APPLICATION OF A STATISTICAL ANALYSIS OF TRAFFIC FOR THE DEVELOPMENT OF LITHUANIAN ROAD NETWORK

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INTRODUCTION

The development of the economy in Western Europe and other countries as well as convenient geographical position enabled Lithuania to become a transit country between West and East as well as North and South. Lithuania's membership in the European Union sets high requirements for Lithuania's transport infrastructure and its transport sector since transport has been recognized as a priority branch of the Lithuanian economy. The Lithuanian processes of integration are related to certain additional costs, which are allocated for the even development of regions as well as the development of the road sector. Funds have been used due to the increasing demand to carry passengers and cargo, from the European Regional Development Fund as well the Lithuanian Maintenance and Development Programmed. It is intended to invest these funds expediently with the purpose of reducing uneven social and economical development of regions and to improve their transport infrastructure.

The Lithuanian road network is sufficiently dense; however, its technical parameters do not meet the increasing traffic needs and do not comply with the level accepted by the EU transport infrastructure's development. One of the important tasks of road transport is to improve communication on roads of less developed Lithuanian districts that have large industrial and business centers as well as agricultural enterprises and tourism objects [1]. The gravel road-paving programmers have been implemented since 1998. The goal of the programmers is to reconstruct roads of state significance in the Republic of Lithuania with the aim to decrease social and economic differences between counties and districts.

GRAVEL ROAD PAVING PROGRAMMES IN LITHUANIA

Regional roads, which belong to the low traffic volume group, make up 69% or more than 14,700 kilometers of national significance in the Lithuanian Republic roads. Due to a lack of funds, Lithuania still has 9,220 km of unpaved regional roads of state significance, and gravel pavement on them has completely deteriorated. These roads shall be preserved and properly maintained in the future. The required parameters of road infrastructure shall be maintained with regard to the increasing needs of the Lithuanian economy and society.

A rapidly increasing number of vehicles (currently, the ratio is 426 vehicles per 1000 inhabitants) pose a lot of problems related to social welfare, environmental protection, life and traffic quality improvement, which have to be solved immediately. Many of these problems are caused by people who live in the sanitary protection zones of gravel roads, which make up more than 60% of all roads that are of regional significance, as well as by the users of these roads [2].

Renovating and paving gravel roads improve the quality of life and traffic's use on regional roads. In 1998-2000, the Paving of Gravel Roads Program was implemented, according to which 935 kilometers of gravel roads were paved. The implementation of the 2001-2004 Investment Project of Lithuanian Roads (Gravel Roads) according to which 189 sections of gravel roads were paved, the total length of which is 634 kilometers, will be completed in 2004. It is planed to pave more than

2,200 kilometers of gravel roads and to improve the communication between administrative centers and settlements, to reduce accident rates as well as reduce the need and cost to maintain and repair regional roads until 2015 [2]. More than 277 kilometers should be paved from 2004-2005.

Disproportions among regions according to the ratio of gravel roads and roads with other types of pavements have changed inconsiderably. The proportion of gravel roads and roads with other types of pavements in regions will remain the same at the beginning of 2005 as at the end of 2000. Today the proportion of gravel roads and roads with other types of pavements is 0,74 [3]. The difference is only that there are no regions, where gravel roads are more than roads with other types of pavements. The analysis that was carried out in the Lithuanian gravel road projects enabled us to draw the conclusion that the planned rates for asphalt paved gravel roads are insufficient in the some Lithuanian regions. Following this analysis, its was recommended that Lithuania solve its regional roads problems through the usage and implementation of the principles of sustainable road network development [4]. Therefore, the traffic input data is very important, because the gravel road selection for paving was based on traffic volumes.

TRAFFIC ON REGIONAL ROADS

When designing and optimizing road structures, it is very important to collect the following data on traffic volumes:

- Annual average daily traffic (AADT);
- Average daily traffic of heavy vehicles (I_k);
- The increase of traffic that is expressed by the traffic's volume increase coefficient.

This data enabled us to identify the road category, design road parameters for its plan and the longitudinal section as well as to ensure visibility on the roads, and the pavement structure's class.

