Analysis of Low-Volume Roads in Postwar Lithuania

Skirmantas Skrinskas, *Vilinius Technical University, Lithuania*

An overview is given of research carried out in the autumn and winter of 1992–1993 to determine the characteristic features of the road network in Lithuania as well as the main factors influencing the development of a network of low-volume roads. Estimates were used to calculate the relationship between the number of unpaved roads and the number of inhabitants in rural areas and to propose the coefficient road loss in topographical maps. The average length of all Lithuanian roads was defined for the first time. The paper is structured on a chronological as well as a geographical basis because of the way in which the analysis was organized. According to a specially prepared methodology, aerial photographs on a scale of 1/10,000 made on average in 1952 and topographical maps on a scale of 1/10,000 made on average in 1982 were analyzed and compared. Seventeen territories were selected randomly, each territory having an average size of 1,830 hectares (4,522 acres) and belonging to different geographical regions. Approximately 0.05 percent of the territory of Lithuania was thoroughly analyzed.

The earliest evidence of inhabitants in the present-day territory of Lithuania dates back to the 10th millennium B.C. The evolution of the Lithuanian state was linked to the necessity to counter the "religious" fervor of crusading Germanic knights. Lithuania was the last pagan state in Europe to be converted to Christianity. The first mention of the name of the country in written sources occurred in the year 1009 A.D. Lithuania is a country lying on the eastern shore of the Baltic Sea. Situated on the border of the last glacier, this country is the geographical center of Europe. The area of the country covers 65.2 km^2 (25.2 mi^2). In the west of the country the climate is mild, but the eastern part of Lithuania with the main European lake belt has a continental climate. Twenty-eight percent of the country is covered by forests. Though the maximum altitude is only 292 m (958 ft), the country is rather hilly. The average yearly temperature is 6°C (43°F), and the average rainfall is 620 mm (24.4 in.). The population of Lithuania is 3.7 million; 2.5 million live in urban areas and 1.2 million in rural areas. The population of Vilnius, the capital city, is 596,000. The country's gross domestic product was 10.9 billion Litas ($2.7 billion U.S.) in 1993. The average monthly wage in August 1994 in Lithuania was 369 Litas ($92.3). In November 1994 the minimal standard of living was 56 Litas ($14 U.S.) per month (*1*). State or public roads total 21 111 km (13,110 mi). In 1994 the main and national public roads [including 394 km (245 mi) of motorways] constituted 4866 km (3,022 mi). Traffic flows on these roads vary from 14,000 to 500 vehicles per day. Regional roads, which are low-volume public roads with traffic flows of less than 1,000 vehicles per day, total 16 245 km (10,088 mi). The surface of 97.9 percent of the main and national roads and 35.8 percent of the state low-volume roads is hard pavement. The other

49.8 percent or 10 523 km (6,535 mi) of state roads are gravel (2). The data about the other low-volume roads in the country were unknown until this study was performed. The recent economic problems of the country are reflected in a decrease in financing for the road sector. In 1994 the country's funds allotted for roads were limited to 98.3 million Litas ($24.6 million U.S.), which is only 25.2 percent of the money used for public roads in Lithuania in 1988. All construction of new roads has stopped. The only exception is a section of the international Via Baltica highway, financed from foreign loans. Because of insufficient financing in the last 6 years, the capital cost of state roads has depreciated 37 percent. The Lithuanian Road Administration shifted its attention to preserving existing hard-surface roads with surface dressing and rehabilitation. Particular concern was given to low-volume gravel roads. For this purpose, general information about low-volume roads in the country was needed.

Scope of Work

The main aim of the research conducted during the autumn and winter of 1992–1993 was to determine the characteristic features of the road network in Lithuania and the main factors that influence the development of a network of low-volume roads.

During the analysis of the collected data, estimates were used to calculate the relationship between the number of unpaved roads and the number of inhabitants in rural areas and to propose the coefficient of road loss in topographical maps. For the first time, the average length of all Lithuanian roads was defined.

