VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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EFFECTIVENESS OF INVESTMENTS IN THE DEVELOPMENT OF ROAD INFRASTRUCTURE

Summary of Doctoral Dissertation
Social Sciences, Economics (04S)

Vilnius LEIDYKLA TECHNIKA 2009

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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INVESTICIJŲ EFEKTYVUMAS PLĖTOJANT AUTOMOBILIŲ KELIŲ INFRASTRUKTŪRĄ

Daktaro disertacijos santrauka
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Introduction

Topicality of the problem. In Lithuania, as well as in the other countries the main objective is to ensure the growth of national economy and competitiveness. One of the investment priorities is the improvement of transport infrastructure. Road infrastructure is one of the main factors determining the effectiveness of transport operation. In addition, it is of vital importance to the State's economic and social development due to the fact that in Lithuania more than 50% of all cargoes and 98% of passengers are carried via road. Although the roads in Lithuania are in a better condition than the roads in the neighboring Baltic States, the highway smoothness is worse comparing with the lowest class roads in Finland. Furthermore, gravel roads make more than 8000 km (38% from the total road length) and in the Western European countries such roads do not exist any longer. A lot of methods are created in order to justify road investments and to determine their rational usage. The methods are constantly being improved due to the change in economic situation and other factors. Annually more than 500 transition road projects are created in Lithuania. However, due to the limited budget of road infrastructure, it is advisable to analyze each project separately, relying on the parameters of that road in order to compose a list of priorities referring to the effectiveness of the investment for the implementation of these projects.

The object of investigations. The object of investigations of current work is investments planning into road sector by selecting priority road sections for investment.

Aim of the work – to analyze the effectiveness of investments while developing road infrastructure, after evaluating the expenditures for designing, implementation, exploitation, the period of time the investments would start to pay dividends and the dynamically changeable conditions of traffic volumes and the quality of speed and surface. In order to achieve the aim of this study it is compulsory to do the following **tasks**:

1. to analyze the importance of road infrastructure in the contemporary economic system, and the current conditions in Lithuania's road sector;
2. to analyze the problems occurring in the management of the investment projects and the content of road investment projects;
3. to determine the main parameters which are related with the expenditures;
4. to determine functional dependence between the main road quality parameters and change of financial costs;
5. to create a model which will help to determine the effectiveness of road infrastructure investment projects;
6. to investigate a chosen road section relying on the created model.

Methodology of research includes statistical analysis, mathematical modeling, LP-search ("Sobol's quazirandom sequences" method), and programming methods.

Scientific novelty. A universal model was created in order to analyze road infrastructure investment projects determining their benefit for minimization of expenditures of the society and state, applying LP-search ("Sobol's quazirandom sequences" method) and composing the totality of all the criteria in financial aspects.

Practical value. Applying this model we can assess the benefit which is provided by road investment projects to the society, to assess the period of time it takes to pay dividends, and to list the projects according to the priorities. After composing functional dependences of the change of all parameters for all road categories and transport modes, it could be possible to adjust (depending on economic and financial conditions) the programmes of laying roads in Lithuania, reconstruction and maintenance programmes, referring to real conditions.

Defended propositions

1. The model for determining the effectiveness of road investments.
2. Application of global "Sobol's quazirandom sequences" method, determining the section of priorities.

Approval of the results. Focusing on the subject of the dissertation, three articles were published and two lectures in the international conference were red.

The scope of the scientific work. The scientific work consists of the general characteristics of the dissertation, introduction, 4 chapters, conclusions, list of literature, list of publications and addenda. The total scope of the dissertation – 156 pages, 30 numbered equations, 26 pictures, 28 tables and 4 addenda.

1. The Increase of the Effectiveness of the Investments as the Priority of Road Infrastructure Development Economic Investigations

State's economic growth is closely related with transport system including the need to fix and reconstruct the roads. Due to a better economic situation, and GDP growth (GDP in 2007 made up LTL 96,7 bln, transport, warehousing and relations amounted 11,67% of GDP, road transport – around 6,2%) the intensity of road transport is growing and it has a great influence on the conditions of the roads. More investments should be made for road maintenance and development in order to diminish the rate of accidents (because of high accidents rate the country loses 3% of GDP every year) and costs of road users.

Appropriate maintenance and development of road network enable free movement of goods and the growth of economy.

Better road infrastructure encourages not only the growth of import, export, transit and local transportation volumes, but also the development of businesses. The better road quality will allow diminishing the rate of tragic accidents and shortening the time of the journey. Well-developed road network will allow using new free movement possibilities, increase tourism volumes, will encourage citizens to move more actively.

Asphalting of gravel roads will improve living conditions in the road areas, connection possibilities with outer regions. Furthermore, there will be better possibilities to connect with agricultural, trade and administrative centers.

As a result, the improvement and development of Lithuania's transport infrastructure will have long-term and positive effect on State's economy and competitiveness on the international level.

2. The Effectiveness of Investments in Developing Road Infrastructure

The organized project must be justified in strategic, financial, economic, technical and traffic safety aspects, also economic indicators of the project must be assessed. The components of road user costs and persons residing in the road impact zone are as follows:

Vehicle Operating Costs (VOC). While driving on the road different costs are sustained, consisting of fuel, lubricants, maintenance, tyre costs, drivers, salary and other expenses. A part of these costs depends on roughness of the road surface, number and width of traffic lanes, driving speed, road curviness, longitudinal gradient.