Automatic traffic counters are not installed to monitor traffic on gravel roads. The AADT is estimated and based on the data of traffic volumes during a certain fixed period.

The increasing traffic volumes of regional roads have an impact on the development of the road network. The number of heavy vehicles has increased in the traffic flow; axle loads of vehicles have been increasing steadily, and are much heavier than the previous standard ones; heavy vehicles are often overloaded. This speeds up the pavement's deterioration. Roads that were constructed earlier do not comply with the increasing traffic volumes' demands and often do not bear the increased loads of vehicles. Pavement repair and reconstruction works are planned according to the traffic volumes and its composition. From 1998-2002 Vilnius Gediminas Technical University's Road Department researchers studied traffic volumes on regional gravel roads. The main gravel roads linking urban and rural residential areas with the main and national roads were selected for the research. The scope of the research that was carried out is shown in summary data in Table 1.

Table 1. Data of gravel road research amount in regions

Region	Amount of research carried out on gravel roads	
	The number of routes on roads	Total length of roads
Alytus	55	462
Kaunas	102	917
Klaipeda	73	793
Marijampole	48	519
Panevezys	116	1130
Siauliai	113	1270
Taurage	49	531
Telsiai	62	523
Utena	109	1073
Vilnius	129	1134
Total	856	8351

In total, 856 routes of gravel roads were selected for the research, the total length of which made up 8,351 km, (80.6 % of the total length of all gravel roads), and calculations are for the beginning of 1998.

In analysis of traffic on gravel roads, the roads are classified [5]:

- I group – roads with low traffic volume (AADT < 50 vpd),
- II group – roads with moderate traffic volume (AADT varies from 51 to 150 vpd),
- III group – roads with high traffic volume (AADT varies from 151 to 250 vpd),
- IV group – roads with very high traffic volume (AADT > 251 vpd).

Each enterprise has gravel roads with high and/or extremely high traffic volumes. The summary data on regional gravel roads are zoned according to regions [5]. The density of gravel roads with various traffic volumes is shown in histograms in Figs. 1–4.

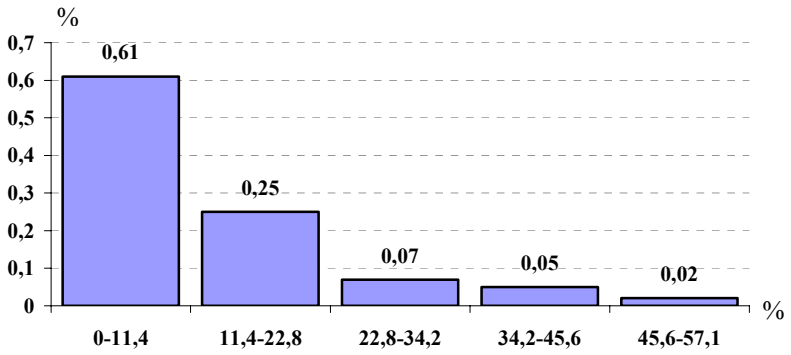

Figure 1. *Part of the low traffic volume in the gravel road network maintained by enterprises %*

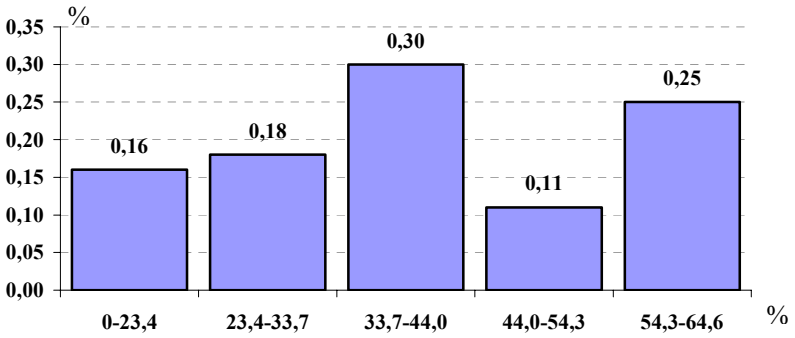

Figure 2. *Part of the moderate traffic volume in the gravel road network maintained by enterprises %*