The paper is structured on a chronological as well as a geographical basis. This structure was possible because of the particular way in which the analysis was organized. According to a specially prepared methodology, 1952 aerial photographs and 1982 topographical maps, both on a scale of 1/10,000 were analyzed and compared.

Seventeen territories were selected randomly, each territory had an average size of 1,830 hectares (4,522 acres) and belonged to a different geographical region. Approximately 0.05 percent of the territory of Lithuania was thoroughly analyzed.

This paper gives an overview of the study results. The figures are expressed using two decimal places; however, accuracy is limited to one decimal place.

Chronological Basis

The period from 1952 to 1982 in Lithuania and the other Baltic countries was a period of far-reaching communist changes in agriculture and economy. In 1952, World War II had long been over, and the partisan movement against the Soviets was almost over.

The collectivization of land had been completed on paper; that is, the documentation had been done but one-family farms still existed. Collectivization in agriculture, agricultural and economical centralization, and land reclamation would begin and develop rapidly.

However, by 1982 all possible gains of the communist economy had been achieved, and the economic level of all three occupied Baltic countries was falling along with the economy of the entire former Soviet Union. No real sociopolitical changes had been made. The Food Program and *Perestroika* were started after 1982. Almost a decade remained until the fall of communism and the independence of Lithuania.

In Lithuania, the surface occupied by roads decreased from 1.83 to 1.65 percent. The average length of unpaved road grew from 508 m (1,667 ft) to 672 m (2,205 ft). The ratio of the road distance to the straight distance on a chart (route factor) for the journeys on all roads within Lithuania increased from 1.11 to 1.14. The average road density decreased from 2.63 km/km^2 (4.24 mi/mi^2) to 2.33 km/km^2 (3.95 mi/mi^2). The average density of unpaved roads diminished even more—from 1.76 km/km^2 (2.84 mi/mi^2) to 1.36 km/km^2 (2.19 mi/mi^2). As shown in Figure 1, the average length of unpaved road from the farmstead to a road with a better surface grew from 810 m (2,657 ft) in 1952 to 830 m (2,723 ft) in 1982.

There were also changes in the structure of the road network. Territory occupied by the circuit road network (the network in which one can go from one node to another by two or more routes) extended from 73.7 to 80.8 percent, and the territory of the branching road network (the network in which one can go from one node to another by only one route) decreased from 26.3 to 19.4 percent. The number of basins of branching networks decreased 2.24 times.

The number of all roads (not the length) decreased by 28.1 percent, and the number of unpaved, low-volume roads was reduced by 38.8 percent. In 1952, 90.8 percent of the roads in the country were unpaved; in 1982 the percentage decreased to 77.3 percent.

Many factors contributed to these changes. After an agricultural reform in the 1920s in prewar Lithuania, almost all the agricultural territory was divided into single-family farms. But during the period of collectivization in agriculture and the growth of collective farms, new land use was based on the estimated effectiveness of vast farming areas in which it was easy to operate heavy machinery. Single-family farms were eliminated. Farmhouses were moved to the center of collective farms or destroyed. Short straight roads that led to the farmsteads from the larger roads were ploughed up or reclaimed with the surrounding land areas. The hastily