Annual Accident Costs (AC) makes a great effect to society. The accident rate in Lithuania is one of the highest in Europe. An accident rate is an important indicator of economy, i. e. the less number of people die or are injured, or the number of transport vehicles is damaged, the greater economy is received. The price of accidents with deaths, injuries, and of the technical traffic accident is differentiated.

Travel Time Costs (TTC). The travel time is expressed by generalized costs that combine travel time and pecuniary expenses. The time spent on travel is considered as costs with respect to an individual since he may not engage in any other activity at that time. The value of the time saved depends on the fact what an individual may create during that time.

Social and Environmental Effects (SEE). The quantities of pollutants in case if the project is implemented and is not implemented are determined. The pollution of air, dust on gravel roads, noise, and hothouse effect should be analyzed.

Repair and Maintenance Costs (RMC). The repair and maintenance costs consist of the direct costs of planning, designing and implementation of the structure, and operational (maintenance) costs (while implementing the project) of the structure (the costs of permanent maintenance, regular repairs, project monitoring (ex-ante and ex-post) costs.

3. Promising Model to Identify the Effectiveness of Road Infrastructure Project Efficiency

Based on these data a general model of investment efficiency may be formed:

$$\underset{\to 0}{S} = -(S_1) - (S_6^{''}) + \{(\Delta S_2) + (\Delta S_3) + (\Delta S_4) + (\Delta S_5) + (S_6^{'})\}, \quad (1)$$

where S_1 – road design and construction costs; $S_6^{''}$ – RMC after the project implementation; ΔS_2 – difference of VOC before and after the project implementation; ΔS_3 – difference of AC before and after the project implementation; ΔS_4 – difference of TTC before and after the project implementation; ΔS_5 – difference of SEE before and after the project implementation; $S_6^{''}$ – RMC before the project implementation (benefit after the project implementation).

Having revealed each Eq. 1 term we will receive:

$$\begin{aligned}
\underset{\to 0}{S} = & -\sum_{i=1}^{m} S_{1i} \cdot L - L \cdot B^{"} \cdot 1000 \sum_{i=1}^{m} \sum_{j=1}^{n} D_{ij}^{"} + \\
& \left\{ \sum_{i=1}^{m} ((AADT_i^{'} \cdot VOC_i^{'} - AADT_i^{"} \cdot VOC_i^{"}) \cdot \frac{L \cdot 365}{10^3} + \right. \\
& (AADT_i^{'} \cdot AR_i^{'} - AADT_i^{"} \cdot AR_i^{"}) \cdot \frac{L \cdot AC \cdot 365}{10^6} + \\
& AADT_i^{'} \cdot \frac{LVi}{V^{'}} - AADT_i^{"} \cdot \frac{LVi}{V^{"}}) \cdot L \cdot 365 + \\
& \begin{pmatrix} AADT_i^{'} \cdot (0,535 \cdot L_1 + 0,029 \cdot L_2) - \\ -AADT_i^{"} \cdot (0,446 \cdot L_1 + 0,024 \cdot L_2) \end{pmatrix} \cdot 365 + \\
& \left. \left(L \cdot B^{'} \cdot 1000 \sum_{j=1}^{n} D_{ij}^{'} \right)) \right\}.
\end{aligned} \quad (2)$$

where *AADT* – annual average daily traffic, vpd; *VOC* – vehicle operating costs, EUR/km, where:

$$VOC = \sum_{i=1}^{m} VOC_i \cdot ks_i \cdot ktf_i, \qquad (3)$$

where VOC_i – sum of vehicle operating costs by category of transport (car, busses, heavy trucks, and prime movers);
ks_i – coefficient of traffic flow distribution speed;
ktf_i – coefficient of traffic flow distribution;
L – length of road section, km;
L_1 – length of road section in the build-up area, km;
L_2 – length of road section in the not build-up area, km;
AR –accident coefficient in the section under study;
AC – average costs per one accident in the road section, EUR, where

$$AC = \sum_{i=1}^{m} AC_i \cdot n, \qquad (4)$$

where AC_i – sum of accident costs (accident with deaths, accident with injuries, technical accident);
n – number of accidents;
V – vehicle speed in the road section, km/h;
LV_i – travel time costs, EUR/h, where

$$LVi = \sum_{i=1}^{m} LVi_i \cdot ktf_i \cdot hs_i, \qquad (5)$$

where LVi_i – sum of travel time costs by transport category;
ktf_i – coefficient of traffic flow distribution;
hs_i – average travel time, h.
D – maintenance costs for the road, EUR/1000m^2, where

$$D = \sum_{j=1}^{m} D_j, \qquad (6)$$

where D_j – sum of maintenance costs (repairing, cleaning, winter maintenance, etc.)
B – width of the road section, m.

The Regression Equations of Model Components. During operation of the paved road, its technical characteristics change, therefore we take into consideration an increase in roughness of the road surface, and its reduction in the 8th and 16th years of project existence when an overhaul of the surface is carried out. Based on the correlation between the VOC (1000 vehicles km/year) and the roughness of the road surface (measured by International Roughness Index – IRI) the regression was deduced by Eq. (7).

The surface roughness index of the paved road ranges between 1,5 to 6 m/km therefore in the Fig.1 the following range for deducing was used (Eq. (8)).