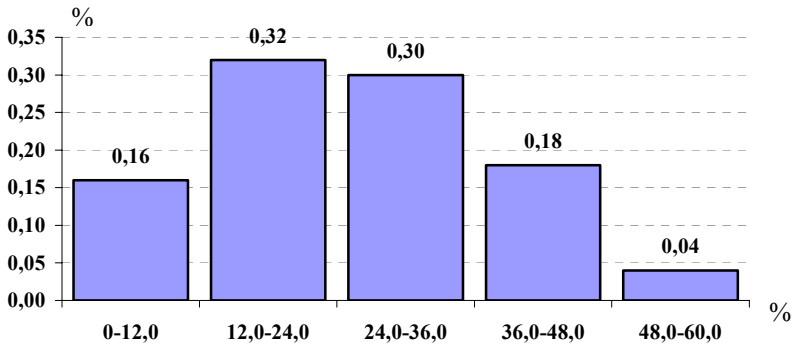

Figure 3. *Part of the high traffic volume in the gravel road network maintained by enterprises %*

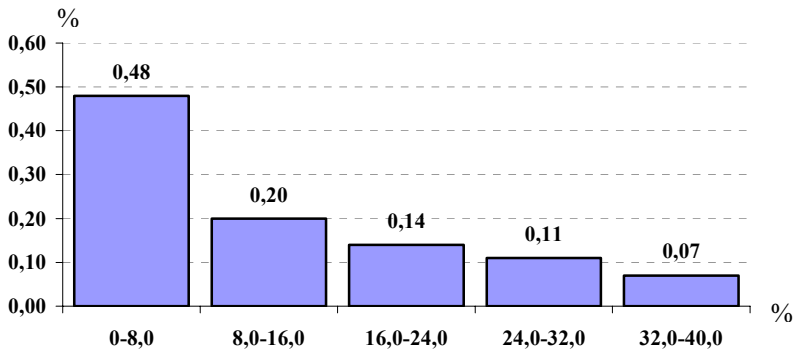

Figure 4. *Part of the very high traffic volume in the gravel road network maintained by enterprises %*

When analyzing traffic volumes on gravel roads from separate enterprises and regions, the differences between heavy vehicles and car volumes were noticed. It was identified that the calculated total AADT on the regional gravel roads in separate regions varies inconsiderably, and cars prevail in the traffic flow [5].

Lithuania has 12.5 % of gravel roads with traffic volumes less than 50 vpd. Gravel roads with moderate traffic volumes in separate enterprises are from 23.4 to 65 %, and 49.5 % in the countryside and are the prevailing group of gravel roads according to traffic volumes. Gravel roads with high traffic volumes make up 25.6 % in the countryside: although their percentage varies from 0 to 58.9 % in separate enterprises. The number of gravel roads with very high traffic volumes is almost the same as the number of gravel roads with low traffic volumes, i. e. 12.4 %, although in enterprises units it varies from 0 to 36.9 %.

The presented results of traffic volume's research show that taking traffic volumes into account shall solve the gravel road upgrading tasks. Therefore, when solving the tasks of gravel road's sustainable development, more detailed research is required, i. e. the number of gravel roads set down for various traffic volume road groups in each region shall be known (investigated and identified) in the future.

Referring to the data of statistical analysis the distribution of road according to traffic has been presented and roads have been grouped.

APPLICATION OF TRAFFIC VOLUMES' RESEARCH ON GRAVEL ROADS WHEN SOLVING TASKS OF SUSTAINABLE ROAD NETWORK DEVELOPMENT

Methodology of Zoning Gravel Roads According to Regions

Based on an analytical expression, which shows the interaction of the environment with the road, it is recommended to zone gravel roads according to traffic volumes and their condition when solving concrete gravel road renovation tasks. When zoning gravel roads with various traffic volumes, the following stages are established in the methodology of zoning gravel roads according to traffic:

- Monitoring traffic on a gravel road,
- Estimation of annual average daily traffic on gravel roads,
- Classification of gravel roads according to traffic volumes in enterprises and regions, by dividing them into low-traffic-volume, moderate-traffic-volume, high-traffic-volume and very-high-traffic-volume gravel roads,
- Zoning gravel roads according to traffic volumes.