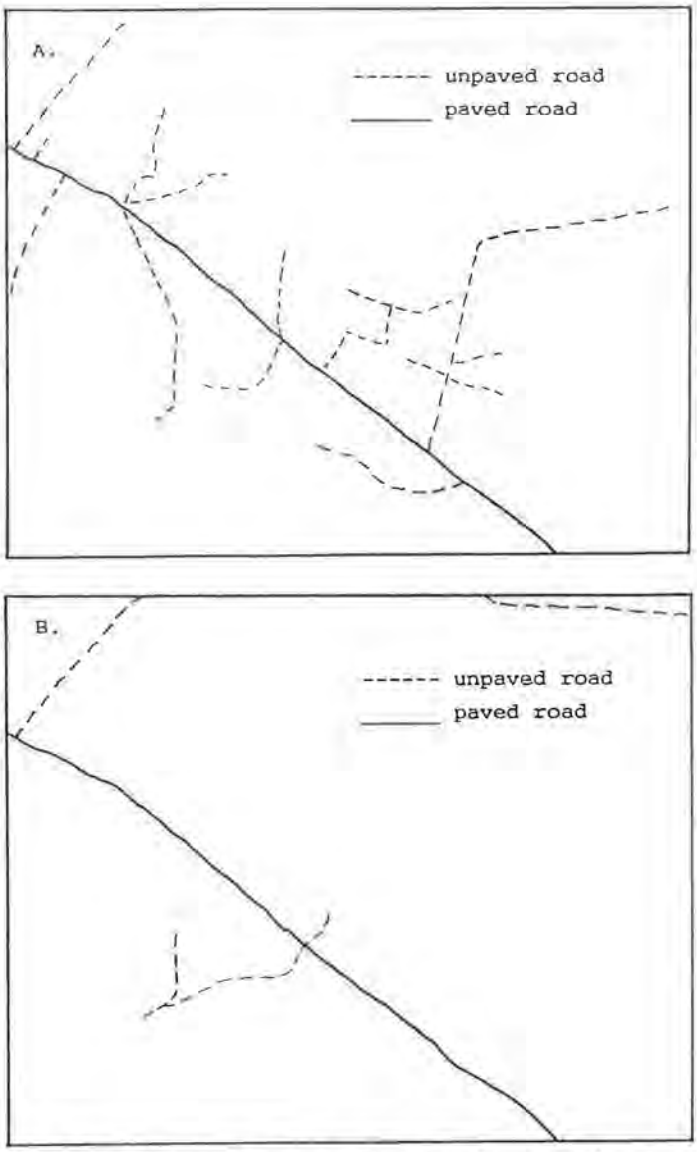

FIGURE 1 Short straight roads that led to farmsteads from larger roads were ploughed up or reclaimed with the surrounding land; Klaipėdos region, Pajūrio lowland, Lithuania: (*a*) 1953 aerial photograph scale 1/10,000; (*b*) 1981 topographical map, scale 1/10,000.

made collective farms and the sequential centralization of local low-volume transport flows and the decrease of population in the country areas because of industrialization in the cities lessened the need for interregional transportation. But roads among new farming centers and between farming centers and cities were improved, surfaced, straightened, or built anew. Directions of main local traffic flows changed considerably.

But, despite regional centralization and the shortening of existing transport connections, the length of the route from the farmer's home to the road with the better surface increased. During this 30-year period, positive increases occurred only in the length of hard-surfaced roads, which increased from 8200 km (5092 mi) in 1952 to 21 671 km (13,458 mi) in 1982, and the administrative distribution of the length of state or public roads, which increased from 15 886 km (9865 mi) in 1952 to 19 994 km (12,416 mi) in 1982. However, the length of the so-called departmental low-volume roads that do not belong directly to the state but to various ministries or departments decreased more rapidly—from 19 700 km (12,234 mi) in 1952 to 11 997 km (7,450 mi) in 1982.

Statistical data show that in 1982 the total length of public and departmental roads reached a low—31 991 km (19,866 mi) (*3*). Only in 1983 did the total length of roads in Lithuania start to grow. The period from 1952 to 1982 characterizes the decrease in length of Lithuanian roads.

The determined spread of the circuit road network and the decrease of the branching road network (or fast decrease of branching road network basins) led to greater interaction by means of transport among different ethnic groups and, more generally, in the light of all former Soviet society, interaction among nations and cultures. Even an abnormal change of the ratio between hard-surface roads and unpaved roads from 1:18.8 to 1:5.92 within 30 years had no significant influence on the total lengthening of the road network. The country experienced great economic, psychological, and spiritual damage.