Based on statistics, the index of roughness the gravel road surface may reach up to 18 m/km, yet an index of 14 m/km is already considered as a very poor condition of road surface. The index range of the country's gravel surface roughness is very wide – from 5 to 14 m/km. The lower limit is achieved right after grading, yet, depending on the weather conditions and traffic volume, the coefficient increases fast. Therefore in the Fig. 2 the marginal limits from 5 to 14 m/km were selected.

$$y = 72{,}241x + 878{,}8. \quad (7)$$

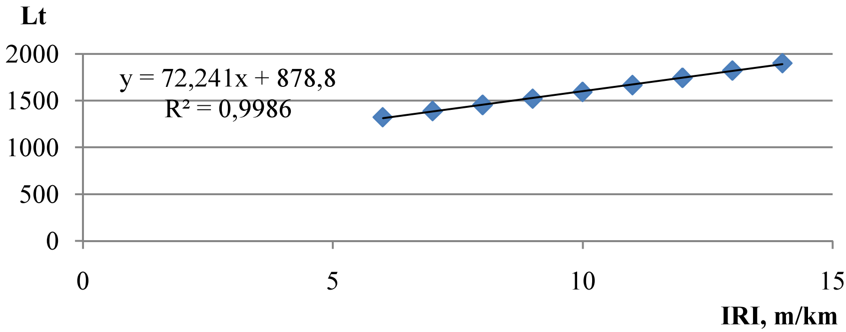


Fig. 1. VOC correlation between the surface roughness in case of the gravel road

$$y = 53{,}637x + 993{,}42. \quad (8)$$

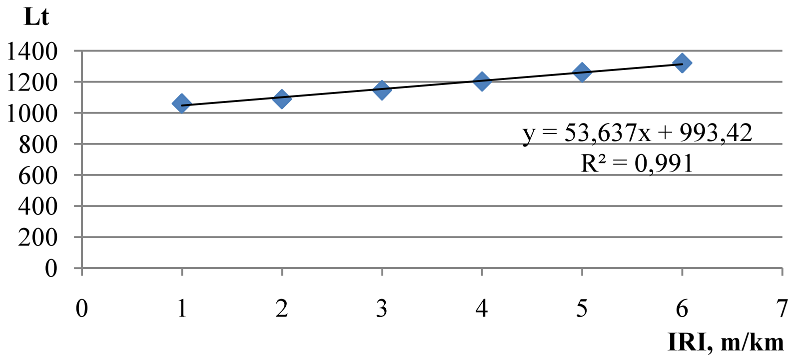


Fig. 2. VOC correlation between the surface roughness in case of the paved road

Vehicle speed also influencing VOC. Based on the correlation between the vehicles speed and the coefficients of traffic flow distribution speed the regression was deduced in Fig. 3 (Eq. (9)).

$$y = 0{,}0003x^2 - 0{,}0394x + 2{,}3757. \quad (9)$$

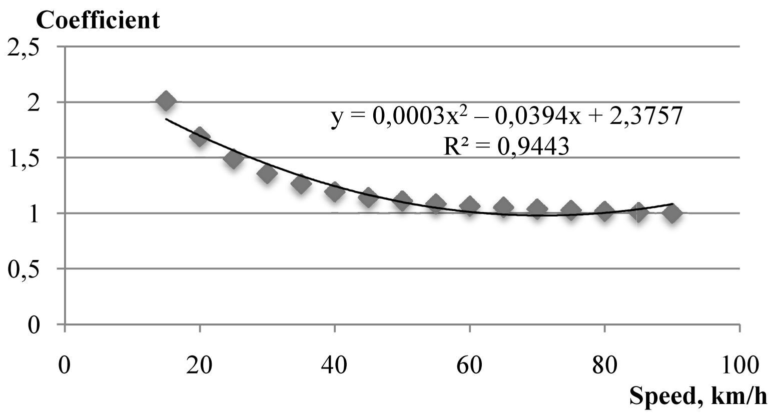
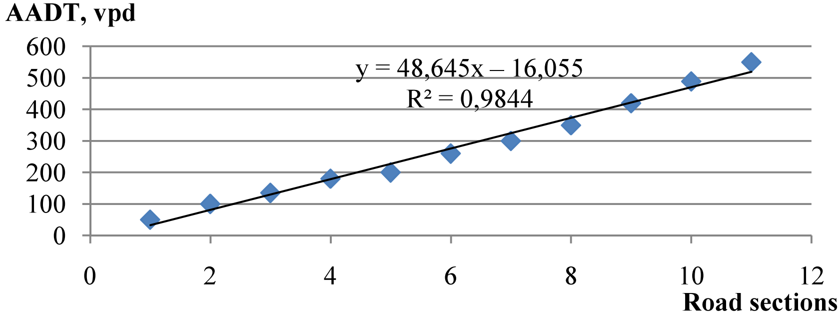


Fig. 3. Correlation between the vehicles average speed and rise in VOC

To assess the Average annual daily traffic (AADT, vehicles per day), data of *Technical and economical monitoring of the gravel road paving works financed by the European Union Regional Development Funds for the 2004–2005 period* (TKTI, Kaunas, 2007) road was used. In a number of sections, the traffic volume changes insignificantly after the project implementation, yet sometimes it increases even 3 times. According to the values of 54 sections, traffic volume fluctuating from 50 to 550 vpd on the gravel roads and from 55 to 605 after paving these roads. Based on these data, a regression equation of traffic volume with respect to random sections is deduced in the Fig. (4, 5), (Eq. 10,11).



