ISSN 1407-6160

TRANSPORT AND TELECOMMUNICATION

Volume 13. No 2

2012

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Transport and Telecommunication

Volume 13, No 2 - 2012

ISSN 1407-6160
ISSN 1407-6179
(On-line: www.tsi.lv)

Riga – 2012

05/J80

All articles are reviewed.
Articles can be presented in the journal in English.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)67100594. Fax: (+371)67100535.
E-mail: transport.journal@tsi.lv, http:// www.tsi.lv

TRANSPORT and TELECOMMUNICATION, 2012, Vol. 13, No 2
ISSN 1407-6160
The journal of Transport and Telecommunication Institute (Riga, Latvia).
The journal is being published since 2000.

The papers published in Journal “Transport and Telecommunication” are included in
SCOPUS (since 2008, Vol. 9, No 1), **Elsevier Database**
www.info.scopus.com
www.elsevier.com

CONTENTS

Investment Risk Management and Economic Aspects of Transport Infrastructure Development
Gintautas Labanauskas, Ramūnas Palšaitis........ 101

A New Approach to Assessment of Infrastructure Projects on Urban Transport Systems
Daiva Griskeviciene, Algirdas Griskevicius, Ausrine Griskeviciute-Geciene........ 108

Airport Benchmarking and Spatial Competition: a Critical Review
Dmitry Pavlyuk........ 123

The Research on Competitiveness of Road Transport Enterprises: Lithuanian Case
Jonas Lazauskas, Gintautas Bureika, Valdas Valiūnas, Robertas Pečeliūnas, Jonas Matijošius, Saulius Nagurnas........ 138

Multiple-Criteria Analysis and Choice of Transportation Alternatives in Multimodal Freight Transport System
Eugene Kopytov, Dmitry Abramov........ 148

Development Trends of Air Passenger Transport Services and Service Distribution Channels
M. Rebezova, N. Sulima, R. Surinov........ 159

Traffic Flow Simulation on Discrete Rate Approach Base
Mihails Savrasovs........ 167

Authors' index........ 174

Personalia........ 175

Cumulative Index........ 180

Preparation of Publications........ 185

Transport and Telecommunication, 2012, Volume 13, No 2, 101–107
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0008-6

INVESTMENT RISK MANAGEMENT AND ECONOMIC ASPECTS OF TRANSPORT INFRASTRUCTURE DEVELOPMENT

***Gintautas Labanauskas*[1], *Ramūnas Palšaitis*[2]**

[1]*SE Inland Waterways Authority*
Raudondvario pl. 113, LT-47186, Kaunas, Lithuania
E-mail: glabas@is.lt

[2]*Vilnius Gediminas Technical University*
Plytinės g. 27, LT-10105, Vilnius, Lithuania
E-mail: trvadyba@ti.vtu.lt

The major causes of investment riskiness into transport infrastructure relate to international economy instability, lack of clearly defined and accurate information on the overall processes of international intermodal transportation, absence of objective information due to inconsequent market research as regards interpretation of economic, political and other aspects.

Assessment of objective integrated investments into public transport sector as a very specific branch of economy should necessarily be evaluated as multiple indicators affecting different spheres of community, and the final solution should be drawn when all multi-criteria indicators are well appraised. Economy based grounding of the optimal choice from all possible variants when solving specific tasks of the transport sector, depends on the economic expediency of the constructed subject. The main factors of effective usage of investments become apparent in the process of solving the task of road or railway network development optimisation.

Keywords: transport, infrastructure, investments, efficiency, risk

1. Introduction

Development of countries and welfare created is dependent on their integration into globalisation processes, implementation and application of global technologies, cooperation and interchange of raw materials and production. Integration of logistics centres and transport terminals into the transport system pays the key role in these processes. This proposition is welcomed by [Button, K. J., Langley, J., Coile, J., Gibson J., 2008] and [Kondratowich, L., 2003] who emphasize that reliably functioning European transport system is the premise of for integration, trade and development of economy, competitive ability and equal living conditions in the continent.

Majority of scholars emphasize, that basic elements of transport infrastructure, as constituent of the business, gives to the state an economic and social benefit. Risk management is one of the key issues when planning investments into intermodal transport infrastructure. Investment decision-making requires thorough analysis of the problem both, on the national and international scale, and only then the most rational decision (project) can be made with the view of the effective risk lowering, i.e. seeking the least possible costs.

The attention to methodological reasoning of investments in missing objects of transport infrastructure and to research of positive results for Lithuanian economy is paid, emphasizing their effect in efficiency and stability of economical development in Lithuania [Labanauskas, G., 2010], [Labanauskas, G., Palsaitis, R., 2010], [Palsaitis, R., Labanauskas, G., 2008].

2. Investments Risk into Transport Infrastructure Modelling

One of the most complicated problems among those of risk management when making concept based investments, including investments into transport infrastructure, is commeasuring the efficiency and riskiness of the event or process under analysis, i.e. assessment of the value of stock dividends' increase that would justify acquisition of a more risky stock, or what should be the growth in mean profitability of the investment into a transport infrastructure to encourage taking a variable interest rate loan.

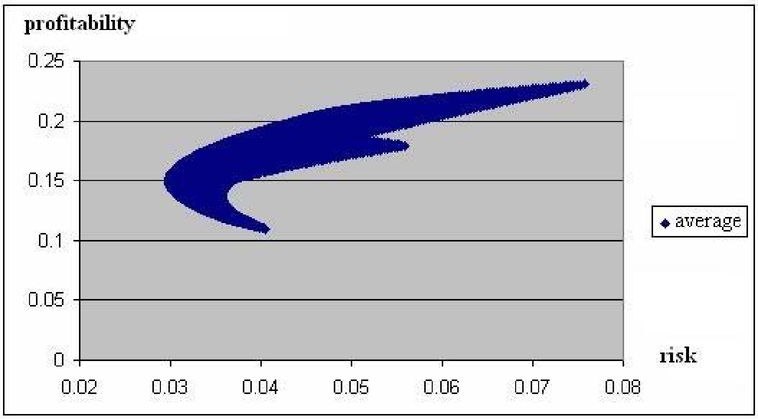
Solution of these problems is more advanced in theory and practice of investment decision-making. The studies of fundamental investment decision-making [see H. Markowitz, 1952, W. F. Sharpe, 1963, J. Tobin, 1965, Ch. Vaughan, 1997] disclose the existence of the efficient line in the mean profitability-risk plane, which is measured by profitability standard deviation. The main characteristics of the efficient line is that its points – investment possibilities, measured against profitability-risk indicators, cannot be improved on account of reducing mean profitability or riskiness if the value of the collateral parameter for evaluation is not changed.

In practice we pretty often have to face the natural risk management problem when trying to find the optimum (rational) distribution of the capital for the risk management among different risk groups. Solution of this problem is one of the most complete theories of investment portfolios.

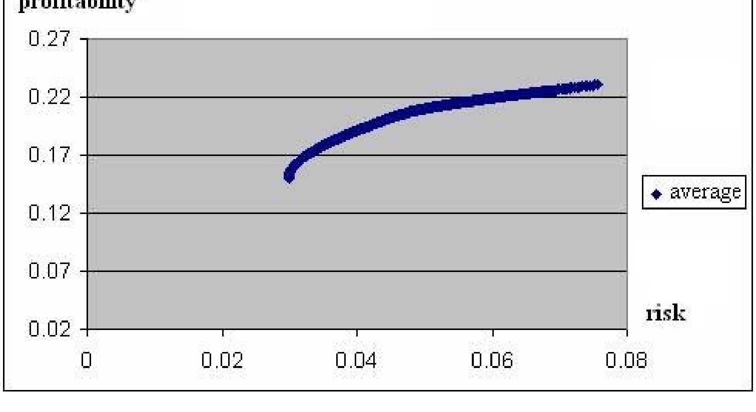
Computer modelling have been used to solve stochastic programming targeting at establishing the optimal proportions of the transport investments risk management among the three risk groups (portfolios). In Fig. 1a, section a we have a set of so called answers or portfolio values measured by internal effect and standard deviation (riskiness); section b presents the so called efficiency line with the mean values of the maximum net effect set on ordinate and the risk set on abscissa.

It clearly shows the investor's net profitability results: R1 (0,1502; 0,0299) – limiting the minimum risk, R2 (0,2066; 0,0478) – maintaining mean risk and R3 (0,2304; 0,0756) – accepting the maximum risk. A specific subject, depending on his interests pursued which are usually expressed by utility function, chooses a certain level of risk, and at the same time a certain coupling of mean profitability and risk.

It is very important that information system development receives a proper concern. In the theory of investment great attention is given to evaluation of the decision possibility (reliability) guarantee. As one of the measures for the information system development and cultivation of the investment criteria adequacy is classification of decision possibilities [see A. Rutkauskas, A. Miečinskienė, V. Stasytytė, 2008], taking into account possibility efficiency and reliability as well as the level of riskiness which depends on the riskiness of the processes under analysis (interest rate, currency exchange rate and alike) and on the ability of a subject – the recipient of the risk consequences to manage it.



a) Portfolio set and profitability

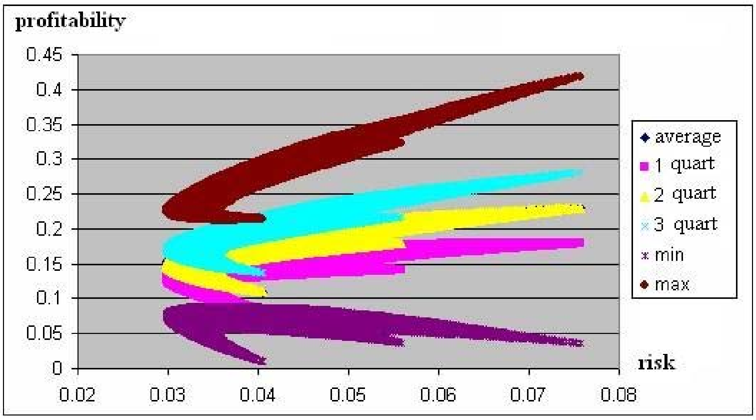


b) Efficiency line

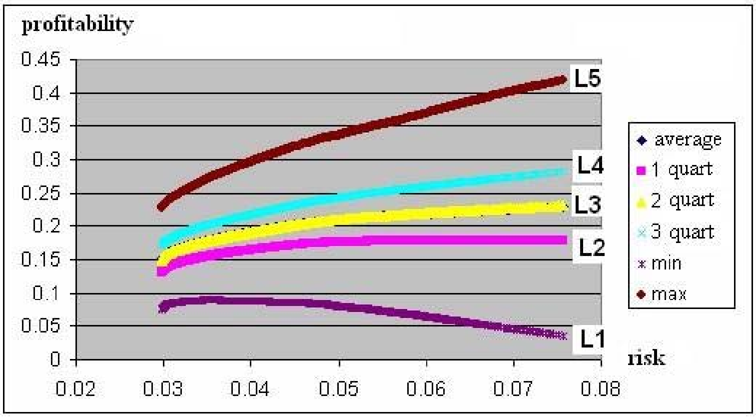
Figure 1. "Standard deviation – mean" portfolio set and efficiency line

If on Figure 1 instead of the portfolio as a random mean value the values of quartiles are introduced, then we would obtain respectively the sets of portfolio quartiles and the value of risk possibilities (Fig. 2 section a) and, analogically, the efficiency lines (Fig. 2 section b). The distinctive feature of these lines is the case when each point on a certain efficiency line $(l_i \subset L_i)$ corresponds certain levels of guarantee or reliability (here l_i and L_i are guarantees of 95 % and 5 % respectively):

$P\{\xi \geq l_5\} = 0.05$, $P\{\xi \geq l_4\} = 0.25$, $P\{\xi \geq l_3\} = 0.5$, $P\{\xi \geq l_2\} = 0.75$, $P\{\xi \geq l_1\} = 0.95$.



2a) Set of all quartiles – standard deviation portfolios



2b) Efficiency lines

Figure 2. Set of all quartiles – standard deviation portfolios and efficiency lines

3. Economic Aspects of Developing Chains of Transport Infrastructure

Level of the modern scientific-technological advancement requires radical changes in the society's attitude towards efficiency of social-economic measures designed for the development of the specific branches of material production and assessment of their functioning, and transport in particular. Currently, the choice of one possible alternative investment into development of infrastructure is often predetermined by personality and lobbyist practice instead of invoking the comparative theory of economic efficiency. Selection of the European level projects is often based on typical methods applied for the assessment of investments and economic efficiency of modern technology.

Consequently, assessment of objective integrated investments into public transport sector as a very specific branch of economy should necessarily be evaluated as multiple indicators affecting different spheres of community, and the final solution should be drawn when all multi-criteria indicators are well appraised.

Investment projects' efficiency according to the description given in the Automobilių kelių investicijų vadovas – Investment [Guide, 2006] and [Guide to Cost-Benefit Analysis of Investment Projects, 2008], is a category reflecting a project's conformity to the goals and interests set by its participants.

The general scheme of the investment project efficiency consists of the two stages. In case of the transport infrastructure projects at the first stage general indicators of the project efficiency are estimated enabling to make an aggregated economic assessment of possible variants of the projected decision, the so-called commercial efficiency. Evaluation of the commercial efficiency is carried out only in those cases when the project is considered to be of great value to the society. Evaluation of a possible financing scheme, revision of the investors' list as well as assessment of the financial possibility of the project implementation and its efficiency are carried out in the second stage. With the investment projects run by the State it is recommended to apply complex analysis for their evaluation.

