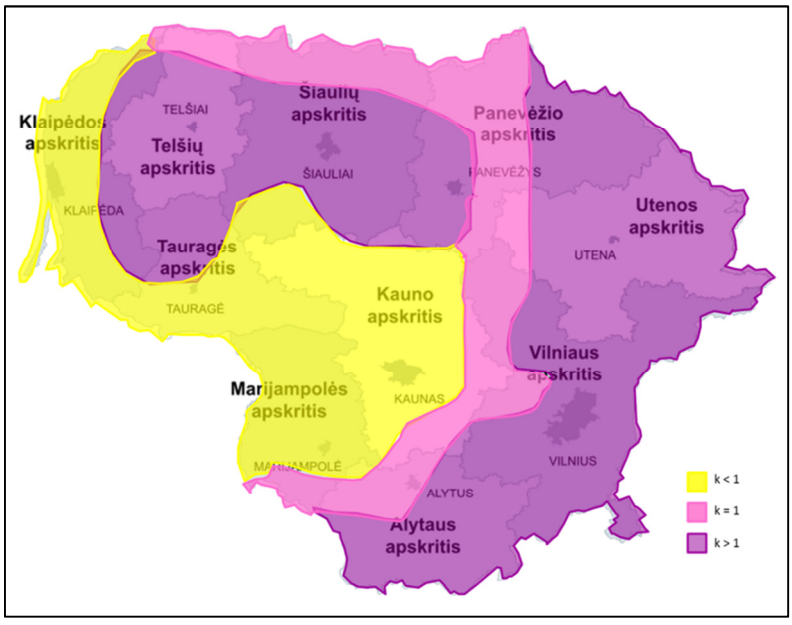

Figure 3 – General map of all factors when the climatic coefficient is higher and equal to 1

The map in Figure 3 shows that from the marked zones the largest amount of funds (k > 1) is required for the roads situated in the middle west Lithuania (around Telšiai, Šiauliai and Šilalė), in the north-eastern, eastern and south-eastern parts of Lithuania.

However, as mentioned before, it is possible to derive not only the general climatic coefficient of all characteristics but also of each separate characteristic since the impact of each characteristic on maintenance services in a cold period is not homologous and it must be determined. For instance, the map of distribution zones by the coefficient of average snowfall duration (in hours) per year (Figure 4).

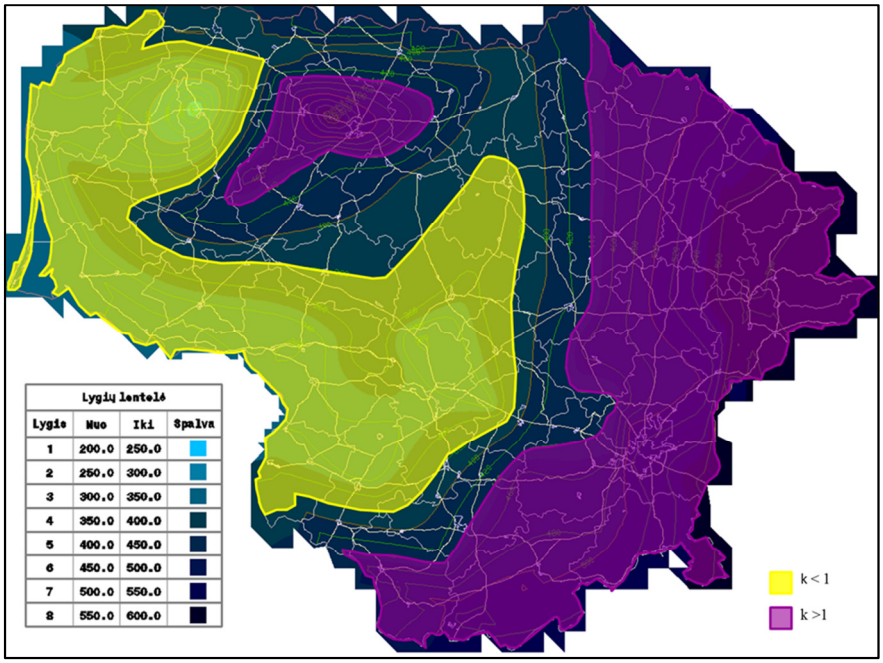

Figure 4 – Distribution zones by the coefficient of average snowfall duration (in hours) per year

Based on the map of distribution zones by the coefficient of average snowfall duration (Figure 4) it could be stated that the largest amount of snowfalls occurs and the snow must be most often cleaned from the roads (k_i > 1) maintained by the winter road services in the north-eastern, eastern, south-eastern parts of Lithuania and in Šiauliai County.

The above given maps and all the other mentioned in this article could be used to determine of what severity the average multi-year winter is most frequent in the certain zone of the country. This information could help to calculate in more detail the Winter Severity Index.

In future, calculation of the WSI is recommended to be improved by introducing additional climatic factors that also affect organization of road maintenance operations in winter. Correspondingly, the number of weighting coefficients would increase and calculations would become more accurate.

4. CONCLUSIONS

There are many and different principles of climatic regioning in the world. Climatic regions are identified not only by particular meteorological elements but also by their complexes, climatic regioning of applied nature is carried out. Due to a large variety of human

economic activities, affected by climate, and due to a varying climatic impact on the other components of geographical sphere, the general scheme of climatic regioning which would meet the requirements of the whole economic sectors is impossible.

From geographical point of view Lithuania is divided into regions according to the most characteristic weather conditions where regions are not related by one or another climatic index. When designing, building or maintaining roads it is necessary to take into consideration not only the average climatic indices of the whole Lithuania but also to study in detail the LHS and RWIS data mostly close to the certain road.

When analysing probability for the occurrence of meteorological factors having the largest effect on road users, first of all, it is necessary to determine the time of winter season when bad and extremely bad traffic conditions could be caused by the following factors – blizzard, glazed ice, snow, fog, wind, low temperature and large air humidity or their combinations.

A climatic coefficient (s) has been suggested (of snowfall cases and duration, freezing rain cases and duration, blizzard cases and duration) which would help to revise the quantity of maintenance works and their costs in winter. The zone where the value of climatic coefficient is higher than 1 represents the most frequent unfavourable weather conditions for road maintenance.

The calculated climatic coefficients show that the largest extent of maintenance is required for the roads situated in the zones of Samogitian Highlands (middle and southern parts of Telšiai County, south-western part of Šiauliai County and northern part of Tauragė County), south-eastern part (almost the whole Vilnius County, north-eastern part of Alytus County, south-eastern part of Utena County) and not a large northern part of Lithuania (northern part of Panevėžys County).

The Winter Severity Index, currently used for winter road maintenance, include the most important climatic parameters which affect road maintenance, however, it is suggested to improve it by adding several factors that are also important, e.g. to determine air humidity and negative temperature of road surface since a negative temperature or the transitions of air temperature over 0^{o}C, when there is no certain humidity and precipitation, have no significant effect. Besides, this would increase the number of weighing coefficients, and calculations would be more accurate.

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