$$y = 48{,}645x - 16{,}055. \tag{10}$$

Fig. 4. AADT in gravel road sections

$$y = 53{,}51x - 17{,}66. \tag{11}$$

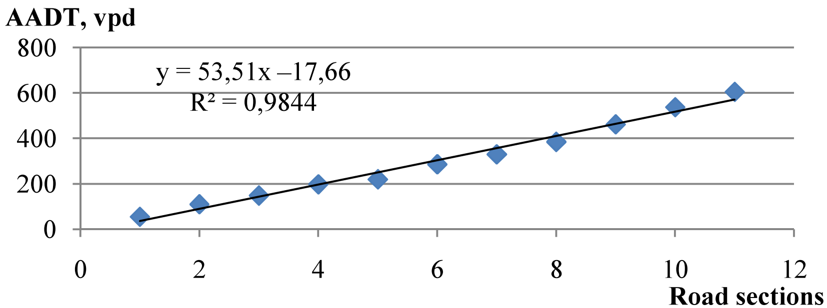


Fig. 5. AADT in road sections after paving

Average vehicle speed depends on roughness of road. According to calculations with HDM-4 model, the correlation between the average vehicle speed and roughness of road was determined in Fig. 6, 7. (Eq. 12, 13)

$$y = -4{,}6053x + 107{,}07. \qquad (12)$$

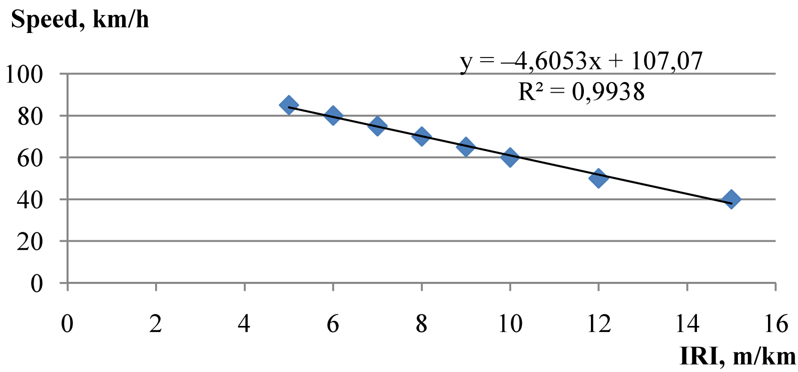


Fig. 6. Correlation between the average vehicle speed and roughness on gravel road

$$y = -0{,}5238x^2 + 1{,}6429x + 89{,}452. \qquad (13)$$

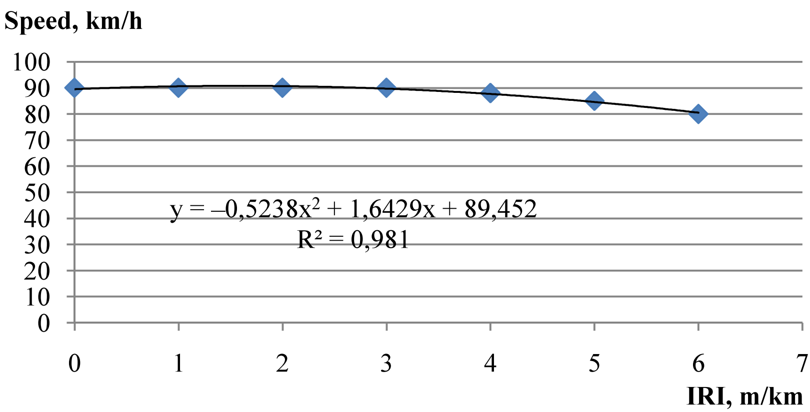


Fig. 7. Correlation between the average vehicle speed and roughness on paved road

According to the adaptation of the TARVA (abbreviation from finish TARVAL: A tool for estimation of traffic safety effects of riad improvement) model, developed at the Technical Research Centre of Finland (VTT) for the Finnish National Road Administration (Finnra), for Lithuania TARVAL, the rate of effect of the engineering measures on the accident rate after paving the gravel road increases from 1,0 to 1,1. Yet, after assessing the rates of integration of safe traffic measures, it is assumed that the accident rate decreases to 0,96 on average.

According to the statistical data of road maintenance in Lithuania for the past eight years, the costs of maintenance of the gravel road and of the paved road was calculated in Figs. 8 and 9; Eqs 14 and 15).