Based on the EU methodical recommendations and the Lithuanian Manual for Road Investments the system of criteria indicators for evaluation of road and railway projects' efficiency have been set, comprised of:

1. Integral effect (E integr.) – the total of the discounted (given for a certain period of time) effects for the entire period of the project life cycle;
2. Profitability Index (PI) – ratio of the sum of diverse results and the present costs to the amount of investment;
3. Internal Rate of Return (IRR), i.e. a fixed discount rate over a certain period of time that makes the sum of the diverse results and the present costs are equal to the sum of the given investments;
4. Payback period depending on discounting – a minimum period of time from the start-up of the project implementation beyond the limits of which the integral effect becomes and remains positive;
5. Integral costs (IC) – the sum of the costs over the entire period of the project life cycle.

Solution of the optimised transport tasks with the view to onetime costs of investment into road and railway transport infrastructures for building connections with logistics centres and terminals (reconstruction, major repairs, etc.) as well as cargo flows (by roads and railways) is very important when choosing the most economically rational criterion: "minimum integral costs", meaning:

1. Investments made during the construction period (reconstruction and others) – KI;
2. Investments that are needed for the execution of the planned reconstruction works, to forward or to renew a technical road project (if any) during the accounting period of its operation – KR;
3. Investments into road or railway transport at the initial stage of the subject operation – KID;
4. Additional annual investments into road or railway transport to meet the yearly increase in the regional transport needs – KP;
5. The scope of community expenditures on redeeming of valuable lands to make implementation of road and railway projects possible – KL;
6. Value of circulating funds which conforms yearly production and consumption on the roads, i.e. in the state of "freeze in" – KF.

The first two indicators of onetime costs (KI and KR) that in the investment road and railway projects indicate investments into construction (reconstruction) works are always well considered. The value of these indicators is assessed for each variant of transport tasks in accordance with an estimated value.

The third indicator (KID) – investments into road or railway transport that are necessary for performing cargo carriage at the start-up of the exploitation, and the recommended calculation could be made according to the equation:

$$K_{oa} = \frac{A}{T_a}\left(\frac{Qo}{q_c \beta\gamma} t_{pr} + \sum^{i} \frac{P_{oi}}{v q_c \beta\gamma} \neq t_n\right), \tag{1}$$

where

A – comparative investments into units of transport means and a company's infrastructure for the region's one recorded automobile or van;

T_a – exploitation period of one unit of transport in hours within duration of one year;

t_{pr} – mean duration of outage of a transport unit in hours wasted for its loading in one voyage period;

Q – general size of carriage by roads or railway in tones within one year period;

t_n – loses sustained due to outage at the crossroads, railway crossings, and boarder crossings;
P_{oi} – annual turnover of cargo carriage by road or railway transport within one year period to the road or railway type, t/km;
i – number of road and railway types in a region;
v – technical velocity of a cargo transport on a main infrastructure roads, km/h;
q_c – mean nominal load of one transport unit in tons;
β, γ – run and load coefficients of transport units.

The size of space allotted for warehouses, logistics centres and other premises under construction is estimated according to the amount of loads in inventory:

$$F = \frac{q^1}{k\delta}\left(m^2\right), \tag{2}$$

where
k – coefficient of the useful storage place;
δ – loading rate per one square meter of the useful storage space (in tons per sq. m).

Hence the investments into the construction of warehouses, logistic centres and other premises should be calculated as follows:

$$K_{ts} = S_1 \frac{q^1}{k\delta} + S_2 q_2, \tag{3}$$

where
S_1 – mean construction costs of one sq. meter of a public warehouse;
S_2 – construction costs of a special-designed warehouse (refrigerated, for storing hazardous goods) per one ton of load.

Amount of the annual loss due to the increased need for circulating asset (K_n), which is conditioned by the need to accumulate load stores in case of seasonal or traffic constraints (road blockades, institutional actions – Latvia, Russia) when some roads are not used, is calculated dependent on the duration of outage defined by equation:

$$K_n = \frac{K_v Q}{12}, \tag{4}$$

where
Q – total amount of the projected annual material resources, in tons;
K_v – costs of one ton of goods in accumulated stocks.

When comparing possible variants for transport – related problem solution it is important to project operating (running) costs that are comprised of:

- costs of yearly repair and maintenance of regional roads or railways ($C_{tg.c}$);
- costs of intermediate road repair, assigned to one year service between the repairs (C_{tgp});
- costs of yearly cargo carriage in each variant under comparison (C_{tper});
- public (external) losses due to traffic accidents (C_{tken});
- public (external) losses due to irregular traffic flows (C_{treg}).

The costs of yearly road or infrastructure connection repairs and maintenance may be determined, irrespective of traffic intensity and volume of carriage (because these costs compared to others are relatively low), by applying calculation normative or on the grounds of perennial statistical data.

Similarly the costs of yearly intermediate road or railway connection repair may be estimated.

The costs of yearly cargo carriage in each possible variant of road or railway connection construction (reconstruction) under comparison may be determined as to their component parts: drivers' salaries and extra-payments (C_{tat}), variable costs (C_{tkin}), fixed costs (C_{tpast}), taxes and charges (C_{tmok}), can be estimated by the equation:

$$C_{tper} = C_{tat} + C_{tper} + C_{tpast} + C_{tmok} \,. \tag{5}$$

However, estimation of one-time investments into labour resources necessary for the maintenance of different category roads or railways and for creating required state transport infrastructure is not enough. Aside from the labour costs that include workers' salaries, it is necessary to estimate additional operating labour costs, related to formation of social funds, improvement of working conditions, etc. Therefore the list of operating costs for separate variants under comparison will not be full without assigning additional operating costs for labour resources ($C_{t\,dr}$).

Hence, comparative economic evaluation of possible variants of investment project according to the criterion "minimum integral costs" should also include estimation of operating costs:

$$C_{tbendr} = C_{tgc} + C_{tgp} + C_{tper} + C_{tmok} + C_{tpapild} + C_{treg} + C_{t\,dr} \,. \tag{6}$$

Economy based grounding of the optimal choice from all possible variants when solving specific tasks of the transport sector, depends on the economic expedience of the constructed subject. The main factors of effective usage of investments become apparent in the process of solving the task of road or railway network development optimisation.

3. Conclusions

Development and implementation of the risk management system for the transport investments modeling will become a tool to attain higher efficiency and stronger security only in the case it is supported by an overall information on the reliability of the decision efficiency and the affect of the risk as compared to the usefulness of the decision.

At present for the evaluation of investments into the national transport infrastructure objects the standard assessment methodology is used. For the evaluation of investments assessment to the transport infrastructure main objects the comparative multiple criteria methodology with reference to state the transport development strategy must be used.

Among the most objective and practically applicable methods the method of "multistage dynamic model approximation" or the method of "several statistical sections" is most commonly used for estimating the total (integral) disposable and operative costs for all transport infrastructure needs of the region (its road, construction and maintenance of stationary buildings, etc.). The most optimal and objective results depend on the precise determination of total cost value parameters at each of their statistical section.

References

1. Automobilių kelių investicijų vadovas. (2006). Kaunas: VĮ „Transporto ir kelių tyrimo institutas“.
2. The Cohesion Fund 2000–2006. (1999). Application for Assistance. Environment and Transport. Council regulation (EC) No 1164/94 of 16 May 1994, Council regulation (EC) No 1264/1999 of 21 June 1999 and Council regulation (EC) No 1265/1999 of 21 June. European Commission, Electronic version.
3. Guide to Cost-Benefit Analysis of Investment Projects. (2008). Brussels: European Commission, Directorate General Regional Policy.
4. Kondratowicz, L. (2003). Identification of factors that determine location and functional structure of logistics centres – a comparative study. In *Report for Work Package 1. Networking Logistics Centres in the Baltic Sea Region* (pp. 103-117) Poland: Departament of Scientific Publications of the Maritime Institute in Gdansk.
5. Langley, J., Coile, J., Gibson, J. (2008). *Managing Supply Chain: A Logistics Approach*. Canada: Cerngage Learning.
6. Labanauskas, G. (2010). *Substantiation of investments into development of the prioritized overland transport infrastructure in Lithuania*. Vilnius: Technika.

7. Labanauskas, G. (2010). *Substantiation of investments into development of the prioritized overland transport infrastructure in Lithuania.* Vilnius: Technika.
8. Labanauskas, G., Palšaitis, R. (2007) Study of possibilities to establish regional transport terminal in Kaunas. *Transport,* 22(2), 118–121.
9. Markowitz, H. M. (1952). Portfolio selection, *Journal of Finance,* 7(1), 77–91.
10. Palsaitis, R., Labanauskas, G. (2008). Analysis of transport terminals network strategic planning. In Proceedings of the 8th International Conference "Reliability and Statistics in Transport and Communication", 2008 (pp. 216–219). Riga. Latvia: Transport and Telecommunication Institute.
11. Rutkauskas, A. V., Miečinskienė, A., Stasytytė, V. (2008). Investment Decisions Modelling along Sustainable Development Concept on Financial Markets, Technological and Economic Development of Economy. *Baltic Journal on Sustainability,* 14(3), 417–427.
12. Sharpe, W. F. (1963). A simplified model for portfolio analysis. *Management Science*, 9(2), 277-293.
13. Tobin, J. (1965). The theory of portfolio selection. In F. H. Hahn and F. R. P. Brechling (Eds.), *The Theory of Interest Rate* (pp. 3–51). London: Macmillan.
14. Vaughan, E. J. (1997). *Risk Management*. New York: John Willey and Sons, Inc.

Transport and Telecommunication, 2012, Volume 13, No 2, 108–122
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0009-5

A NEW APPROACH TO ASSESSMENT OF INFRASTRUCTURE PROJECTS ON URBAN TRANSPORT SYSTEMS

Daiva Griskeviciene[1], Algirdas Griskevicius[2], Ausrine Griskeviciute-Geciene[3]

[1, 2]Vilnius Gediminas Technical University
Transport Management Department
Plytines 27, Vilnius LT-10105, Lithuania
Ph.: +370 5 2370633. E-mail: griskeviciene.daiva@gmail.com, griskevicus.algirdas@gmail.com

[3]Department of Urban Engineering
Sauletekio av. 11, LT-10223, Lithuania
Ph: +370 67109752. E-mail: ausrine.griskeviciute@vgtu.lt

The scientific analysis of currently used assessment principles of the development on urban transport systems; subsystems on vehicles, passenger and freight transportations, special public services, pedestrian and bicyclists has been carried out. Each subsystem needs technical infrastructure, the set of informational and traffic control means. Moreover quantitative and qualitative development of transport infrastructure is necessary for appropriate operating of whole communication system. Unfortunately an increase in the level of automobilization, growing transport flows in urban territories and decreasing investment for the development of transport infrastructure are the main barriers for urban development. An uncontrolled increase in automobilization changed the character of the usage of urban territories, urban structure, stimulated the process of agglomeration and formed new problems.

The results of expert evaluation and statistical analysis highlighted the influence of each subsystem on the sustainable development of whole urban transport system by technical, traffic safety, social-economic, environmental and other specific aspects. Objects of technical infrastructure that should be treated as infrastructure of urban road transport system were identified. The results of statistics analysis allowed determine features of separate objects necessary to evaluate; assess and adjust separate stages, key principles and quantitative and qualitative criteria of assessment of the development on urban transport systems infrastructure.

Keywords: sustainable development, urban transport systems, project assessment, statistical analysis, expert survey

1. Introduction

During the process of global integration the number of citizens covering large territories in cities constantly increases. Problems of urban development are becoming relevant. Therefore general urban policy determining main directions for urban development is a complicated and integral part of general policy on state territorial planning and development. Environmental, economic, demographic, planning, technical, managerial and other factors have an influence on complicated, multifunctional processes of urban development. The effect of these factors is usually methodologically assessed in three main aspects: economic, social and environmental. The cohesion of these aspects is the frame for sustainable urban development. Assumptions for sustainable development have to be regularized in planning documents. Local authorities as decision makers have to consider the requirements of territorial planning documents. This principle has to be adopted in the process of strategic planning and implementation of the development of urban transport systems.

One of the most important problems in the whole system of planning is that the connection between strategic planning and territorial planning is rather week. Territorial planning has no official methodology for determination of public infrastructure development trends and opportunities defined. The solutions of valid territorial planning documents partly determine the directions for development of separate cities and other urban territories, and also the necessity of modernization and development of technical infrastructure. Contrary strategic planning uses principles for the definition of evaluation criteria and results in order to determine specific development trends of infrastructure usually without the correspondence to the solutions of territorial planning documentations. In the context of sustainable planning, in order to develop relevant public, and also transport infrastructure, ensuring accessibility and availability, secure performance, in the same time avoiding negative impact to the environment and society, it is necessary to create a determined and unified model of development on transport systems infrastructure [7, 9].

This article presents the scientific approach for the creation of theoretical model to assess the development of urban transport systems' infrastructure in Lithuania.