The coefficient of road loss was determined by comparing the results of the analysis of aerial photographs and topographical maps on a scale of 1/10,000 with the changes documented by statistics for this 30-year period (*3*). The coefficient of road loss shows the probability that roads visible in aerial photographs will not be visible on topographical maps. In this comparison, the probability of road disappearance was 0.05 or 5 percent. A coefficient of road loss equal to 1.05 was used to measure the length of all roads in Lithuania in 1982.

Too little territory was included in the study (0.48 percent), and the methodology of the analysis improved as the work progressed. Also there were differences in road numbering. All these factors are reflected in the accuracy of the estimates. However, results of the study are significant enough to achieve certain goals. The study attempted to estimate the length of all Lithuanian roads. The study also determined the possible speed of the changes in the network of roads with different pavement surfaces. Finally, the study hypothesized a relationship between the length of the low-volume road network and the size of the rural population.

The decrease in the number of unpaved roads corresponds to the decrease in the population in rural areas according to the formula

$$N = 0.83^{-1}P$$

where

N = decrease in percentage of number of unpaved roads in country,

P = percentage of population (between 25 percent to 65 percent living in rural areas of Lithuania (*4*).

According to the research data, the length of all roads in the country in 1952 was about 172 000 km (106,800 mi). This length is 4.83 times greater than the length recorded in the statistical data of that time (*3*).

Data in this study indicate that the length of all existing roads in Lithuania in 1982 (taking into account the coefficient of road loss in topographical maps) was approximately 160 000 km (99,400 mi). It was five times greater than the length indicated by the Lithuanian Road Administration data about public and departmental roads (*3*).

Since no research data on the length of all Lithuanian roads in 1993 are available, the projection of approximately 163 000 to 165 000 km (102,000 mi) is based on the total increase in the length of public and departmental roads, the economic decline of the last 10 years, the further decrease in the number and total length of unpaved roads leading to the farmsteads, and recent changes in the sphere of agriculture (privatization of land, new land ownership, and farmers). The length of all roads in the country is still 3.73 times greater than that indicated in Lithuanian Road Administration statistical data or nearly 7.77 times greater than the length of all public roads (*3*). In January 1993, it was said that in Lithuania there were only public and local roads (Table 1).

Geographical Basis

An analysis of the influence of various geographical peculiarities of the land surface on road parameters follows.

When the density of the road network was between 3.0 and 3.8 km/km^2 (4.8 to 6.1 mi/mi^2), the area covered by farmlands in this country was between 53.8 and 73.5 percent. When the land covered by forests ex-

TABLE 1 Length of Lithuanian Roads in Postwar Period

Year	Length (km) by Type of Road			Total Length (km)		
	Public	Departmental	Local	Statistical Data	Study Data	Difference (%)
1952	15,886	19,700	—	35,586	172,000	483
1982	19,994	11,997	—	31,991	160,000	500
1993	21,109	—	22,895	43,968	163,000–165,000	373

ceeded 55.4 percent, the density of the road network did not exceed 2.0 km/km^2 (3.2 mi/mi^2).

The lowest route factor of 1.02 was observed in the hilly plateaus with fir groves and deciduous woods and in the plains with fir woods and deciduous groves in the middle and southeastern part of Lithuania in morainal or zandrian plains.

The highest route factor (1.26 to 1.27) was determined in the plains covered by fir woods and deciduous groves together with plains covered only by deciduous groves. This landscape corresponds to preglacial lacustrine plains or to localities of flat alluvial plains with valleys covered by pine groves, which were characteristic of territories in the western and southwestern parts of the country.

The average route factor in Lithuania in 1952 was 1.11, and in 1982 it was 1.14. It is not high because there are no great differences among altitudes. For example, in Great Britain in 1967 the route factor was 1.17; in Sweden it was 1.21 in 1964 (*5*).