$$y = 48{,}52x^2 + 103{,}94x + 3586{,}3, \tag{14}$$

$$y = 19{,}408x^2 + 41{,}577x + 1434{,}5. \tag{15}$$

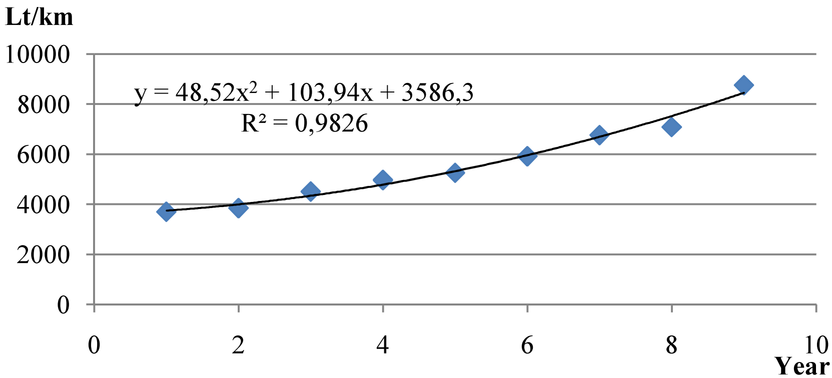


Fig. 8. RMC of the gravel road with respect to time

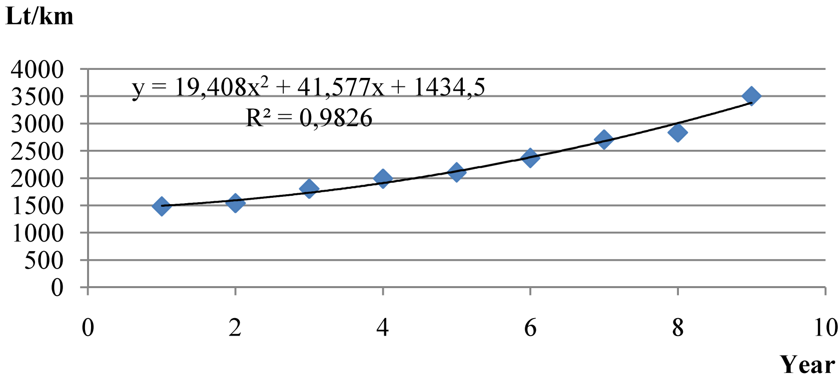


Fig. 9. RMC of the paved gravel road with respect to time

Social and environmental effects were calculated by Lithuanian conditions.

Based on data available, the limits of change in each term of the model are expressed in regression Eq. (3–15). Having entered them into Eq. 2 and receive:

$$
\begin{aligned}
&\underset{\to 0}{S} = -\sum_{i=1}^{m} S_{1i}\cdot L - L\cdot\sum_{i=1}^{m}(19{,}408\mathrm{x}_{10}^{2} + 41{,}577\mathrm{x}_{10} + 1434{,}5) + \\
&\left\{\sum_{i=1}^{m}(((48{,}645\mathrm{x}_1 - 16{,}055)(72{,}241\mathrm{x}_2 + 878{,}8)(0{,}0003\mathrm{x}_3^2 - 0{,}0394\mathrm{x}_3 + 2{,}3757) - \right.\\
&(53{,}51\mathrm{x}_4 - 17{,}66)(53{,}637\mathrm{x}_5 + 993{,}42)(0{,}0003\mathrm{x}_6^2 - 0{,}0394\mathrm{x}_6 + 2{,}3757)\cdot\frac{L\cdot 365}{10^3} + \\
&((48{,}645\mathrm{x}_1 - 16{,}055)AK' - (53{,}51\mathrm{x}_4 - 17{,}66)AK'))\cdot\frac{L\cdot VVAK\cdot 365}{10^6} + \\
&(48{,}645\mathrm{x}_1 - 16{,}055)\frac{LVi}{(-4{,}6053\mathrm{x}_7 + 107{,}07)} - \qquad (16)\\
&(53{,}51\mathrm{x}_4 - 17{,}66)\frac{LVi}{(-0{,}5238\mathrm{x}_8^2 + 1{,}6429\mathrm{x}_8 + 89{,}452)})\cdot L\cdot 365 + \\
&\begin{pmatrix}(48{,}645\mathrm{x}_1 - 16{,}055)(0{,}535L_1 + 0{,}029L_2) - \\ -(53{,}51\mathrm{x}_4 - 17{,}66)(0{,}446L_1 + 0{,}024L_2)\end{pmatrix}\cdot 365 + \\
&\left.(48{,}52\mathrm{x}_9^2 + 103{,}94\mathrm{x}_9 + 3586{,}3))\right\}
\end{aligned}
$$

LP-Search is a determinate analogue of Monte Karlo method which allows to choose optimal value while solving multicriteria tasks and while assessing various requirements and limitations. This method was suggested by Russian scientists: I. M. Sobol and R. B. Statnikov. The main advantages of the method:

- the possibility to analyze several criteria at the same time. This method allows to assess values (no quantity limitations) of several criteria which could be simultaneously eliminating each other and the specialist does not have to guess which value is better. This means that the specialist does not have to simplify the task to only one criteria and to assess various weight rates, optimal values could be chosen in the process of data processing;
- usage of equally distributed sequences. Usage of equally distributed sequences while probing multidimensional unitary cube enables to decrease the number of experiment values and to process complex functions. Equally distributed sequences are so called LP_τ sequences which are evaluated as the best from all other known equally distributed sequences.

For the selection of optimal x_1–x_{10} values the model released using the global optimising method “LP search”. Having determined the marginal values of each x, the method enables to select an optimal whole of all criteria. Since road parameters vary from year to year, different variables introduced each year, in the project existence cycle of 20 years. Scheme of the efficiency determination model is shown in Fig. 10.

4. Empirical Research to Identify the Efficiency of Investments Road Infrastructure Development

The results of empirical investigations (applying the created model and LP-search):

If annual average daily traffic is 50 vpd, the project does not start to pay dividends during its life cycle (20 years); therefore the project should not be implemented if traffic intensity is not foreseen.

If annual average daily traffic is 200 vpd, the project starts to pay dividends at 13 year of its life cycle. At the end of its cycle (20 years), the current net value makes LTL 15655, as a result, this project could be implemented.

If annual average daily traffic is 350 vpd, the project starts to pay dividends at 5 year of its life cycle. At the end of its cycle (20 years), the current net value of investments increases about 2 times. Such non-asphalted section should not be implemented because it is not economically beneficial. This project should be added into the list of priorities.