2. Current System of Planning

The methodology that is recently put into practice is being developed over the last 12–15 years. After the planned economy period, the rules, standards and regulations of design and construction are newly developed. They relied on the basis of the pre-existing documents and the newly created laws of independent Lithuania. The methodology and procedures of development of programs and preparation of investment projects and assessment of them started to be created anew. Due to extremely difficult economic conditions as the country regained its independence, the state funds and the European Commission‘s technical/financial assistance have been directed to implementation of major ex-ante studies and investigations of transport communications and preparation of investment projects. The following were the projects of the international significance of reconstruction, modernization and development of separate elements of General Trans-European network in the territory of the Republic of Lithuania: on the highways, rail roads, international airports of Vilnius, Kaunas, Palanga, and the state seaport of Klaipėda. The state has given priority and partial funding to major projects. It is important that together with the reconstruction and modernization of transport arteries of international significance, preparation of their investment project and multidimensional reading at the state level and the European Union (EU), the regulations for the design and construction with their procedures which are applied in the EU have been validated in Lithuania. Technical support that has been accompanying the implementation of these innovations made it possible to absorb these principles quickly and apply them more widely including all planning and design activities of inside objects.

New investments for urban transport infrastructure have not been allocated for a decade. Local authorities of urban territories could only maintain the existing infrastructure and ensure communication of population at the minimum. The problem started to be solved in 1991 while implementing financial support of the EU through the PHARE program. The development and improvements in the level of transport systems on a national scale is inseparable from the level of allocated investments depending on a national policy towards the modernization and development of the transport sector and available possibilities. Having determined the problems of the sector, having formulated the trends and objectives for the development of the whole transport sector and different transport modes, the concrete projects of transport infrastructure are evaluated one by one. The aim of this evaluation is to determine the input of each project to achieve the planned objectives of the sector.

Current trends of development on urban transport infrastructure show, that along with the development of urban areas and decrease in the height of building in the big cities of the country, the integration task arose outside formed population centres. The priority is given to the transport infrastructure projects that meet sustainable development principles and are designed to 1) construct missing streets or roads of bypasses in urban areas and 2) reconstruct the intersections for the free movement 3) modernize the traffic control in the formed part of city ensuring priority passage to public transport and arranging intersections of highways and streets, 4) reconstruct bridges over rivers and viaducts through the railways, 5) modernize and develop urban radial arteries and exit roads from cities 6) assimilate and develop underground space and new buildings for car parking, 7) develop existing and assimilate modern infrastructure for internal communication of the city and communication with the external transport system [2, 10, 15].

Figure 1 shows that the current system of strategic planning consists of three levels. Comparing with other EU countries financial support plays a great role in the process of planning of whole transport sector, but the process of assessment of transport infrastructure development is not so clear. This can be illustrated by the correlation between the stage of strategic planning and the implementation of separate projects. Priority projects are being identified during the stage of strategic planning (ex-ante assessment). Usually these projects are selected after the specific order – to comply the expressions of strategic criteria or preliminary calculated economic and financial criteria without paying more attention to detail expression of social, environmental or other aspects. More detailed evaluation usually is prepared after the selection during the beginning of the implementation stage or sometimes together with technical designing. This principle is not correct because priority projects can describe different type of transport infrastructure, have different objectives and different tasks in the aspect of national level but still have same importance in the aspect of local level. Moreover the system of strategic planning still does not correspond to the system of territorial planning. Priority investment projects are being selected according to the criteria that meet the requirement of strategic documentations of international and national level. Basic objective for impact assessment on solutions is often ignored as guiding principles of one-day benefit. Besides, practice of 10–15 years shows that General plans determining trends of more or less sustainable development of urban territories started to be prepared quit late comparing with strategic development documentations. Therefore this was a reason to ignore requirement of territorial planning out of the selection and assessment of priority investment projects. Only during the last programming period of 2007–2013 the implementation of territorial planning documentations was included in the financial mechanism of the EU support. Therefore it is widely debated to improve the system of planning, consultation and development in the sphere of new forming solutions of territorial development in the country. However more progressive and developed countries experience these problems as well. Although they have more practice, they similarly form planning objects to strengthen transport sector [2, 5, 9, 10].

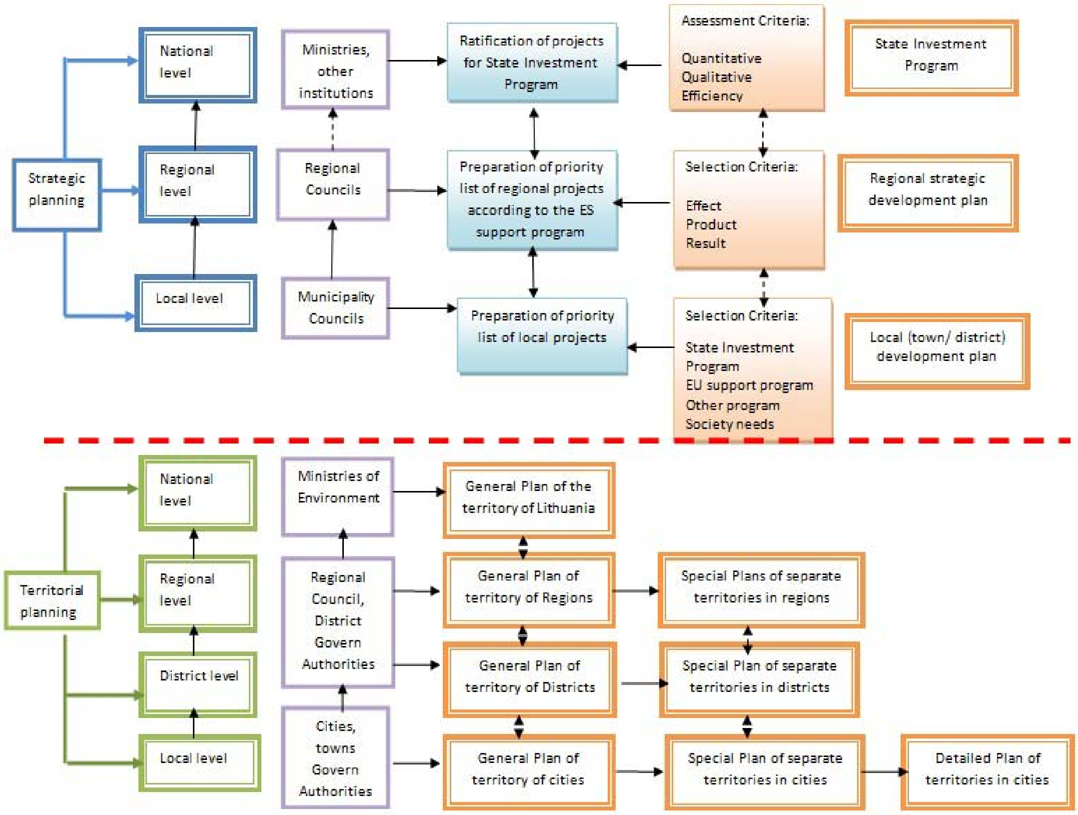


Figure 1. Current system of strategic planning of investment for transport sector in Lithuania

In addition to basic uncertainties of common system of transport development planning, these urban problems can be attributed:

- ✓ ***Urban transport infrastructure systems apply for the definition of public infrastructure***; Transport, social infrastructure and utility networks are often named as components of public infrastructure. However, such a description is not accurate, since the communication system operates in a specific urban area, which is influenced by various factors that may have no impact on other parts of public or social infrastructure. Generally transport system is recognized as an aggregate of pedestrian, passenger and vehicle means and necessary technical infrastructure, information and traffic regulations mean.
- ✓ ***Development of urban and rural road transport systems infrastructure is not separated;*** Generally urban and rural road transport systems are different. Key factors influencing on differences and similarities of urban and road transport systems are as follows: technical infrastructure; transport demand and possibilities; transport modes; occupied area and space for transport needs; environmental, social – economic, financial and other impacts; system administration and management.

- ✓ ***Not all projects for assessment of development of transport systems infrastructure in individual cities and towns are prepared***; the existing experience on this process shows that in most cases the assessment is carried out on those items, the development of which is provided by finance from EU funds, as required by EU legislation. The development of transport infrastructure funded by local government is validated with detailed plan or technical design, where necessity for assessment of object development is not defined.
- ✓ ***There is no uniform system for urban transport systems infrastructure projects' assessment***; optimal effects can be expected only if basic solutions are adequately motivated. According to the Governments it is authorized to interpret assessing impacts of projects solutions. Since there is no basic definite methodology the effects of interpretations are experienced in various socio-economic, engineer-technical and natural environments inseparable from each other and having additional and continuing connections. Therefore if problem occurred in one sphere (environment), it can cause more negative short-term or long-term effects.
- ✓ ***The organization of common urban transport systems infrastructure development is not regulated;*** throughout legislation system of the Republic of Lithuania, today there is no regulation on public and social and transport infrastructure development in urban areas. The legislature has not adopted the law that complexly regulates the infrastructure of urban areas. The Land Law of the Republic of Lithuania, the Spatial Planning Law of the Republic of Lithuania, and the Construction Law of the Republic of Lithuania governs individual developmental stages of infrastructure in urban areas, but does not define a clear system, entities that organize and participate in the development of urban infrastructure, their rights, duties and responsibilities [1, 2].
- ✓ ***A large shortfall for the development in urban public infrastructure;*** in general the infrastructure development in urban areas is actually being funded by local government budgets and by budgets received and accumulated in funds of municipal urban development, i.e. by budgets of building legal and natural persons in accordance with individual funding agreements with the municipality. Current practice shows that the total of own funds is not sufficient for upgrading and developing urban infrastructure. Due to uncertain use of finances from local, state and private sectors in urban sustainable development, the opportunity to receive the EU financial support is more and more often used.
- ✓ ***Complicated process for taking land for public needs***; current practice shows that property rights are restored in the planning documentation in planned streets and in areas of public infrastructure, aggravating land use for development of infrastructure in residential areas by that, as these areas has to be bought out from private owners or taken for public needs. One of the main reasons is unclear regulation of redeem ability of state-owned land. At present, the territories where transport infrastructure development is planned are not considered as redeemable state-owned land, so after restoration of property rights in these areas, the land must be redeemed or taken for the needs of society, and compensated for the market price. However, in residential areas, especially in large urban areas, a great shortage of vacant state-owned land is already present. Everything is more complex due to the fact that administration of state-owned land is yet not transferred to municipalities [8].

The selection of alternative investment projects of development on transport infrastructure uses number of definite criteria that are common for different types of objects. Usually quantitative criteria as technical parameters, economic or financial indicators are used; therefore selected projects have to be prepared and assessed avoiding qualitative descriptions that cannot be evaluated in monetary value (social, environmental impacts, etc.). Moreover identification of values of separate criteria affect the identification of project's impact factors and targets, prediction on variation, identification and management of project risk types. Therefore different types of criteria cannot be used equally for the assessment of different type of development projects. This can be illustrated by the example of urban and rural road transport infrastructure. The procedures and the requirements used for the international projects of roads were applied to finance, develop, validate and evaluate urban investment projects. The changes, which would determine the assessment of urban transport projects in comparison with rural road investment projects, were not assessed methodologically. Generally applied methodology for development, justification, evaluation and ranking of the projects could not assess the specificity of urban transport systems.

The assessment methodology of urban transport investment projects is more complex in nature because it is related to a series of factors of social, economic, urban development, technology development, financial feasibility, which depend on the macroeconomic and the financial capacity of local authorities, the economic-social needs of urban population and their realized purchasing power, stages of urban development and further planning. A complex set of factors is included in the author‘s investigations, which have been carried out with the purpose, in accordance with the tendencies of development of infrastructure of present urban transport systems in Lithuania and other countries, to develop the model for assessment of planning and design of infrastructure [6, 7].

3. Methodology for the Assessment Model

The gap of clear methodology used for the assessment of development on urban transport systems infrastructure has been filled with the evaluation methods for investment projects of rural roads and other transport sectors. In order to determine the importance of urban transport systems infrastructure to territorial planning and to form development trends, development necessity must be assessed. For this purpose development projects are being prepared.

In order to create theoretical model for the development of urban transport and communication systems infrastructure the expert survey has been carried out. Delphi method has been used for the survey. This method is a qualitative method of forecasting. Delphi method has a lot of forms and is still being developed. This method is useful when in order to determine common decision or propose other alternatives, a panel of experts communicates. Therefore there are few stages of survey usually carried out. Delphi strategy recommends to survey 10–50 experts. The results of the survey do not depend on the size of panel, rather on experts' competence.

The aim of this questionnaire survey is to determine and to systemize the approach of qualified experts performing in the spheres of territorial planning, planning and designing of transport and communication systems and working in public and private sectors. Two-stage survey has been carried out. The first-stage questionnaire was formed seeking to determine actual principle of the substantiation of urban transport and communication systems. Later on, systemized results were returned to a panel of experts for the assessment of the averages of first stage answers. The results were filled with the experts' comments and notes. In order to ensure equity the anonymity and the confinement of dominant influence was guaranteed.

Performing in the spheres of preparation, evaluation and organization of projects on urban and road transport and communication systems and territorial planning 55 experts were invited to participate in this research. Experts were chosen according to their qualification and practical working experience. 40 of invited experts accepted to participate in this research. Till the end of this survey 25 experts participated. According to the small number of official institutions performing evaluation of investment projects and also to recommendations of Delphi strategy it was concluded that this number of experts was sufficient for this survey to be reliable.