Not only the road density, but also the structure of the road network depends upon the size of the area of farmland in the region. Almost all of the circuit road network was in an area that was more than 53.8 percent farmland. The only exception was on the border of the Ignalina and Zarasai regions in the woody eminence of Breslauja, where the road density was very low. The circuit road network in less than 1 percent of the area explored in the 1952 aerial photographs was found to be in the regions where farmland covers 5.8 to 28.3 percent and forests, correspondingly, 88.4 to 66.5 percent of the total territory. A higher route factor was found in the branching road network than in the circuit road network.

General Trends

To summarize the results of the study of different parameters of automobile roads and general trends in changes of geographical peculiarities, the 10 biggest changes (estimates of changes were counted in percentages from the largest number) in the 30-year period are as follows:

1. The number of basins of branching road network decreased 224 percent,
2. The area of swamps decreased 67.1 percent,
3. The number of farmsteads decreased 59.4 percent (*6,7*),
4. The population in rural areas decreased 43.6 percent (*4*),
5. Urbanized territory increased 41.1 percent,
6. The number of unpaved roads decreased 38.8 percent,
7. The number of all roads (including unpaved roads) decreased 28.1 percent,
8. The area covered by a branching road network decreased 26.2 percent,
9. The average length of unpaved roads increased 24.4 percent, and
10. The density of the network of unpaved roads decreased 23.8 percent.

Conclusions

The results of the research are not completely accurate, and the work will be continued. However, conclusions about the tendencies and speed of changes in the period from 1952 to 1982 are clear enough to be considered in the management of low-volume roads in Lithuania.

Also, the estimated length of all Lithuanian roads was found to be 4.8 times longer in 1952, 5.0 times longer in 1982, and forecast to be 3.7 times longer in 1993 than that shown in the statistical data used until now. Figures 2 and 3 show the approximately 163 000 to 165 000 km (102,000 mi) of roads in Lithuania today.

Another conclusion is that the road parameters and the type of road network are functions of the geographical peculiarities of the land. The best indicator was found to be the percentage of the area covered by farmland, the increase in the percentage of which indicates an increase in the area covered by the circuit road network, an increase in the road density, and a decrease in the route factor.

In addition, the development of the road network is influenced by the country's sociopolitical development. During the period dominated by Soviet communism, the

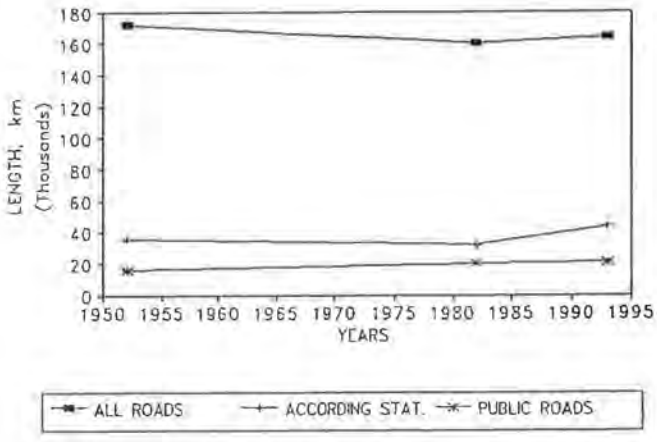

FIGURE 2 Length of Lithuanian roads, 1952 to 1993, as measured in this study.

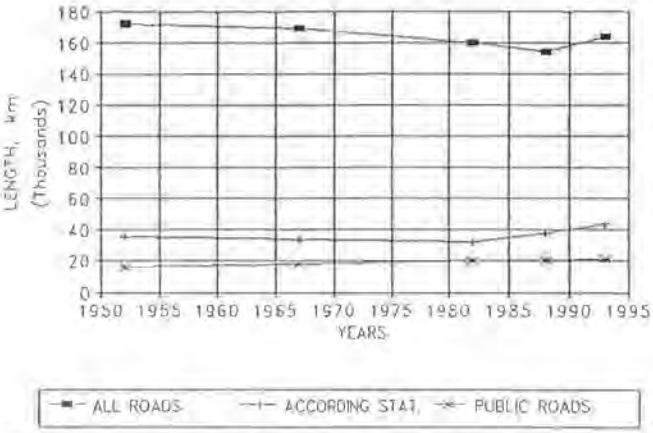

FIGURE 3 Length of Lithuanian roads, 1952 to 1993, as forecast after research according to total number of farmsteads in country.

length of the local road network decreased by 400 km per year, and its density decreased by 0.01 km/km^2 per year.