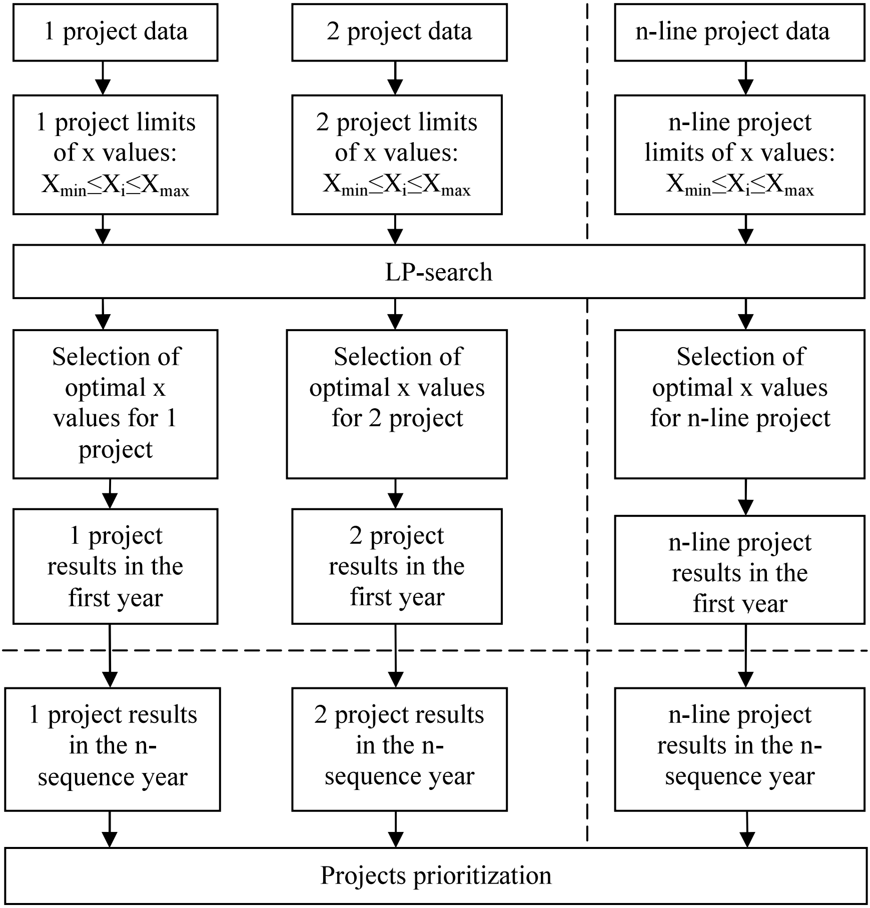


Fig. 10. Block scheme of the efficiency evaluation model

If annual average daily traffic is 500 vpd, the project starts to pay dividends at 3 year of its life cycle. At the end of its cycle (20 years), the current net value of investments increases more than 4 times. There are not many such kind of road sections, usually these roads are in newly settling suburbia. Such roads should be immediately asphalted because the exploitation of them increases the expenditures of road users and the costs of road maintenance. It is not economical to exploit such roads; therefore they should be added into the list of priorities.

General Conclusions

1. After the analysis it was determined that currently road transport covers 98% of passenger transportation and almost 45% of all carried cargoes and this is because land vehicles are mobile and universal and can reach the client at any point (from door to door transportation). However, in order to use the vehicles effectively it is a need to modernize road networks, particularly paying attention to asphalting the gravel roads. Comparing these roads to the roads which have capital surfaces, there are 1,5 times lower speed of transportation, respectively lower travel time, about 1,2 times bigger ecological losses (dustiness, noise) and about 2 times more money should be spend on such roads.
2. When implementing EU supported projects, the State budget by the main taxes returns the sum up to 1,7 times larger than investment.
3. Investigated, that well timed maintenance and reconstruction of transport infrastructure requires about three times less resources.
4. During the study created a unique model enables to determine the period of time it takes to pay dividends or to determine which particular road project in which particular region had the greatest benefit for the society taking into account all its constructive and exploitative parameters. Following that, road fund could be allocated rationally.
5. Functional relations were determined between separate parameters of the model such as variable intensity, dependence of the speed on the quality of the surface, variable expenditures of car exploitation dependence on the quality of the surface, variable funds of road maintenance, rates of accidents, and change in ecological conditions.
6. Investigated, that model used with LP-search enables to determinate not only pessimistic or optimistic, but also possible intermediate investment pay off scenario at the same time.
7. Empirical research was performed in order to examine the effectiveness of the model (to evaluate economic benefit of a particular road investment). The research showed that the greatest benefit is received because of the decrease in auto transport expenditures (~40%) and the time spent on road during the journey (~50%).
8. As a result of increasing traffic intensity, the period of time it takes to pay dividends is getting shorter according to the second order binoma this means that the indicator is one of the main ones which helps to shorten the period of time it takes to pay dividends when evaluating the benefit of the project.

9. This model could be applied for other kinds of road projects too i. e. to choose the best projects for laying new roads and fixing the current ones.

10. This model could be applied for other countries to determine effectiveness of investment into road infrastructure. In order to do this, the rates of composed regression equations should be calculated, referring to statistical data and the limits of rational corresponding parameter change should be determined.

The List of Published Works on the Topic of the Dissertation
In the reviewed scientific periodical publications

Lingaitis, V.; Miškinis, D. 2006. Maintenance Costs of Road Pavement and Motor Vehicles on the Route Vilnius–Kaunas–Klaipeda, *Transport,* XXI (2):131–134. ISSN 1648-4142 print / ISSN 1648-3480 online. (ICONDA, COMPENDEX)

Lingaitis, V. 2008. Mathematical Model of Evaluation of the Efficiency of Investment Into Roads, *Problemy Transportu,* 3: 41–51. International Scientific Journal, Gliwice. ISSN 1896-0596.