During the first stage, 16 questions about substantiation and evaluation of urban transport and communication infrastructure were presented. First 6 questions included general information about a concept of projects' substantiation, and urban transport and communication infrastructure. Other questions were more specific, concerning assessment of separate aspects and criteria used for theoretical model. For general questions the principle of marking the best answer was used. For specific questions the graduation (weighting) system assessing a priority of answer was used: 1– not important; 2 – low importance; 3 – average importance; 4 – very important; 5 – no opinion about it.

The results of accomplished expert survey were systemized in order to select the priority factors and characterizing criteria of different aspects, which should be used in the assessment of the development on urban transport infrastructure. For this purpose method of statistical analysis – Cluster Analysis – was used. Basic concepts of Cluster analysis are Similarity and Dissimilarity (distance): distance indicates how many objects are distant from one another (different); similarity shows the proximity of objects. Similar objects belong to the same cluster, remote objects – to different clusters. Crucial moment of Cluster analysis is metrics or in other words – the selection of proximity measure. This measure determines the final division of objects into the groups. Since the answers of expert surveys include large database, authors have used K-means method of Cluster analysis. This method requires specifying the desired number of clusters and therefore it is faster than other method of this analysis [10].

Authors have chosen 4 clusters according to the weighting system, which has been chosen in the stage of Delphi method: 1 – very important; 2 – average important; 3 – low important; 4 – those, which are not included/ weighted of separate experts. In order to reach more detailed results cluster analysis are repeated for each type of urban transport systems' infrastructure objects in order to compose clearer priority list of factors, which need to be included into the assessment of urban transport infrastructure investment projects, and also to create clearer distributions of factors, which need to be expressed in monetary values.

Due to a lack of funds, economic aspect plays a great role in the assessment of investment projects and also in the whole stage of alternative selection. The rationale of transport systems infrastructure development is often associated with the received economic benefit; due to this many of the criteria must be numeric (monetary value). But not all important criteria (e.g. strategic, social and environmental aspects) can be placed in numeric (monetary) form. In order to determine this, tests are performed and in accordance with specific procedures a numerical value for certain criteria is established. Depending on their composition or method for determining the monetary value, the results on project evaluation can be very different. For example, presently, for the economic evaluation of projects prepared for getting financial support from the EU funds Cost-Benefit Analysis (further – CBA) are widely used. This method has a certain level of universality and helps with evaluating factors having no monetary value. CBA deals with a quantitative and (or) qualitative evaluation; social costs are determined, which also take part in justifying project efficiency in terms of traffic safety as well as considering technical and financial aspects. Together with CBA results, the economic values such as Internal Rate of Return, Net Present Value and Benefit/Cost Ratio are determined. Table 1 shows common effects and elements of CBA used in the assessment of transport infrastructure in the EU countries [1, 4, 6, 7].

Table 1. Common effects and elements of CBA used in the assessment of transport infrastructure in the EU countries

Groups of main effects	Elements
Infrastructure costs	Construction costs Costs for object maintenance operation, repair and administration Investigation/ planning designing Land take Residual value
User benefits	Passenger transport time saving, Vehicle operating costs (further-VOC) Benefit to goods traffic
Externalities	Traffic safety, noise, pollution – local/ regional attitudes Climate change Local/regional/global air pollution Water pollution Land use Urban functioning/ renewal
Other	User charges and revenues Disruption from construction

Table 1 confirms that monetary values of such external factors as Travel time, VOC, Traffic safety can be calculated by the help of CBA. Environmental impacts as noise, air pollution, land use, etc. usually have non-monetized values, but these factors usually are quantitatively expressed. Besides economic evaluation, social one is used where the effect of investment projects on the public is determined. Then the results of social evaluation are used for evaluating the project taking into account a strategic aspect, i.e. to describe the need for the project, to justify technical solutions and road safety measures, to calculate the number of created jobs.

The results of economic, social and environmental or other evaluation can be combined in order to get clearer view of alternative projects and choose those projects which solve bigger problems and create higher value-added to society and the country. Therefore authors suggest modifying the CBA method by adding more specific components using the help of Multi-criteria method (further – MCA). The results of expert survey will help to find out, which substantiation aspects can be used for the composite work of CBA and MCA [11, 12].

The next chapters deal with preliminary results of accomplished Expert survey and Statistical Analysis.

4. Main Directions of Investigation

Due to existing problems in the development of urban transport infrastructure, main steps of suggested project assessment model of development on urban transport systems infrastructure are formed and presented for expert evaluation (Fig. 2).

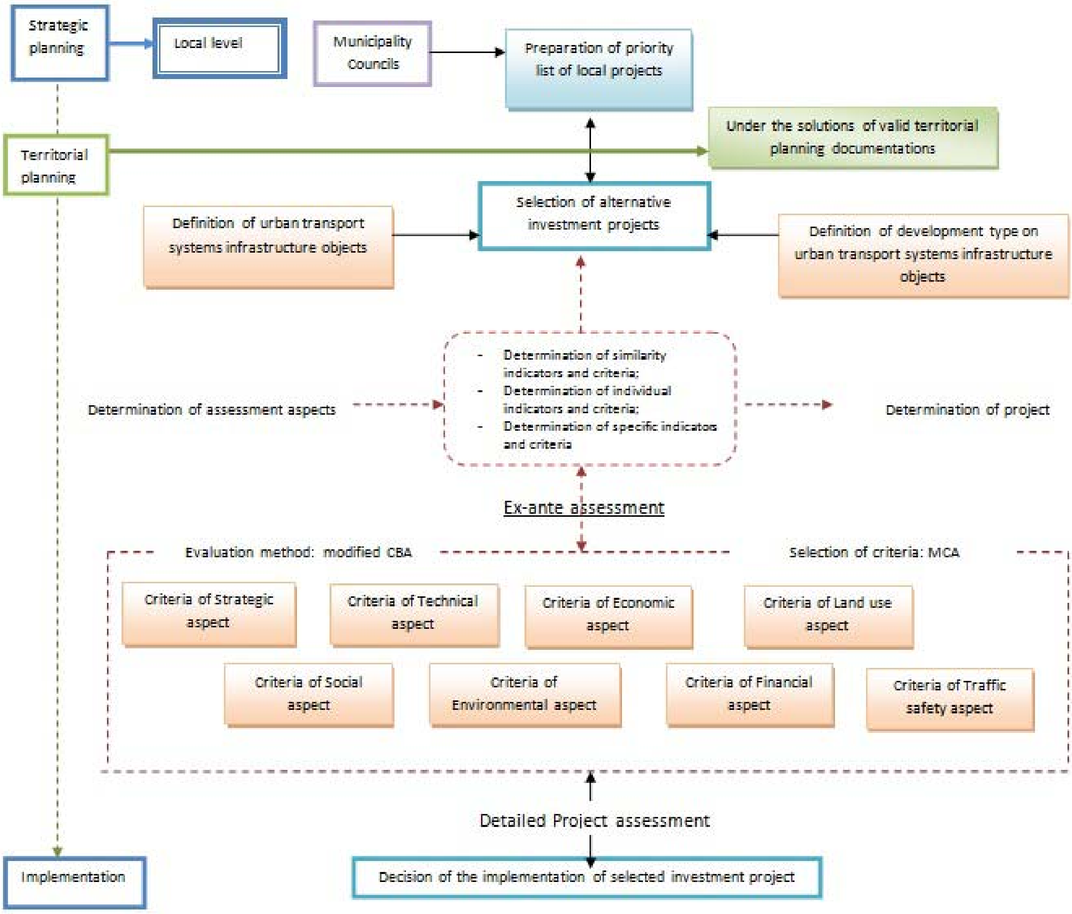


Figure 2. Main steps of suggested project assessment model of development on urban transport systems infrastructure

The first step. Currently, existing legislation in urban sustainable development areas provides only abstract definitions on urban transport systems infrastructure. However, in order to implement for the principles of sustainable development, it is necessary to accurately identify and define the objects that should be allocated to transport infrastructure. In accordance to the number and types of urban spaces of functional transport systems and subsystems and other features, authors have systemized infrastructure groups of urban transportation systems and proposed them for expert assessment (see Table 2).

Table 2. Objects of infrastructure of surface transport and communication systems [5]

Environmental means (noise isolation systems, mounds, road pavement, accumulation and clearing of surface water, bio-barrage, greening, premise protection from noise, etc.)
General communication network (streets, roads, parking lots, paths, territories of transport service, etc.)
Main nodes (all level crossings, pedestrian/ cyclist passages, squares, etc.)
Public Transport infrastructure (route network, rail transport lines, PT traffic lanes, stations, depots, platforms, final nodes, stops, etc.)
Traffic regulation and control means (traffic regulation system with centres (traffic-lights, traffic control devices, variable electronic signs, pedestrian. cyclist passage switches, pavement signing, etc.), Park and Ride system, informational system with centres (display panels, external screens, stock tickers, etc.)
Traffic safety means (traffic watch systems (traffic flows measurement devices, traffic detection cameras, etc.), safe traffic providing systems (speed limiting devices, prominent pedestrian/ cyclist passages, safety islands, boxes, safety mirrors, road reflectors and blinking footprint, etc.), pedestrian, calm traffic zones, etc.

The second step. For determination of necessity to develop urban infrastructure transport systems there is need to define the concept of development and to identify which types or stages of development need substantiation. For that reason, authors have systemized infrastructure types of urban transportation systems and proposed them for expert assessment (see Table 3).

Table 3. Kinds of land transport and communication infrastructure object development [5]

Kinds of surface transport and communication systems infrastructure object development
Maintenance of object
Overhaul of object
New construction of object
Reconstruction of object

The third step. In the scientific literature few specific concepts related to the implementation of development projects are available. Often, definition of project assessment and project substantiation are equated, therefore it is important to find out whether these concepts can be aligned with each other. In addition, it is necessary to establish whether substantiation/assessment of urban transport systems infrastructure development projects must be broken down into separate phases. Table 4 shows conceptions and stages of project substantiation/assessment.

Table 4. Conceptions and stages of Project substantiation/assessment [5]

Conceptions
Project substantiation
Project assessment
Stages of project substantiation/assessment
Only feasibility study
Only investment project
Feasibility study and investment project

The terminology used in Table 4 is officially defined in the legislation of the Republic of Lithuania. The conception of Project Substantiation is defined as the evaluation of expedience of development of the object (repair, construction, reconstruction) in different aspects. The conception of Project Assessment is defined as a systematic and objective determination of suitability, usefulness, efficiency and utility of the project which is planned to implement or has been implemented. Usually project substantiation/ evaluation consist of several separate stages. Feasibility study is a wider concept and is defined as an analysis of alternative object development solutions and substantiation of the most optimal alternative variant in different aspects. An investment project is substantiation of implementation of a certain variant of the object development in the economic and other aspects.

Another important question is to find out what approaches should be included in assessment of development projects on urban transport systems infrastructure. In common structural approach, all projects of communication systems in urban infrastructure development are alike because they share a certain structure, each has a well-defined objective and reachable result, and each project requires certain resources (technique, energy, raw materials and human resources). These resources are always limited so rational use of them is one of the major problems in project implementation. In terms of feasibility, transport systems infrastructure development projects also distinguish in the fact that object's development (construction, reconstruction, etc.) and object's duration of operation is relatively long, and the implementation of a project requires a significant capital.

In Lithuania, there is no official methodology for the assessment of development on urban transport systems infrastructure, for identification of main dimensions; authors used the experience of foreign countries and current rural road transport infrastructure development reasoning techniques and recommendations. Authors have systemized groups of urban transport systems and separate criteria that influence necessity for object development [2, 9]. Table 5 shows main attitudes on Project substantiation.

Table 5. Main attitudes of project substantiation [5]

Main attitudes of project substantiation
Strategic *(describes need and necessity of the development)*
Social *(describes the efficiency of the development to users – publicity)*
Economic (*describes economic benefit/ damage to users – publicity*)
Financial (*describes financial benefit/ damage and input of separate financial sources to total investment*)
Technical (*describes implementation of project according to technical requirements*)
Traffic safety (*describes influence of project on improvement of traffic safety*)
Environmental (*describes negative/positive influence of project on environment*)
Land use (*describes influence of project on sustainable land use*)

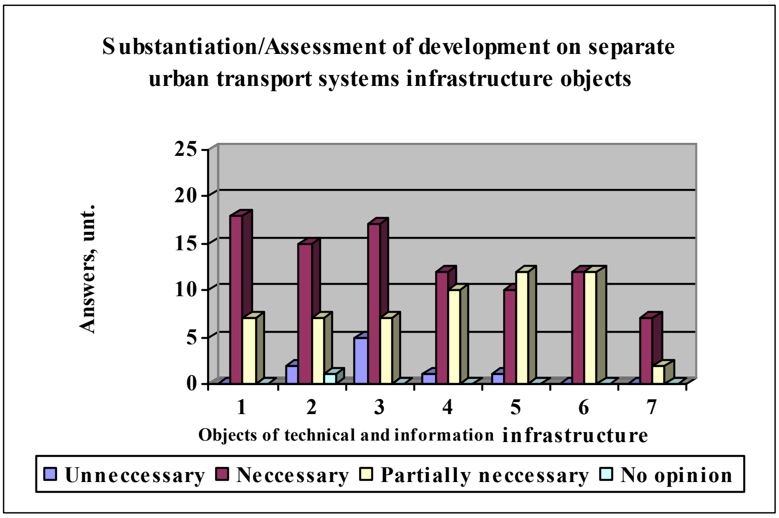
Also in order to determine which urban transport systems need quantitative (financial) or qualitative factor values for infrastructure development, authors have systemized typical criteria of individual grounding aspects and proposed them for expert assessment. In the next chapter expert evaluation of the initial tentative results is provided.