The changes in the development of the road network, especially of low-volume roads, is closely connected to the changes in the number of people in villages and other rural areas. The decrease in the number of unpaved roads corresponds to the decrease in the population in rural areas.

The estimated road parameters depend upon the kind of analysis conducted. The best map scale for general analysis is 1/10,000. It was easier to analyze aerial photographs. The coefficient of road loss in topographical maps (1.05) was estimated when aerial photographs and topographical maps on a scale of 1/10,000 were compared. The accuracy of the results also depends upon the scale of the map analyzed and on the precision of the measurements. As the Steinhaus paradox states: the more accurately an empirical line is measured, the longer it gets.

Finally, after the introduction of a new administrative subdivision of Lithuanian automobile roads, the length of main public roads is now 4866 km (3,022 mi). The length of public low-volume roads is 16 245 km (10,088 mi). All low-volume roads (including public, local, and others) in Lithuania total 97.0 percent of the entire length of the road network of the country.

Similar trends are expected in the analysis of the other two Baltic countries—Latvia and Estonia.

Future Activities

After the Via Baltica and the Vilnius-Panevėpys motorway and the Panevėpys-Diauliai-Klaipėda and Klaipėda-Palanga highways are finished, the network of main roads in Lithuania will be sufficiently developed for the near future. With integration into the dynamic European transport system, continuous attention will be paid to the improvement of the infrastructure of the low-volume roads in the republic. In 1993, the Lithuanian Road Administration started financing research on state gravel roads. Scientists and engineers of the most important Lithuanian road sector organizations (Lithuanian Road Administration, Transport and Road Research Institute, Vilnius Technical University, and Joint Stock Company "Kelprojektas") are working on the problems of state gravel roads. At present, two main topics of research are on the agenda: the development of optimum maintenance strategies for gravel roads and the economic feasibility of laying a hard surface on gravel roads in Lithuania.

The latter study is to be finished in 1995 and is supposed to answer questions on the effects of surface conditions (with emphasis on roughness), pavement characteristics, maintenance strategies, and traffic volume on vehicle operating costs, time savings, maintenance costs, and other factors. Three main tasks for the research are to build a model of economic feasibility for gravel road paving, suggest a methodology for selecting gravel roads for paving, and prepare special economic calculations for the government and for possible foreign investors.

The research is based on the use of the third version of the Highway Design and Maintenance Standards Model (HDM) proposed by the World Bank. The first attempt to economically analyze gravel road paving based on research data was made at the Transport and Road Research Institute where a cost-benefit analysis was made for asphalt paving of a gravel road 8 m (26.2 ft) wide with a surface roughness of 12 m/km International Roughness Index (63.4 ft/mi) and with a traffic volume of 500 vehicles per day. The analysis shows that at a discount rate of 10 percent for the 20-year period, the benefit-cost ratio reaches the level of 2.57 and the internal rate of return is 26 percent. More detailed and accurate calculations for all the test lengths of unpaved roads will be made in 1995.

Even though the HDM usually emphasizes the improvement of road maintenance and is designed for countries with warmer climates, certain changes in the model are expected to describe the key points of the economic feasibility of gravel road paving under the climatic and economic conditions of the Republic of Lithuania and neighboring Baltic and other countries (*8*).

Decisions and proposals concerning low-volume gravel roads that do not belong to the state will be based on the conclusions of the presented analysis, the ongoing research, and the priorities of the private owners.

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