In the other editions

Lingaitis, V; Lingaitienė, O. 2005. Rational Distribution of Investment in Road System, in *Trans&MOTAUTO'05 proceedings of the XIIth International scientific-technical conference*, 73–77. Veliko Tarnovo, Sofija. ISBN 954-9322-13-0.

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INVESTICIJŲ EFEKTYVUMAS PLĖTOJANT AUTOMOBILIŲ KELIŲ INFRASTRUKTŪRĄ

Mokslo problemos aktualumas. Lietuvoje, kaip ir kitose besiplėtojančios ekonomikos šalyse, pagrindinis tikslas yra spartus nacionalinės ekonomikos augimas ir konkurencingumo didėjimas. Vienas iš svarbiausių investicijų prioritetų – transporto infrastruktūros pagerinimas. Kelių infrastruktūra yra vienas iš esminių veiksnių, nulemiančių transporto veiklos efektyvumą, bei turinčių gyvybinę reikšmę šalies ekonomikos ir socialinei raidai, nes mūsų šalyje automobilių keliais vežama daugiau kaip 50 % visų krovinių ir beveik 98 % keleivių. Nors Lietuvos kelių kokybė yra šiek tiek geresnė nei kaimyninių Baltijos valstybių, tačiau net magistralinių kelių lygumas yra prastesnis už Suomijos žemiausios klasės kelių lygumą, nors jis po truputį gerėja. Be to, bendras žvyrkelių ilgis yra pakankamai ilgas ir sudaro virš 8000 km (38 % nuo bendro valstybinės reikšmės kelių ilgio), tuo tarpu kai Vakarų Europos valstybėse jų iš viso nelikę. Nors pasaulyje yra sukurta nemažai metodikų kelių investicijoms pagrįsti bei nustatyti jų racionalų panaudojimo būdą, metodikos nuolat tobulinamos ir ieškoma optimalių lėšų panaudojimo būdų. Lietuvoje kasmet sukuriama daugiau kaip 500 vienmečių ir pereinamųjų kelių projektų, tačiau esant ribotam kelių infrastruktūros biudžetui, tikslinga atlikti kiekvieno projekto analizę su tam keliui būdingais parametrais ir tokiu būdu sudaryti prioritetinį jų įgyvendinimo sąrašą pagal investicijų efektyvumą.

Tyrimo objektas. Investicijų į automobilių kelių ūkį planavimas, parenkant prioritetinius kelių ruožus investicijoms.

Darbo tikslas – ištirti investicijų efektyvumą plėtojant automobilių kelių infrastruktūrą, įvertinus projektavimo, diegimo, eksploatavimo išlaidas ir investicijų atsipirkimo laiką bei dinamiškai kintančias eismo srautų, greičio ir dangos kokybės sąlygas.

Darbo tikslui pasiekti darbe reikia spręsti šiuos **uždavinius**:

a) išanalizuoti kelių infrastruktūros reikšmę šiuolaikinės ekonomikos sistemoje, bei esamą padėtį Lietuvos automobilių kelių sektoriuje;

b) išnagrinėti investicinių projektų valdymo problemas bei automobilių kelių investicinių projektų turinį;

c) nustatyti pagrindinius parametrus, susijusius su sąnaudomis;

d) sudaryti funkcinius priklausomumus tarp pagrindinių kelio kokybės

e) parametrų ir piniginių sąnaudų kaitos;

f) sudaryti kelių infrastruktūros investicinių projektų efektyvumui nustatyti skirtą modelį;

g) ištirti modelį parenkant prioritetinius kelių ruožus investicijoms.

Tyrimų metodika apima statistinės analizės, matematinio modeliavimo, LP-paieškos (anglų kalboje žinomos kaip Sobol‘s quazirandom sequences) programavimo metodus.

Mokslinis naujumas

Sukurtas modelis kelių investicinių projektų visumai analizuoti, nustatant jų naudą dėl sumažėjusių visuomenės ir valstybės sąnaudų (nuostolių), kuriam pritaikius globalaus optimizavimo programą LP-paieška surandama visų kriterijų palankiausia visuma finansiniu atžvilgiu (aspektu).

Praktinė vertė. Autoriaus sukurtu modeliu galima apskaičiuoti kelių investicinių projektų teikiamą visuomenei naudą, atsipirkimo laiką bei sustatyti projektus pagal prioritetinę įgyvendinimo eilę. Sudarius visų parametrų kaitos funkcinius priklausomumus visoms kelių kategorijoms bei transporto priemonių rūšims, galima operatyviai koreguoti (priklausomai nuo kintamų ekonominių ir finansinių sąlygų) Lietuvos automobilių kelių tiesimo, rekonstrukcijos ar priežiūros programas, atsižvelgiant į realias sąlygas.

Ginamieji teiginiai

1. Investicijų į kelių projektus efektyvumo nustatymo modelis.
2. Globalios optimizacijos metodo LP-paieška taikymas, nustatant prioritetinius ruožus.

Darbo rezultatų aprobavimas. Disertacijos tema autorius paskelbė tris mokslinius straipsnius bei skaitė du pranešimus tarptautinėse konferencijose.