5. The Tentative Results of Investigations

Initial data from expert evaluation showed that the project assessment and project substantiation is usually regarded as terms with equal value (70 percent of experts).

Substantiation/assessment linkage of a development project on urban transport systems infrastructure with the planning stages led to dispersal of experts' answers. 40 percent of experts pointed out that project substantiation/assessment should be associated with each planning stage. Systemization of expert's results showed that only 50 percent of experts associate project substantiation/assessment with technical designing and most – 70 percent of experts – with special territorial planning.

Systemizing results of experts evaluation related to assessment of development project on urban transport infrastructure, it became clear that it is necessary to prepare the substantiation of project development for all general communication network (70 percent of answers) and part of the network (30 percent of answers), for all main nodes infrastructure (60 percent of answers) and their part (30 percent of answers), only 10 percent of experts pointed out that substantiation for development of main nodes is not required (Fig. 3).

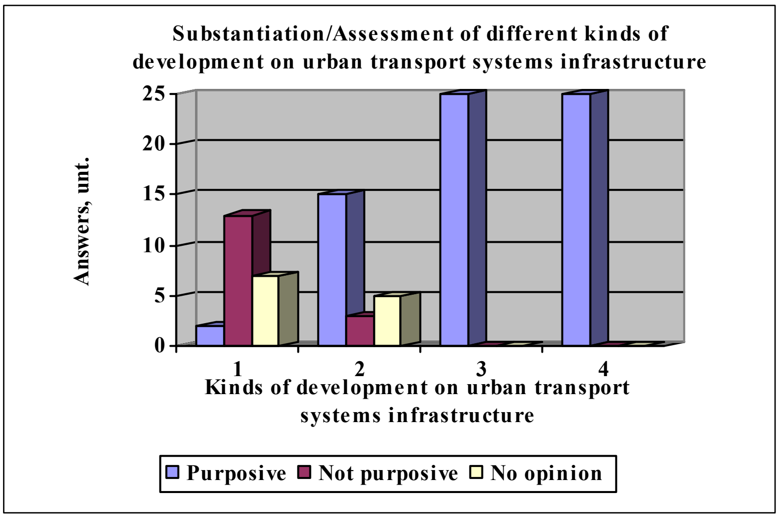


Objects of technical and information infrastructure: 1 – General communication network, 2 – Main nodes, 3 – PT infrastructure, 4 – Traffic regulation and control means, 5 – Traffic safety means, 6 – Environmental means, 7 – other (logistics)

Figure 3. Systemized experts' evaluation results related to substantiation of separate urban transport infrastructure development projects

As Figure 3 shows, for necessity to substantiate public transport (PT) infrastructure development projects 70 percent of experts were in favour, 30 percent of experts needed this for a part of the infrastructure, and 10 percent stated that the substantiation for the development of PT infrastructure is not required. The need of substantiation of traffic regulation and control and traffic safety development projects was presented for 50 percent of experts, 40 percent were in favour of necessity for substantiation of part measures, and 10 percent of experts pointed out that the substantiation for the development of traffic regulation and control means, and traffic safety means are not required. Substantiation for the development of environmental means is necessary, experts divided equally for development substantiation of all and part of measures. 30 percent of experts further noted that the rationale of development of logistics centres infrastructure is also necessary.

In evaluation of types of development on urban transport systems infrastructure, all the experts pointed out that for the reconstruction of facilities and construction of new facilities the substantiation must be carried out. 60 percent of experts noted that the substantiation is appropriate for major repairs of facilities, and only 10 percent of experts noted the appropriateness of the substantiation of the maintenance facilities (Fig. 4).

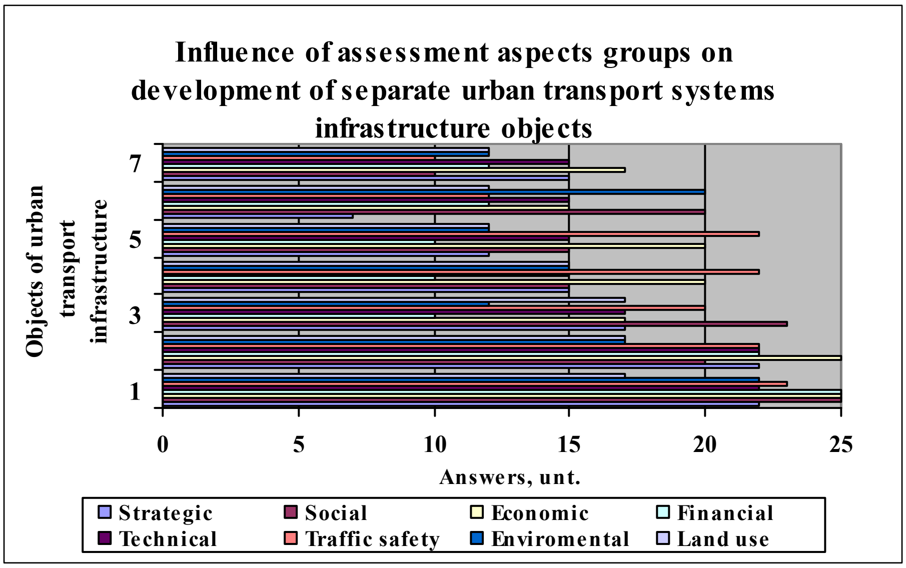


Kinds of development on urban transport systems infrastructure: 1 – Maintenance of object; 2 – Major repairs of object; 3 – New construction of object; 4 – Reconstruction of object

Figure 4. Systemized experts' results related to substantiation/assessment of different kinds of development on urban transport systems infrastructure

Evaluating of stages of development on urban transport systems infrastructure projects, all experts were for preparation of both feasibility studies and investment projects for the development of general communication network and main nodes infrastructure. 60 percent of experts have noted that the feasibility study and investment project should be prepared for the development of PT infrastructure, traffic regulation and traffic control means and traffic safety means, environmental means. 20 percent of experts pointed out that for the development of PT infrastructure, traffic regulation and control, and traffic safety means, environmental means, the preparation of a feasibility study would be sufficient, 10 percent of experts pointed out that for PT infrastructure, traffic regulation and control means, and traffic safety means, environmental means, it would be sufficient to prepare the investment project. One expert further noted that feasibility study and investment project should be developed only for major projects, as for small projects such implementation process is too expensive.

Evaluating the influence of transport systems infrastructure development on substantiation of urban transport systems infrastructure, it was noted that it is appropriate to substantiate the development of groups of urban transport systems infrastructure at least in part of aspects groups. In addition it has been noted that no new approaches were provided by the experts. Most attention was brought to substantiation of the general communication network development as follows: 91.25 percent of experts noted that the substantiation should include all assessment aspects. 86.25 percent of experts pointed out that all the groups need to be included in substantiation of the development of the main nodes: in this case the least responses were collected for environmental and land use aspects. The least attention was received for development substantiation of traffic safety means (58.75 percent of experts) and environmental means (57.5 percent of expert): in most of these cases, most answers fell for traffic safety, environmental and technical aspects, least – for strategic and financial aspects. For substantiation of PT infrastructure development most evaluations were collected for social, technical and economic aspects (Fig. 5).



Objects of technical and information infrastructure: 1 – General communication network, 2 – Main nodes, 3 – PT infrastructure, 4– Traffic regulation and control means, 5 – Traffic safety means, 6 – Environmental means, 7 – other (logistics)

Figure 5. Systemized experts' results related to the influence of substantiation/assessment aspects groups on development of separate urban transport systems infrastructure objects

Evaluating the importance of separate aspects, it is noted that any aspect has been associated with the development of urban transport systems infrastructure and it is appropriate to incorporate them into substantiation of separate transport systems infrastructure development. Systemized expert answers show that economic aspect (82.85 percent of answers) and the traffic safety aspect (78.57 percent of answers) were the most popular, least – the land use aspect (57.14 percent of answers). Figure 6 shows systemic percentage distribution of substantiation/assessment aspects groups of urban transport systems infrastructure development projects.

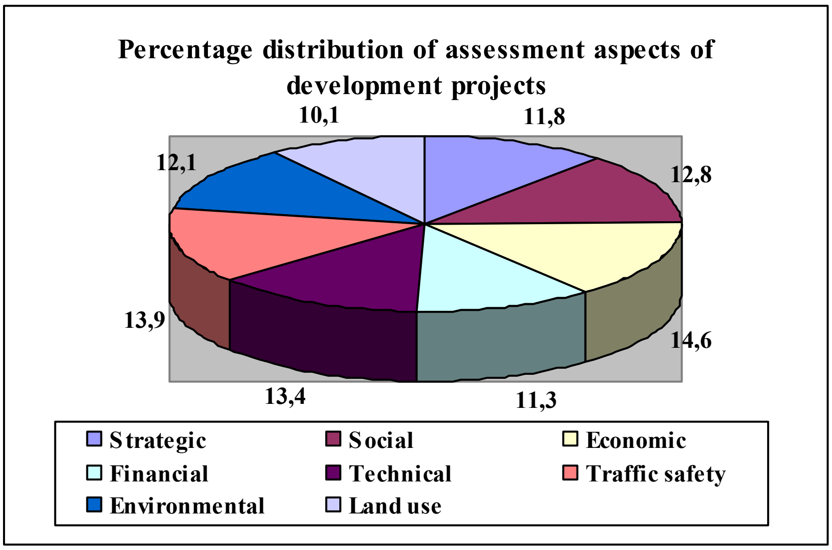


Figure 6. Percentage distribution of assessment aspects of urban transport systems infrastructure development projects

Figure 6 shows that percentage distribution of substantiation/assessment aspects is quite equal in all experts' answers: a significant difference cannot be excluded. This proves that all traditional aspects used in transport infrastructure development substantiation are important and have to be included in general substantiation/ assessment system. The determination of values of separate criteria can have influence on increase or decrease of relevance of one or another aspect.

Systemized initial results of expert survey have proved that criteria of the assessment of development on urban transport systems infrastructure can be separate as follows:

- ✓ Strategic aspect: 90 percent of experts noted that these criteria have most influence on substantiation of general communication network and PT infrastructure development, lower influence on substantiation of main nodes infrastructure development.
- ✓ Social aspect: 90 percent of experts have noted that all presented criteria are equally important for substantiation of general communication network and PT infrastructure development.
- ✓ Economic aspect: 80 percent of experts have noted that these criteria have most influence on substantiation of genera communication network and PT infrastructure development, 40 percent of experts noted that these criteria are important also for substantiation of traffic regulation and control means and traffic safety means development.
- ✓ Financial aspect: 70 percent of experts have noted that these criteria have most influence on substantiation of PT infrastructure development, less influence on substantiation of traffic regulation and control means and traffic safety means development.
- ✓ Traffic safety aspect: all experts noted that these criteria have most influence on substantiation of traffic regulation and control means and traffic safety means development.
- ✓ Technical aspect: 80 percent of experts noted that these criteria have most influence on substantiation of same general communication network, main nodes and PT infrastructure development.
- ✓ Environmental aspect: 80 percent of experts noted that these criteria have most influence on substantiation of environmental means, also general communication network and main nodes development.
- ✓ Land use aspect: all experts noted that land use criteria have influence on substantiation of all group of urban transport systems infrastructure development.

Systemizing initial results of Cluster analysis the list of priority criteria was formed. In order to ease the process of project selection 2–3 the most important criteria common for each type of grouped transport infrastructure objects were chosen for the description of each assessment aspect (see Table 6).

Table 6. List of priority criteria of main aspects of projects assessment

Main aspects of project assessment	Selected criteria	Expression	Description
Strategic	Compliance with strategic goals of regional development raised by local level institutions	Qualitative + quantitative	Distance, km Part in whole network, km, rate
	International/ state/ local level demand for development of object	Qualitative + quantitative	Distance, km Plots of land, m^2, ha Part in whole network, km, rate
Social	Impact on inhabitants employment	Quantitative	New workplaces, number Added value of one workplace, Lt
	Impact to inhabitants mobility	Quantitative	Distance, km Added value of one trip, Lt
	Impact on accessibility of public social services	Qualitative + quantitative	Distance, km Average value of service price, Lt
Economic	Economic benefit	Quantitative	Economy of Vehicle operating costs, Lt Economy of Travel time costs, Lt Economy of environmental costs, Lt Economy of social costs, Lt Economy of traffic safety costs, Lt Economy of land use costs, Lt
	Project payback time	Quantitative	Time, year
	Project risk	Qualitative+ Quantitative	Social, environmental, technical risk, etc. Overhead costs, Lt
Financial	Project investment	Quantitative	Budget sums, Lt
	Project income/ expenses	Quantitative	Sums, Lt
	Project effectiveness	Quantitative	Rate of return; Net present value of project, etc.
Technical	Complexity of technical solutions	Quantitative	Technical parameters Price of construction works, Lt
	Type of solutions	Qualitative + quantitative	Amount of project activities Amount of construction works Price of construction works, Lt Salary for project staff, Lt
	Structure and volumes of traffic	Quantitative	Type of traffic participators Average volumes, aut./h; ped./h; bcl./h
Traffic safety	Accident rate	Quantitative	Costs, Lt Economy of accident costs, Lt
	Impact on decrease of accident number	Quantitative	Number of Accidents per km; m^2
	Impact on the selection of technical solutions	Quantitative	Amount of construction works Price of construction works, Lt
Environmental	Impact on human health	Quantitative + qualitative	Economy of environmental costs (noise, air pollution, dusts), Lt
	Impact on aesthetic view of landscape	Quantitative + qualitative	Reduced plots in urban territories, ha Average price of plots in urban territories, Lt
	Impact on natural surroundings	Quantitative + qualitative	Reduced plots in surroundings, ha Average price of plots in natural territories, Lt

The continuation of Table 6

Main aspects of project assessment	Selected criteria	Expression	Description
Land use	Compliance with requirements of regulation on land use	Quantitative + qualitative	Total area, ha Built up area, ha Area for infrastructure, ha
	Impact on neighbouring land	Quantitative + qualitative	Occupied territories, ha Occupied build up territories, ha Occupied natural territories, h
	Necessity of land taking for public purposes	Quantitative + qualitative	Average price of plots in urban territories, Lt Average price of real estate, Lt Average price of plots in undeveloped territories, Lt. land, Lt

Table 6 shows that selected specific criteria still can be described by quantitative or qualitative expression. In order to modify CBA method, these criteria have to be express by monetary values. In this case method of MCA can play a great role choosing the right criteria for monetary expressions.