According to the road's condition, the following stages are established in the methodology of zoning gravel roads: preparatory, experimental investigation and completion works. In the preparatory stage, gravel road routes to be researched were selected from the road data bank. During the experimental investigation stage, research on the road was carried out. Research data were systematized and processed by using mathematical statistical methods. During this stage, statistical indices of gravel road networks in each region were estimated and evaluated. During the final stage, by using data of traffic volumes on gravel roads maps were drawn of the zoning of gravel roads.

Zoning According to Traffic Volumes

Experimental investigations on traffic volumes were carried out by us on gravel roads and showed that traffic volumes on regional gravel roads and roads maintained by enterprises vary considerably. The zoning of gravel roads according to the traffic volumes on them is necessary to justify gravel road renovation amounts in regions. According to the principles of the road network's sustainable development, first of all, gravel roads with very high and high traffic volumes are renovated. Maps of zoning gravel roads according to traffic volumes on them are presented in Fig. 5–8.

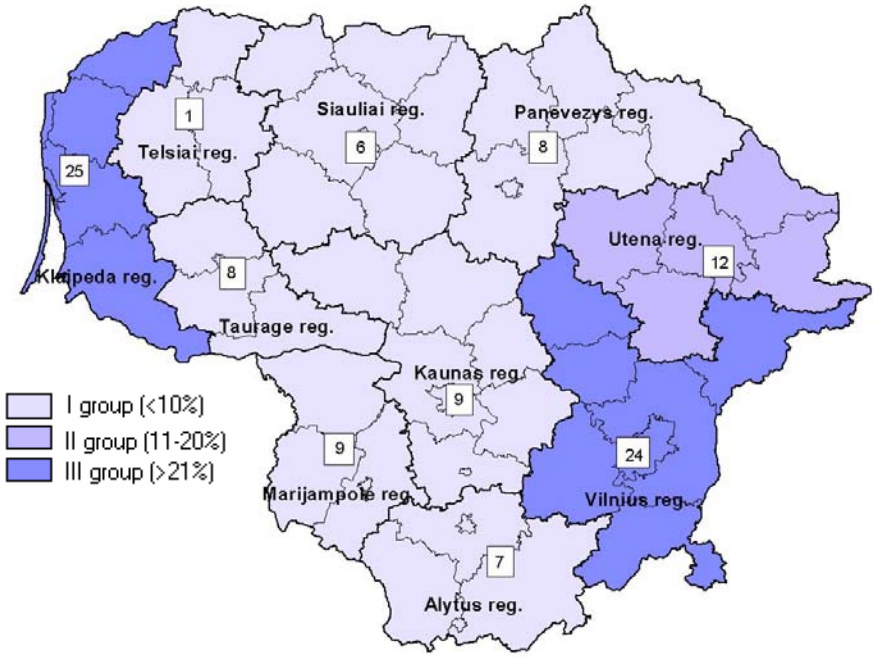

Figure 5. *Zoning gravel roads when AADT is less than 50 vpd*

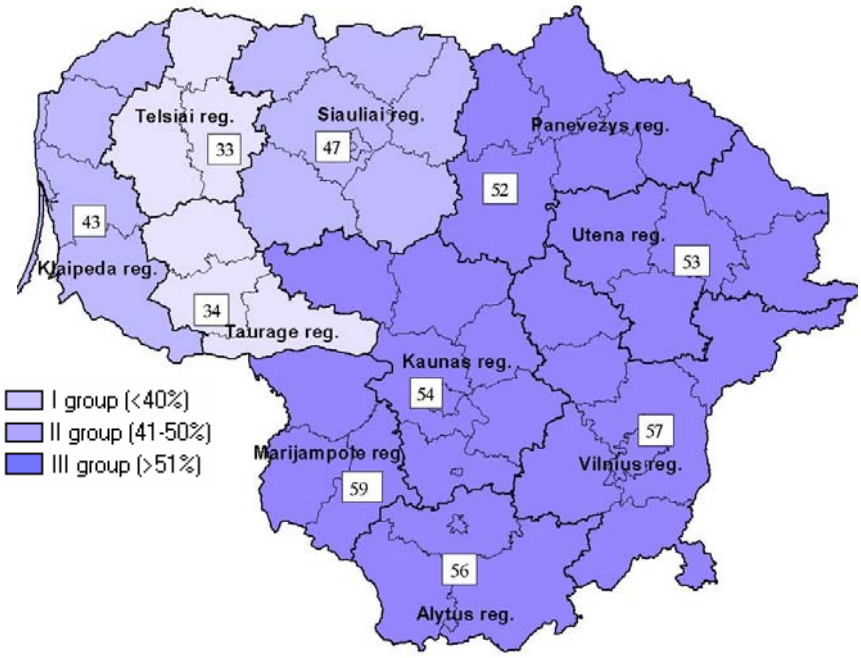

Figure 6. *Zoning gravel roads when AADT is 51-150 vpd*

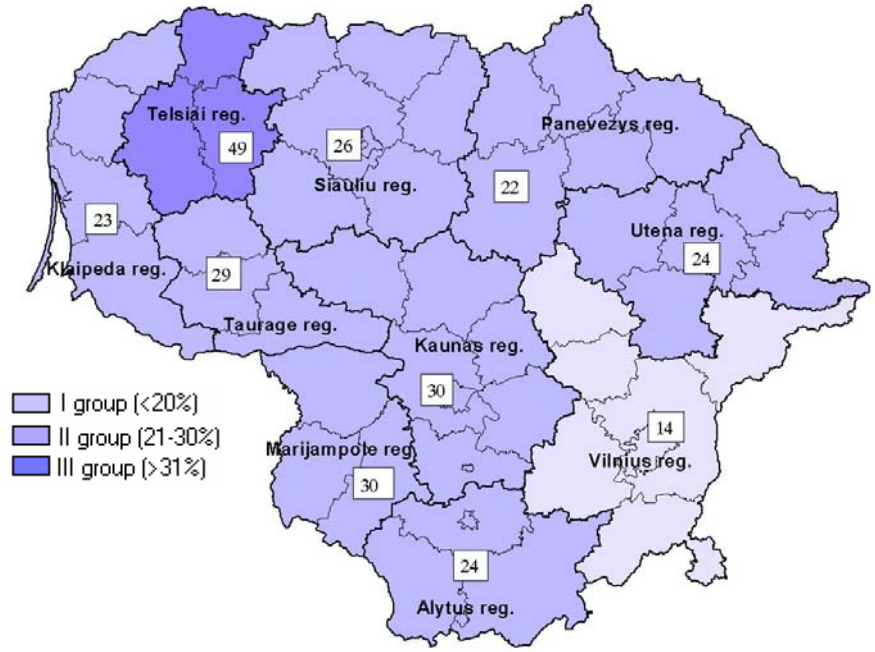

Figure 7. *Zoning gravel roads when AADT is 151-250 vpd*

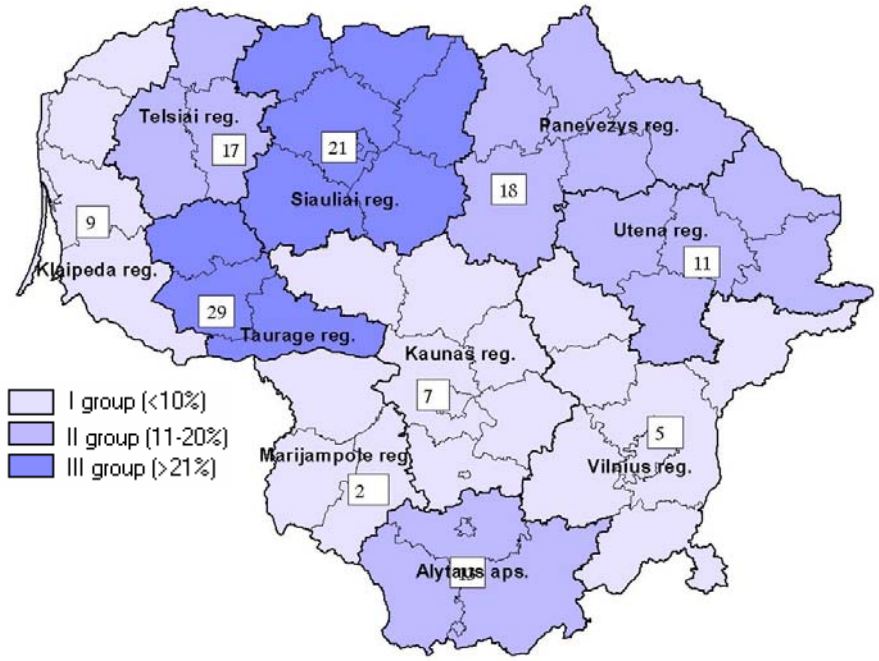

Figure 8. *Zoning gravel roads when AADT is more than 251 vpd*