Darbo struktūra. Disertaciją sudaro įvadas, keturi skyriai, rezultatų apibendrinimas, literatūros sąrašas, publikacijų sąrašas ir priedai. Bendra disertacijos apimtis – 156 puslapiai, 30 numeruotų formulių, 26 iliustracijos, 28 lentelės ir 4 priedai.

Įvadiniame skyriuje nagrinėjamas problemos aktualumas, analizuojama mokslinė literatūra, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autoriaus pranešimai ir publikacijos, disertacijos struktūra.

Pirmasis skyrius skirtas Lietuvos kelių infrastruktūros analizei, jos reikšmei šalies ekonomikos sistemoje. Skyriaus pabaigoje formuluojamos išvados ir konkretizuojami disertacijos uždaviniai.

Antrajame skyriuje analizuojamos investicinių projektų valdymo problemos, automobilių kelių investicinių projektų pagrindimas, ekonominis, finansinis įvertinimas bei išskiriamos pagrindinės kelių naudotojų ir kelių priežiūros sąnaudų (nuostolių) komponentės.

Trečiajame skyriuje pristatomas perspektyvus kelių infrastruktūros investicijų efektyvumui nustatyti skirtas modelis. Naudojant statistinius duomenis modelis pritaikomas žvyrkelių asfaltavimo Lietuvos sąlygomis efektyvumui nustatyti. Pateikiama globalios optimizacijos LP-paieška metodo analizė.

Ketvirtajame skyriuje atliekami empiriniai tyrimai ir pateikiami investicinio kelių projekto efektyvumo, naudojant sukurtą modelį ir jam pritaikant globalios optimizacijos LP-paieška metodą, apskaičiavimo pavyzdžiai.

Bendrosios išvados

Analizuojant šiame darbe iškeltus uždavinius, gauti tokie apibendrinti rezultatai:

1. Atlikus tyrimą nustatyta, kad pastaruoju metu automobilių transportui tenka 98 % keleivių, bei 45 % visų vežamų krovinių, kadangi sausumos transporto priemonės pakankamai mobilios, universalios ir gali pasiekti klientą bet kuriame taške (transportavimas „nuo durų iki durų“). Tačiau veiksmingam jų naudojimui reikia modernizuoti kelių tinklą, ypač didelį dėmesį skirti žvyrkelių asfaltavimui. Juose, lyginant su keliais kuriuose paklotos kapitalinės dangos, ne tik 1,5 karto mažesnis transportavimo greitis ir atitinkamai trumpesnis transporto priemonių eksploatacinis laikas, bet ir apie 1,2 karto didesni ekologiniai nuostoliai (dulkėtumas, triukšmas), atitinkamai tokių kelių priežiūrai reikia skirti beveik dvigubai daugiau lėšų nei asfaltuotiems keliams.
2. Apskaičiuota, kad įgyvendinant Europos Sąjungos remiamus projektus, per pagrindinius mokesčius į valstybės biudžetą iš karto sugrąžinama iki 1,7 karto didesnė nei investuota suma.
3. Nustatyta, kad savalaikė transporto infrastruktūros priežiūra ir nuoseklus atnaujinimas reikalauja apie tris kartus mažiau lėšų.
4. Sudarytu modeliu galima nustatyti pasirinktų investicinių projektų greičiausią atsipirkimo laiką ar visuomenei teikiamą didžiausią naudą konkrečiame regione su keliui būdingais konstrukciniais bei eksploataciniais parametrais ir tokiu būdu racionaliai paskirstyti ribotas kelių priežiūrai ir plėtrai skiriamas lėšas.
5. Nustatyti funkciniai ryšiai tarp atskirų modelio parametrų, kaip kintamas eismo intensyvumas, važiavimo greičio priklausomumas nuo dangos kokybės, automobilių eksploatacijos sąnaudų kaita nuo kelio dangos kokybės, kelio priežiūros lėšų kaita, avaringumo, ekologinių sąlygų kaita.
6. Nustatyta, kad modeliui taikant globalios optimizacijos metodą LP-paieška, vienu metu nustatomi ne tik pesimistiniai ar optimistiniai, bet ir galimi tarpiniai investicijų atsipirkimo scenarijai.

7. Modeliu atlikus empirinius tyrimus nustatyta, kad didžiausia ekonominė nauda gaunama dėl sumažėjusių autotransporto priemonių eksploatacinių sąnaudų (apie 40 %) ir sugaišto laiko kelyje (apie 50 %).

8. Apskaičiuota, kad didėjant eismo intensyvumui, investicijų atsipirkimo laikas mažėja pagal antro laipsnio binomą. Tyrimo metu nustatyta, kad eismo intensyvumas yra vienas iš pagrindinių rodiklių trumpinant investicijų atsipirkimo laiką.

9. Sukurtas modelis tinkamas investicijų į žvyrkelių asfaltavimą efektyvumui nustatyti Lietuvos sąlygomis. Taip pat jį galima pritaikyti kitų rūšių kelių projektams įgyvendinti, t. y. parenkant prioritetinius projektus tiesiant naujus kelius bei taisant esamus.

10. Modelį galima pritaikyti investicijų į automobilių kelių infrastruktūrą efektyvumui kitose šalyse nustatyti. Tam tikslui, remiantis statistiniais duomenimis, reikėtų apskaičiuoti sudarytų regresijos lygčių koeficientus ir nustatyti racionalias atitinkamų parametrų kitimo ribas.

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EFFECTIVENESS OF INVESTMENTS IN THE DEVELOPMENT OF ROAD INFRASTRUCTURE

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