This primary analysis also proved that specific criteria of social and land use aspects together with criteria of environmental aspects have to be included into the economic evaluation. Main indicators of social-economic development of separate urban territories can be used for the calculation of monetary values. This stage of analysis will be presented more detailed in the next article.

6. Conclusions

During the process of global integration the number of citizens covering large territories in cities constantly increases. Problems of urban development are becoming relevant. Therefore general urban policy determining main directions for urban development is a complicated and integral part of general policy on state territorial planning and development. There is an important methodological problem in the design of urban planning and development for assessment, comparison and selection of development programs and plans and the investment projects. This gap has been filled with the evaluation methods of investment projects on rural roads and transport of other sectors.

In order to create theoretical model for the development of urban transport systems infrastructure the expert survey has been carried out. The aim of this questionnaire survey was to determine and to systemize the approach of qualified experts performing in the spheres of territorial planning, strategic planning and designing of transport and communication systems and working in public and private sectors. The questionnaire presented in this article was formed seeking to determine actual principle of the assessment. Due to existing problems in the development of urban infrastructure, main steps of assessment model were formed and presented for expert evaluation: definition of urban transport systems infrastructure objects; definition of development type on urban transport systems infrastructure objects; determination of key aspects and criteria for project substantiation. The results of accomplished expert survey were systemized in order to select the priority factors and characterizing criteria of different aspects which should be used in the assessment of the development on urban transport infrastructure. For this purpose method of statistical analysis – Cluster Analysis – was used.

The results of initial analysis have showed that all traditional aspects of assessment of development on transport infrastructure are important and have to be included in general system of project substantiation. The determination of values of separate criteria can have influence on increase or decrease of relevance of one or another aspect. When comparing the alternative projects and identifying the level of project's implementation need, social, environmental and other aspects that define the qualitative value of the project, also play important roles in the need for assessment. Identification of values of the separate criteria affect the identification of project's impact factors and targets, prediction on variation, identification and management of project risk types. For this detailed statistics the researches have to be carried out.

Since the rationale of transport systems infrastructure development is often associated with the received economic benefit; due to this many of the criteria must be numeric (monetary value). But not all important criteria (e.g. strategic, social and environmental aspects) can be placed in numeric (monetary) form. The suggested model of the assessment helps to mark necessary criteria of assessment aspects and modify CBA method in order to evaluate and describe more detailed social benefit of investment project on development of urban transport infrastructure. MCA method plays a great role choosing the right criteria for monetary expressions. This stage of analysis more detailed will be described in the next article.

References

1. Asensio, J., Roca, O. (2001). Evaluation of Transport Infrastructure Projects beyond Cost-Benefit Analysis. An Application to Barcelona's 4th Ring Road. *International Journal of Transport Economics*, XXVIII(3), 387–403.
2. Bivainis, J.; Butkevičius, A. (2003), Methodologic aspects of evaluation of state budget programmes. *Journal of Business Economics and Management,* 4(1), 53–61.
3. De Brucker, K., Macharis, C., Verbeke, A. (2011). Multi-criteria analysis in transport project evaluation: an institutional approach, in European Transport/Transporti Europei. *International Journal of Transport Economics, Engineering and Law,* 47, 3–24.
4. Eliasson, J., Lunderg, M. (2010). Do Cost-Benefit Analysis Influence Transport Investment Decisions? Experiences from the Swedish Transport Investment Plan 2010–2021. In Proceedings of European Transport Conference 2010 (25 p.). Glasgow, Scotland, UK. Available on the Internet: http://www.etcproceedings.org/paper/do-cost-benefit-analyses-really-influence-transport-investment-decisions-exper
5. Griskeviciute-Geciene, A. (2011). *Questionnaire survey of assessors/organizers/customers of projects of communication system infrastructure development working for public institutions and in the private sector of the Republic of Lithuania*. Vilnius, Lithuania, Vilniaus Gediminas Technical University.
6. OECD publication. (2001). *Report of the European Conference of the Ministers of Transport. Assessing the Benefits of Transport*. ECMT 2001: OECD Publications, No. 51789 2001.
7. OECD publication. (2008). *Report of International Transport Forum. The Wider Economic Benefits of Transport: Macro-, Meso- and Micro-economic Transport Planning and Investment Tools.* Summary and Conclusions. Discussion Paper No. 2008-6. Joint transport research center, Boston, USA. Available on the Internet: http://www.internationaltransportforum.org/jtrc/discussionpapers/DP200806.pdf
8. Silva, A. B., Ribeiro, A. (2009). An Integrated Planning for Cities to Promote Sustainable Mobility. In Proceedings of European Transport Conference 2009 (14 p.). The Netherlands: Available on the Internet: http://etcproceedings.org/paper/an-integrated-planning-for-cities-to-promote-sustainable-mobility
9. Lithuanian Real Estate Development Association. Work group publication. *Sustainable Territorial Development in Planning and Urbanity.* Vilnius, Lithuania, 2008. 110 p.
10. Rudzkiene V. (2005). *Social Statistics.* Vilnius, Mykolas Romeris University, Lithuania
11. Tamošiūnienė, R., Šidlauskas, S., Trumpaitė, I. (2006). The multicriterial evaluation method of the effectiveness of the investment projects. *Business: Theory and Practice,* 7(4), 203–212.
12. Turskis, Z., Zavadskas, E. K., Peldschus, F. (2009). Multi-Criteria Optimization System for Decision Making in Construction Design and Management, in Engineering Economics. *Economics of Engineering Decisions,* 1(61), 7–17.
13. Ustinovičius, L., Zavadskas, E.K. (2004). *Statybos investicijų efektyvumo sistemotechninis įvertinimas (In Lithuanian). [Decision support system in construction]: Monograph.* Vilnius: Technika.
14. Vergauwen, B. (2010). Ex-post Economic Analysis of an Infrastructure Project in the Port of Antwerp. In Proceedings of European Transport Conference 2010 (24 p.). Glasgow, Scotland, UK. Available on the Internet: http://etcproceedings.org/paper/ex-post-economic-analysis-of-an-infrastructure-project-in-the-port-of-antwerp
15. Zavadskas, E. K., Kaklauskas, A., Peldschus, F., Turskis, Z. (2007). Multi-attribute assessment of road design solutions by using the COPRAS method. *The Baltic Journal of Road and Bridge Engineering*, 2(4), 195–203.

Transport and Telecommunication, 2012, Volume 13, No 2, 123–137
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0010-z

AIRPORT BENCHMARKING AND SPATIAL COMPETITION: A CRITICAL REVIEW

Dmitry Pavlyuk

Transport and Telecommunication Institute
Lomonosova 1, Riga, LV-1019, Latvia
Ph.: (+371)29958338. E-mail: Dmitry.Pavlyuk@tsi.lv

During the last two decades the European airport industry is liberalised and turned to competitive market environment. This fact attracts an increasing scientific and practical interest to analysis of airport efficiency and its determinants, as well as different aspects of airport competition. This paper contains a critical review of existing researches in these two areas – airport efficiency and spatial competition among airports. We analysed modern approaches to airport benchmarking, their advantages and shortcomings, and systematised a wide range of related academic studies. We paid special attention to empirical researches of spatial competition as a factor affecting airport efficiency. Despite the fact of a well-developed theory of spatial competition and signs of its growing effects in the airport industry, we discovered a lack of studies devoted to the relationship between airport efficiency and spatial competition.

Keywords: airport efficiency, benchmarking, spatial competition

1. Introduction

The legislative liberalisation process of the EU air transportation market was completed in 1997 [1–3]. Nowadays all European airlines can provide connections between any origin and destination airports without any restrictions (excluding that related with airports' capacity). Liberalisation of the air transport industry also concerned airport enterprises and initialised significant changes of airports ownership and management. Airlines, operating in a competitive environment [4], gained an option to choose partner airports and therefore obtained influence possibilities. Those changes forced airports, originally considered as natural monopolies, to adapt to new, competitive market conditions. Besides these institutional changes on the air transportation market, there are other sources of increasing competition pressure. Development of high-speed rails, interregional bus transportation and, generally, transport networks also can be considered as an additional factor influencing competition between airports [5].

A competitive industry advances severe claims for enterprises' capitalisation and efficiency. Historically managed by government, many airports were involved into privatisation process to attract private investments and improve operational efficiency. Beginning from 1987, when UK government sold its seven major airports (including London Heathrow, Gatwick, and Stansted) to a private sector firm (British Airports Authority), many European airports became partly or completely private. Being under government ownership, airports' management was oriented (in an ideal case) to maximizing social welfare, at country and regional levels. After privatisation, these objectives were superseded by profit maximisation, usual for a commercial marketplace. One of main sources of company profit maximisation is operational efficiency, so efficiency estimation and improvement became a subject of interest of privately managed airports [6].

Airport efficiency benchmarking can serve different purposes [7] and has important implications for a number of stakeholders. Scotti [8] outlines the following interested parties:

– Airports management require efficiency comparison between airports to improve airport operations and enhance its standing in a competitive environment.
– Airlines management is interested in identifying of efficient airports for their operational activities.
– Municipalities require efficient airports for attracting businesses and tourists into a region.
– Policy makers need for benchmarking for airport improvement programs for making optimal decisions about resource allocation.

There are several well-known scientific approaches to efficiency estimation, but their applications to the airport industry are related with additional industry-specific complexities. The majority of efficiency estimation methods are based on comparison of economic agents having comparable resources. Concerning utilised resources, European airports are very heterogeneous. There are a set of social, climate, and economic conditions which make airport environment conditions heavily compatible. Also airports are significantly differentiated on the base of average passenger income and trip purposes (business or leisure), which also can be considered as an obstacle for airport comparison and efficiency estimation. Another benchmarking problem is related with a specific type of competition between airports. The legislatively competitive environment doesn't guarantee competition itself. Competition between airports is limited by their geographical location and obviously has a spatial component. Although number of European airports is increasing during last decades [9], there are some geographical areas where a competition pressure is weak or absent. European legislative authorities try to compensate this lack of competition pressure by different forms of regulation [10], which also complicates airport benchmarking.

Significant demand for airports benchmarking from different stakeholders in connection with task complexity attracted academic researchers to pay attention to this problem. There are more than a hundred research papers, published during last two decades, are devoted to airports efficiency estimation. The most significant reports are the Global Airport Performance Benchmarking Reports 2003–2011 produced by Air Transport Research Society (ATRS) [11], the Airport Performance Indicators and Review of Airport Charges reports by Jacobs Consulting, the Airport Service Quality programme by Airports Council International. Some local authorities which control the airport sector also provide their own benchmarking reports, e.g. Avinor AS (Norway) [12], Civil Aviation Authority (UK) [13], and others. Many related researches are also executed within the bounds of the German Airport Performance (GAP) research project, a joint study between three German universities

This paper contains a critical review of exiting airport efficiency researches in respect of used approaches and mentioned empirical difficulties. We pay special attention to spatial competition between airports and taking it into account in airport benchmarking.

2. Airport Efficiency Benchmarking: Theory and Applications

The airport business model

A classical definition refers economic efficiency [14] as usage of available resources (inputs) to maximise the production of goods and services (outputs). For the airport industry defining of inputs and outputs is not straightforward. Currently, an airport is considered as a connection hub between a public (serving passengers and cargo) and an airline (serving aircraft fleet movements) [15]. Airport outputs for these two groups are different – air passenger movements (APM) and air transport movements (ATM). A choice of output specifications is important for further efficiency estimation and can lead to different results and conclusions (see, for example, Pels [16] for a comprehensive discussion).

Concerning airport activity, both APM and ATM outputs are not homogeneous. There are two main components – passengers and cargo, which obviously have different 'handling' processes. A frequently used unit, which integrates passenger and cargo outputs, is a work load unit (WLU). Usually WLU equals to 1 passenger or 100 kg of cargo. Evidently a WLU is a weak indicator, but quite attractive and frequently used due to its simplicity.