The drawn maps show that gravel roads with moderate traffic volumes are the most common in regions, i.e. they make up from 33 to 59 %. The ratio of gravel roads with high and very high traffic volumes varies in these regions. This disproportion shall be taken into consideration when setting gravel road renovation tasks for regions.

Application of the Data in Zoning Gravel Roads when Solving Gravel Road Renovation Tasks

When formulating gravel road renovation tasks, gravel is assessed from the ecological point of view, i.e. its composition, resistance to abrasion, wear since gravel road wear depends on the gravel mineralogical petrographical composition and grading as well as its state (dry, damp, or waterlogged).

The main gravel road renovation task is formulated as follows: solution of gravel road renovation problems according to the principles of sustainable development in regions by taking traffic into account and reducing environmental pollution.

When solving this task, first of all, (Line I) gravel roads with very high traffic volumes are asphalt paved; then (Line II) gravel roads with high traffic volumes are asphalt paved. The amounts of asphalt paving works in regions are classified according to the length of gravel roads with very high traffic volumes of a certain region, which is calculated using the following formulae proposed by the authors (formulae1-4):

$$L_{iR} = L\frac{p_i}{100}, \tag{1}$$

here L_{iR} – the amounts of asphalt paving works calculated for i region, in km; L – the amounts of asphalt paving works set for a certain period in the country, in km; p_i – part of gravel roads with extremely high traffic volumes in %.