Nowadays, activity of airport enterprises is not limited with aeronautical services, but includes parking, retailing, food and beverages, passenger access, and other services. Today these non-aeronautical services, originally considered as complementary, play an important role in the airport business [17]. According to ATRS reports [11], a share of non-aeronautical revenues is increasing during the last decade and for some European airports exceeds 50% (for example, for German busiest Munich and Frankfurt airports). Thereby these diverse non-aeronautical activities became an important component of overall airport performance.

Financial indicators can be considered as an alternative to physical measurement of airport outputs. The most frequently used are operational costs and revenues. Usage of financial indicators allows smoothly handle diverse airport activities, but requires information about local prices and airport-specific conditions (like government subsidies, etc.).

Recently some researches also included some negative outputs into airport benchmarking. These undesired outputs can have different forms like environmental emission and noise [18] or passenger delays [19].

Resources, utilised by airports, and airport-specific conditions are even more heterogeneous than outputs, and their definition is quite challenging. The primary set of resources usually includes labour resources (e.g. number of employees) and infrastructure resources (number of runways, airport surface area, number of terminal or gates, number of check-in desks, number of baggage reclaim belts). All materials and outsourced services are usually included in financial form. Non-aeronautical resources (like parking spaces, retail points, etc.) should also be included into consideration.

A range of factors affecting airport performance is very wide and includes airport ownership and management structure, hub status, region-specific characteristics like tourist- and business-attractiveness, climate and whether conditions and others. Also from modelling perspective, airport physical outputs can be considered as resources for financial outputs.

Summarising, we can note a great variety of approaches to the airport business model, its outputs and resources. Recently several comprehensive voluminous reviews of airport empirical studies were published [13], [20].

Airport benchmarking techniques

The theory of efficiency estimation provides a wide range of estimation methods with their own advantages and limitations. Scientific approaches, used for airport benchmarking, start from relatively simple linear indexes, but further include more complicated frontier-based models. Hirschhausen and Cullman [21] presented an excellent review of methodologies used for airports benchmarking.

Partial factor productivity indicators

The simplest one-dimensional way of efficiency estimation is a direct ratio of a chosen airport output to a given resource used. Indicators, constructed on the base of this strategy, are called partial factor productivity (PFP) indexes. Due to a great diverse of airport outputs and inputs, the range of PFP indexes is very wide. PFP indexes are not related to overall airport's efficiency, but reflect a particular aspect of its activity [22]:

- Labour productivity indexes – APM per employee, ATM per employee, WLU per employee.
- Infrastructure productivity indexes – APM per terminal, WLU per airport's surface square meter, ATM per runway.
- Financial performance indexes – operational costs per WLU, overall/aeronautical revenue per WLU, overall revenue to expenses ratio.

Nowadays PFP indexes for undesired outputs are also frequently used – average delays, delay minutes per ATM, green gas emission per ATM, etc.

PFP indexes are widely used by airport management staff, because the meaning of a PFP indexes and sources of its values are obvious, calculation of PFP indexes is elementary, and each index separately doesn't require full set of data. Each PFP index provides valuable information about a particular area of interest, but by definition cannot provide a full picture of airport performance. PFP indexes don't consider differences in input/output prices and other operating environment conditions; leave factor substitution out of account [13], and so can be considered just as a good complementary research tool.

Stated weaknesses of PFP indexes led to development of methodologies which allow calculating overall efficiency values. All methodologies can be classified on the base of their principle (averaging or comparing with frontier values) and presence of a random component (deterministic or stochastic approaches). A classification of widely used methodologies is presented in the Table 1.

Table 1. Classification of methodologies used to estimation of firm's efficiency or productivity

	Deterministic	*Stochastic*
Averaging	Total productivity factor (TFP)	Classical regression models
Frontier	Data envelopment analysis (DEA) Free disposal hull (FDH)	Stochastic Frontier analysis (SFA) Distribution-free approach (DFA) Thick frontier approach (TFA)

Source: own classification, based on Liebert and Niemeier [20], and Hirschhausen and Culman [21]

Methodologies, based on averaging of values, consider a relationship between weighted airport outputs and inputs. Total factor productivity (TFP) indexes use prices to weight input/output values, when regression estimates these 'weights' by minimizing the sum of squared residuals. Averaging methodologies assume that all airports in a sample operates efficiently, which obviously doesn't match the real situation when a difference between outputs of two airports with similar resources can be explained not only by a random component, but also by technical or managerial efficiency. Frontier-based methodologies (like data envelopment analysis or stochastic frontier analysis) allow inefficiency components by construction, but require a larger volume of data for estimation.

Parametric approaches to airport benchmarking

TFP indexes are ratios of weighted outputs to weighted inputs, where market prices are used as weights. Two most frequently used TFP indexes are Tornqvist index [23] and Caves, Christensen and Diewert (CCD) index [24], which can be considered as flexible forms of classical Laspeyres or Paasche indices.

Market prices, required for calculation of TFP indexes, are rarely available and valid, which can be a reason of a limited number of TFP applications to the airport industry. The most frequently cited researches, based on TFP, are the ATRS Global Airport Performance Benchmarking Reports [11] and related analytical studies [6]. Authors constructed a variable factor productivity index and used it for productivity comparison of airports around the world. Nyshadham and Rao [25] applied TFP indexes to estimation of European airports efficiency and compared the results with partial indexes. Gitto [26] applied TFP indexes as one of tools for analysis of Italian airports efficiency.

Charnes, Cooper, and Rhodes in 1978 [27] proposed a data envelopment analysis (DEA) approach to estimate overall company efficiency. DEA is a frontier approach, based on linear programming techniques, which allows directly taking airport inefficiency component into account. DEA constructs an efficiency frontier without market price values and without assumptions about a functional form of the frontier, which makes it easy-to-use and powerful efficiency estimation tool. The Malmquist index [24], defined using distance functions for a multi-input, multi-output technology, is frequently used to analyse airport efficiency changes over time.

DEA estimator is non-statistical by construction which makes it sensitive to data problems and prevents usage of popular research techniques like confidence intervals and hypothesis testing. Moreover, DEA estimator is biased upward [28] and inconsistent for non-convex frontiers. Simar and Wilson [28] suggested bootstrapping procedures to solve these problems and improve statistical properties of DEA estimates.

A practically important research area, which is lying outside the basic DEA model, is examination of factors influencing airport efficiency values (like airport ownership structure, hub status, etc.). A typical two-stage approach to deal with these factors includes calculation of DEA efficiency values and further their regression on explanatory factors. DEA efficiency values are obviously limited to the [0, 1] closed interval, so regressions with a censored dependent variable are used. Simar and Wilson [29] discussed properties of two most frequently used regression models – Tobit and truncated, and suggested an alternative double bootstrapping procedure.

DEA is the most frequently used academic approach to airports benchmarking. More than a hundred scientific researches, oriented on different practical and theoretical aspects of DEA model, were published during last two decades. Comprehensive literature reviews can be found in [20], [30], and [31]; in this paper we will just present DEA-based researches published in last years.

Gillen and Lall [32] published an analysis of US airports, based on the two-stage DEA approach with a second stage Tobit regression with environmental, structural and managerial variables. This research can be considered as a pioneering one and a base for many modern DEA-based airport benchmarking researches. Another frequently cited DEA application is Sarkis' US airports performance analysis [33].

Recently published studies include several country-specific DEA application for Spanish [34], [35], Greek [36], Malaysian [37], and Latin America's [38] airports. Barros et al. applied Gillen-Lall's approach to analyse airports in United States [39], in Argentine [40], in United Kingdom [30], [41], in Italy and Portugal jointly [42], and in Canada [43].

To the best of our knowledge, the most researched European countries in this aspect are Germany and Italy. German Aviation Research Society (GARS) published a set of researches ([44], [45], [22]), where the approach by Malmqvist-DEA was applied to a sample of German airports. Adler and Liebert [46] complemented DEA efficiency values with second stage OLS, Tobit, and truncated regressions on ownership, regulation, and management characteristics. Ulku, Muller, et al. [31], [47] analysed German airports applying Simar-Wilson's double bootstrapping procedure (among other research approaches).

Gitto and Mancuso published some articles [26], [48–50] with application of Simar-Wilson's double bootstrapping procedure to Italian airports. Other recent DEA applications to Italian airports performance are presented by Barros and Dieke [51] and Malighetti et al. [52].

European airports efficiency was analysed by the University of Bergamo researchers [53], [54]. A special attention was devoted to competitive characteristics of the European airport network, which were included as a factor influencing airport efficiency in Simar-Wilson's model. Also DEA approach was applied to European airports by Pels et al. [16], [55].

DEA is not the only deterministic approach to efficiency estimation. The free disposal hull (FDH) method [56] is a popular extension of DEA, which relaxes DEA's assumption about a convex form of the frontier.

FDH has few applications to the airport industry. Holvad and Graham [57] applied FDH approach to analysis of European and Australian airports and discovered difference between DEA and FDH efficiency estimates for European airports.

However, since DEA and FDH are non-statistical, any deviation from the frontier is considered as inefficiency, making DEA estimates non-robust and exacting to data quality. Statistical models with a random component in specification solve this issue and allow applying standard powerful statistical techniques. Therefore statistical models (both averaging and frontier) became a more popular airport benchmarking tool during the last decade.

Stochastic approaches to airport benchmarking

The most popular statistical model is a classical regression, which estimates a relationship between the mathematical expectation of a dependent variable (usually output) and a set of explanatory variables (inputs). The classical regression requires a predefined functional form of this dependency. Cobb-Douglass function with a constant substitution elasticity and more flexible Translog are the two most frequently used functional forms in airport industry studies. The classical regression is based on averaging technique, so doesn't contain efficiency as a component of a model specification. In relation to airports, the classical regression represents a model of airports productivity, but not efficiency.

The pioneering airport regression analysis studies executed by Keeler [58], and Doganis and Thompson [59] deal with airports cost curve construction. Keeler estimated the Cobb-Douglass regression between operating costs and ATM on the base of pooled panel data of US airports. Doganis and Thompson also constructed Cobb-Douglass regression using WLU as an output and estimated its parameters for British airport cross-sectional data.

Later several similar studies with enhanced model specification (Translog) and estimation techniques (panel data econometrics) were published. Good literature reviews on this subject can be found in [60] and [61].

A statistical approach to frontier construction and efficiency estimation brought to development of a set of models: stochastic frontier model, thick frontier model, and distribution-free model are frequently used ones. Stochastic frontier analysis (SFA), the most popular approach, was presented by Aigner, Lovell, Schmidt [62], and Meeusen and van den Broeck [63] in 1977. This approach, rarely used for airports efficiency analysis before, recently became quite popular. The main strength of SFA is a statistical approach both to frontier and unit efficiency estimation, which makes easily available to apply confidence intervals, significance, hypothesis testing, and other statistical procedures. These advantages require mandatory specification of a frontier functional form and a law of efficiency distribution. Selection of a frontier form is usually made from Cobb-Douglass and Translog functions, and rarely includes more flexible, but data-consuming forms like Fourier-Flexible. Half-normal and truncated normal distribution laws are the most frequently used options for the efficiency (inefficiency) component. The latter (truncated) distribution allows direct inclusion of factors influencing airports efficiency into a model, and simultaneous estimation of all model parameters. In 2005 Greene [64] extended the SFA model with cross-form heterogeneity, which is considered as one of the most important problems with airport benchmarking. Greene's models (called true fixed and random effects models) estimation requires panel data, are currently available for airport applications.

First (to the best of our knowledge) SFA application to airports efficiency analysis was presented by Pels et al. [16], [65]. They applied homogeneous Cobb-Douglass frontier model to a sample of European airports and made comparison of estimation results with DEA-based estimates. Later Oum et al. [66] applied the Translog stochastic frontier model to estimate influence of airport ownership on its efficiency.

During last three years number of studies significantly increased. Barros et al. presented a set of heterogeneous SFA applications to European [67], Japanese [68], and UK [30] airports. Voltes [61] analysed European, American, Oceania, and Asia-Pacific samples of airports, and later Spanish airports separately [69]. Muller, Ulku, and Zivanovic [47] within the bounds of German Aviation Performance project executed a comparison of British and German airports performance, estimated by different techniques (PFP, DEA, and SFA). Pavlyuk [70], [71] has analysed efficiency of European airports using the stochastic frontier model taking spatial competition among airports into consideration. Scotti applied homogeneous SFA model for Italian airports in his doctoral dissertation [8] and related articles [72].

Summing up SFA model applications, we can a growing academic interest to usage of this approach to airports efficiency estimation and a lack of studies with a heterogeneous frontier, which supposed to be a right choice for variegated environment of the airport business.

Two other stochastic frontier methods mentioned in the Table 1 are distribution-free and thick frontier approaches. Both methods remove restrictions of SFA related with mandatory specification of the frontier functional form and inefficiency distribution law and make estimation more flexible, but exacting to a volume of data. These strong requirements to data volume can be considered as one of the main reasons why there are no empirical applications of these methods to airport efficiency analysis.

Summarising this section, we note that the discussion about a correct approach to airport benchmarking is far from complication. There are several different approaches with their own advantages and shortcomings. The problem becomes even more complicated due to diverse nature of the airport business, allowing different approaches to definition of resources and outputs. Despite the complexity of the problem (or maybe thanks to this fact), airport benchmarking attracted a significant attention of world-wide scientific community.