This formula is used to calculate the amount of works in cases when the length (L_{INT} – IV group of regions according to AADT) of roads with very high traffic volumes is less than the amount of asphalt paving works specified in the programmed (L – the planned amounts of gravel road asphalt paving works) set for a certain period in the countryside. The rest of the gravel road asphalt paving programmed ($L - L_{INT}$) is allocated for gravel roads with high traffic volumes. The allocation of these amounts for regions which have more gravel roads with high traffic volumes (L'_{INT} – III group of regions according to AADT) than it was planned to asphalt ($L'_{INT} > L - L_{INT}$), and is a solution of the task according to the principles of sustainable development. When allocating the amounts of asphalt paving works on this part, the amount of asphalt paving works, the total length of gravel roads in the countryside, and the number of gravel roads with high traffic volumes and the length of gravel roads in regions shall be taken into account:

$$L_{jRG} = \frac{L'_{INT}}{L_{\check{Z}V}} \times \frac{p_i \sum_{i=1}^{10} L_{i\check{Z}V}}{\sum_{i=1}^{10} p_i L_{i\check{Z}V}} \times L_{j\check{Z}V}, \tag{2}$$

here L_{jRG} – asphalt paving work's amount on gravel roads with high traffic volumes in i region, in km; L'_{INT} – the total amount of asphalt paving work on gravel roads with high traffic volumes, in km; $L_{\check{Z}V}$ – the total length of gravel roads in the country, in km; p_i – part of gravel roads with high traffic volumes in i region, in %; $L_{i\check{Z}V}$ – length of gravel roads in i region, in km; $L_{j\check{Z}V}$ – length of gravel roads in j region, in km.

The calculated amounts of asphalt paving works shall be recalculated with regard to the different parts of gravel roads with high traffic volumes in regions (expressed in %). The amount of these works shall be calculated as follows:

$$L_{jRG} = \overline{L}_{jRG} \times \frac{p_i \sum_{i=1}^{10} L_{i\check{Z}V}}{\sum_{i=1}^{10} p_i L_{i\check{Z}V}}, \tag{3}$$

here L_{jRG} – the amended amount of asphalt paving works calculated on the gravel roads with high traffic volumes in j region, in km; $\overline{L}_{jRG}$ – medium amount of asphalt paving works in j region calculated according to formula 4:

$$\bar{L}_{jRG} = \frac{L_{RG}}{L_{ŽV}} \times L_{iŽV}, \quad (4)$$

here L_{RG} – amount of asphalt paving works in the country, in km; $L_{ŽV}$ – total length of gravel roads in the country, in km; $L_{iŽV}$ – length of gravel roads in i region, in km; p_i – part of gravel roads with high traffic volumes in i region, in %.

Further solutions of gravel road reconstruction, repair and maintenance problems in terms of the road network's sustainable development are possible by carrying out special experimental investigations of gravel roads. It is recommended that these be classified according to zone gravel roads in terms of various aspects that are based on the findings of the investigation.

By using gravel roads, the environment is basically polluted by the wearing products of gravel, i.e. dust. When traffic volumes are the same, gravel roads in the regions that contain a lot of weak rock particles, wear the most and cause a lot of dust.

Based on data of zoning gravel roads according to traffic volumes and the model to solve the task, the amounts of asphalt paving works on gravel roads with high traffic volumes are calculated for diffrent regions. Here all gravel roads with very high traffic volumes (AADT > 251 vpd) will be asphalt paved since $L_{INT} > L$.

The calculated amount of asphalt paving works shall be amended according to formula 4. According to the results of these calculations, the amended amount of asphalt paving works differ from the calculated ones when the total amount of asphalt paving work and the length of gravel roads are taken into consideration. In some regions this difference makes 1% or 2% (Alytus, Siauliai, Utena regions), whereas in the others some or some dozens percent. Therefore, taking into account traffic volumes on gravel roads, implementing tasks for sustainable development, in separate Lithuania regions shall be solving successfully.

CONCLUSIONS

The most important factors solving road network development problems is traffic. Disproportions among regions according the ratio of gravel roads and roads with other type of pavements have changed inconsiderably. The proportion of gravel roads and roads with other type of pavements in regions will remain the same.

The increasing traffic volumes of regional roads have an impact on the development of the road network and vary in separate regions. The presented results of traffic volume's research show, that taking traffic volumes into account shall solve the gravel road upgrading tasks.

Referring to the data of statistical analysis the distribution of road according to traffic has been presented and roads have been grouped. Using data of traffic volumes on gravel roads maps were drawn of the zoning of gravel roads.

The zoning of gravel roads according to the traffic volumes on them is used solving gravel paving tasks according to the principles of sustainable road network development.

References

[1] Puodziukas V. Achievements and Prospects of Lithuania Integrating in the Transport System of European Union, *Lietuvos keliai*, No1, 2004, pp.6-10. (in Lithuanian)

[2] Zilioniene D., Cygas D. & Juzenas A.A. Design of Low-Volume Roads in Lithuania. In: *Pavement Unbound* /Edited by A.R.Dawson. London, UK: A.A.Balkema Publishers, a Member of Taylor & Francis Group plc, 2004.

[3] Zilioniene D., Juzenas A.A., Laurinavicius A. Experience to Improve and Maintain Gravel Roads in Lithuania. In: *25th International Baltic Road Conference, August 24-27 Vilnius, Lithuania, 2003.* http://www.balticroads.org/conference/en/seminars.html (access in May 27, 2004).

[4] Žilionienė D. *Renovation of Gravel Roads from the Aspect of Sustainable Development of Road Network*: Summary of Doctoral Dissertation, Technological Sciences, and Civil Engineering. Vilnius: VGTU, 2003. 36 p.

[5] Zilioniene D., Cygas D., Dundulis K. Solutions of Gravel Road Renovation Based on Certain Local Conditions in Lithuania, *Transportation Research Record,* 181, Vol. 2, 2003, pp. 267-274. (TRB, National Research Council, Washington, D.C.)