3. Spatial Competition among Airports: Theory and Applications

Airport competition and its elements

The liberalisation of the European airport industry activated market mechanisms. Nowadays competition among airports can be considered as an integral part of the airport industry. According to the mainstream economical view, competition should act like a spur to increase efficiency of airports, forcing them to find better ways of demand fulfilment. During last two decades airport competition became a popular topic of theoretical and empirical studies, and widely recognised as a positive mechanism, leading to resource saving, service quality improvements, and development of the industry as whole. Although this thesis is commonly acknowledged, there are several not unfounded critical opinions in literature. Some authors [73] state that increasing competition leads airports to lack of critical mass (traffic volume required for covering obligatory operating costs), excessive capacities and swallowing up subsidies as a result. Regardless of its consequences, competition process among airports is very diverse. There is a wide variety of ways in which airports compete (the list is compiled on the base of Tretheway and Kincaid [74] and Forsyth [75] studies):

- Competition for passengers with neighbour airports on a shared local market.
- Competition as a destination point (for tourists, businesses, etc.).
- Competition for passengers with other transport modes (high-speed railways, ferries, etc.).
- Competition for connecting traffic.
- Competition for cargo traffic.
- Competition for contracts with airlines.
- Competition of non-aeronautical services (car parking, retail, maintenance).

All presented types of airports competition already play an important role in industry regulation; first two types (competition for passengers on a local market and for visitors as a destination point) are attracting special interest due to industry-specific spatial settings.

Although the presence of competition effects in the airport industry is widely acknowledged, there are little empirical evidences on a strength of competition among airports. Forsyth [76] states mild competition among airports and specifies a set of factors limiting it:

1. Common ownership of neighbour airports. Frequently airports in major European cities (London, Berlin) are owned by one proprietor, which makes competition among them imperfect (if any).
2. Scale economy is very important in the airport industry and it’s difficult for small or new airports to reach the optimal traffic volume.

3. Indivisibility of airport infrastructure complicates a reaction of airport management for demand fluctuations. Airport scale can't be increased (or reduced) continuously or by small pieces under infrastructure restrictions. For example, building of a new runway significantly increases airport scale, but requires significant capital investments at once.
4. Environmental and other legal barriers prevent entry of new airports (to ensure a competitive market).
5. Congestion of some airports makes them insensitive for demand changes.
6. Different airport regulation regimes and government subsidies make competition among airports imperfect.

There are some other sceptical opinions about current strength of airport competition [77], [78]. Despite the specified obstacles for airport competition and widely used regulation mechanisms as a competition replacement, there are a number of strengthening competition indications in European airport industry.

Evidences of strengthening airport competition in Europe

A positive influence of low-cost carriers' (LCC) activity on airport competition is well researched [82], [83], [84]. The entry of low-cost carriers on the European market changed an established airport hierarchy and encouraged the development of small and medium secondary and regional airports. Also LCC catalysed a substantial growth of direct connections between airports. These LCC effects (among others) stimulated a competitive activity in the European airport industry.

Number of new airport entries to the market also can be considered as an evidence of increasing competition. Muller-Rostin et al. [9] estimated the overall level of competition in the airport industry using numbers of newly opened (entry) and closed (exit) airports as indicators. In this study authors investigated competition on a by-country basis for Germany, Italy, UK, Spain, Poland, and jointly for other Eastern European countries.

Strengthening competition on the airport market is also attested by increasing marketing efforts of airport management. According to Tretheway and Kincaid [74], the ratio of marketing staff per passenger in selected UK airports was significantly increased.

An indirect, but meaningful evidence of intensifying competition is an interest to market power estimation from government competition authorities. During last years competition commissions, previously considered airports as natural monopolies, requested some airport market power researches. UK Competition Commission estimated the market power of London Stansted [85] and currently implementing a similar research for Heathrow, Gatwick, and Stansted [86]. The team of the German Airport Performance project executed a research of the Amsterdam Schiphol airport's market power for Netherlands Competition Authority [87] and discovered a slightly increasing competition pressure the airport exposed.

A specific feature of European transportation market is well-developed railways and motorways supported by stable people habits of their usage. Railways and motorways in this context should be considered not only as competitors for air transport, but also as a factor, increasing competition among airports for multi-modal trips. The increasing mobility of population allows airports to compete for passengers living far from airport locations.

Theoretical background of spatial competition

Competition among airports in different areas (for passengers, for airlines, etc.) is different by its nature and has various sources and effects. To the best of our knowledge, one of the most under-researched aspects of airport competition is a spatial one.

Spatial competition is mainly concerned with the locational interdependence among economic agents. The theory of spatial competition is well established and there are a significant number of its applications in different economic areas. Recently models of spatial competition were applied to movie theatres, gas stations, retail places, hospitals, country regions and others, but the airport industry is still weakly covered. Open airport market and increasing number of airports from one side and airports unalterable locations from another create good background for spatial completion in this sector.

A study, frequently cited as a pioneering in the areas of spatial competition, was presented by Hotelling in 1929 [88]. Hotelling considered a basic case of two firms producing homogeneous goods in different locations on a line and stated a key question about competition among firms and their efforts to differentiate from each other. Later the idea of Hotelling's model was developed in different ways.

D'Aspermont et al. [89] introduced quadratic transportation costs for the model, which allowed its equilibrium solution. Salop [90] enhanced the model by replacing the linear locational structure with a two-dimensional circular one. The limitation of homogeneous goods, inadmissibly restrictive for the airport industry, also was addressed. Irmen and Thisse [91] introduced a multi-dimensional model where dimensions can have different weights. They proved that in the equilibrium point a firm differentiate itself from competitors in one dimension, but locate in the centre (close to other firms) for all other dimensions.

Correctness of Irmen and Thisse's model has several corroborations in the airport industry. A set of dimensions can include a price segment of served airlines (from LCC to regular and elite), traffic types (from cargo to connecting or direct passenger flights), flight destinations (from domestic to short- and long-haul international), and airport geographical location. Looking at the European airport industry, we can discover several examples where airports are differentiated in one of these dimensions, but located closely in others. There are European cities with major and secondary airports (London, Paris, Berlin), where the secondary airport is typically served by LCC (and differentiated in this dimension). Another example is airports in Baltic States' capital cities (Riga, Tallinn, Vilnius), which are differentiated geographically and don't have to distance themselves from each other for other dimensions.

A mode of airport competition (quantity-based Cournot competition or price-based Bertrand competition) is also a subject of academic researches [92], [93]. Biscia and Mota [94] presented an outstanding review of studies on both Cournot and Bertrand competition modes in spatial settings.

Empirical studies of airport spatial competition

Empirical estimation of spatial competition among airports is weakly covered by researches. There are two different ways in which airports can compete spatially:

- as a departure point for local population;
- as a destination point for tourists and businesses.

Estimation of the first aspect of spatial competition among airports is usually based on the conception of catchment area. Airport industry researches define airport's catchment area as a geographical zone containing potential passengers of the airport. Usually the geographical definition of airport's catchment area is supplemented with demographic indicators such as population, employment, income and others [95].

Catchment area's radius can be defined in different ways:

- by geographical distance;
- by travel time;
- by travel cost.

The metrics are used linearly or with time (distance) decay functions.

Several empirical researches used overlapping catchment areas as an indicator of spatial competition among neighbour airports. Starkie [80] studied competition between airports for hinterlands as a degree of the airports' catchment areas overlapping (Figure 1) and later applied this approach in his further researches [96], [97].

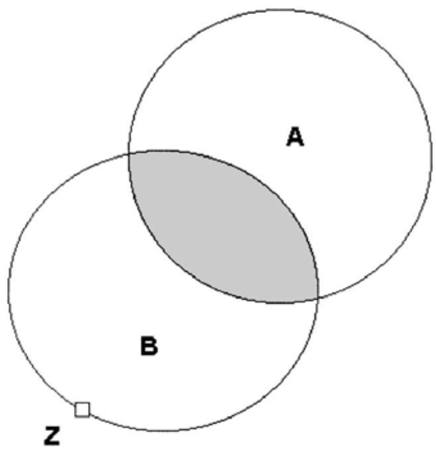


Figure 1. Competition and catchment areas. Source: Starkie, 2002 [80]

Analysis of overlapping catchment areas was supplemented by additional characteristics of airport services like flights frequency, destinations, etc. Strobach [98] constructed an index of spatial airports competition for a particular destination point using a set of factors, weighted by their (author-defined) importance. The factors include transport accessibility (distance and time values for private transport and cost and time values for public transport), traffic characteristics (frequency of flights to a selected direction, minimum connecting time, numbers of gates and check-ins), and characteristics of convenience (parking spaces, terminal area, area of shopping and services). Malina [99] suggested a substitution coefficient, which "defined as the share of inhabitants within the relevant regional market of an airport that consider another airport (...) to be a good substitute from their perspective as well". Hancioglu [78] investigated competition between Dusseldorf and Cologne/Bonn airports using Malina's airports substitution coefficient, mainly based on overlapping catchment areas, and a custom survey of passengers' origin regions. Pavlyuk [70] suggested constructing multiple catchment areas of an airport for different flight destinations. Bel and Fagenda [100], and Adler and Liebert [46] used number of nearby airports as a simple indicator of competition pressure.

Another popular approach to estimation of completion pressure is interviews with experts and airport management [101–103]. This approach is very useful for initial analysis of the competition pressure, but has an obvious shortcoming of subjectivity as well as quantitative measurement problems.

The second way of spatial competition among airports is based on their function to be an intermediate destination point. Leisure and business travellers manage their trips and define intermediate connection points (including airports). This subject of their choice is wider than selection between two (or more) airports in a destination city and relates to trip's route as whole. For example, for a saving trip from London to Moscow travellers can choose between Riga and Tallinn airports as an airline-railway transfer point. Note that the essence of this way of competition is not necessary spatial, but spatial effect can take place in some cases. To the best of our knowledge, there are no studies containing empirical estimation of this aspect of spatial competition between airports.

Spatial competition and airports efficiency

There are few empirical studies of a relationship between spatial competition and efficiency of airports.

Borins and Advani [102] used interviews with airport managers to estimate levels of competition of two types – transferring traffic and catchment areas. Estimated competition levels were included into two classical regression models with passenger and airline orientations. Both competition types are found significantly positive in both models, so authors concluded positive influence of competition on airports activity.

Jing [104] analysed efficiency of Asian cargo airports using the stochastic frontier approach and including competition into consideration. A suggested competitiveness index was constructed on the base of airports ranking by locational, facility, service quality, charges, staff quality, connectivity, and market environment factors. Although airport's geographical location was included into the index, spatial effects are unexamined in the paper.

Pavlyuk [70] suggested index of competition, based on overlapping catchment areas, included it into the stochastic frontier model, and discovered a positive effect of competition pressure on efficiency for a sample of European airports. Non-linear spatial interdependence was investigated in author's further research [71] and a multi-tier model of competition and cooperation effects was suggested. The model estimates provide both positive and negative effects depending on a distance tier.

Scotti et al. [8], [54], [72] suggested an index of competition between two airports on the base of a share of population living in an overlapped region of the airports' catchment areas. Competition was calculated separately for every destination point (exact or reasonably close) and combined into the general competition index using available seats shares as weights. The suggested index of competition was included in a set of inefficiency determinants of a multi-output stochastic frontier model. Estimating parameters of this model for a sample of Italian airports, authors concluded a significant negative relationship between competition pressure and airport efficiency. Authors explained this fact by overcapacity of airports. Airports, acting in more competitive environment, captured limited benefits of air transport post-liberalisation traffic growth, when monopolistic airports easier filled their capacity and improved their technical efficiency.

Adler and Liebert [105] investigated an influence of competition on airport efficiency using a two-stage DEA model. A level of competition was included into the second stage regression as number of significant airports within a catchment area and showed up as a significant factor for results of different regulation forms. The spatial specification of the second stage regression was tested by author, but solely for justifying of the model's robustness.

Spatial econometrics

Recently developed theory of spatial econometrics [106] is a modern and powerful tool for analysis of spatial relationships of different types. Spatial econometrics deals with spatial interaction (a specific form of which is a spatial competition) and spatial heterogeneity in regression models. A key technical component of spatial model is a matrix of spatial weights, which contains values of spatial interdependency (frequently inversed distances) for every pair of sample objects. Methods of spatial econometrics are frequently used for analysis of competition effects in spatial settings [107], but, to the best of our knowledge, there is only one application [71] of these methods to analysis of airport productivity and efficiency.

Summarising the section, we can note that the nature of competition between airports is very complex and this subject is weakly covered by empirical researches. Due to discussed reasons we expect that the competition between airports in Europe will be strengthening in nearest future, and this fact will intensify theoretical and empirical researches in this area. Competition, being one of the best drivers of economic efficiency, should be included into airport benchmarking procedures. The role of spatial competition among neighbour airports is also expected to grow, and methods of spatial econometric can be applied for analysis of airports efficiency.

4. Conclusions and Future Research Directions

During last two decades airport benchmarking attracted a significant attention of the scientific community. Many theoretical and practical studies addressed to this problem are published recently, but methodological base and even problem specification issues are far from a consensus. The airport business is usually considered as an intermediary between population and air carriers, and it makes specification of airport resources and activity results not straightforward. Passengers and cargo transferred by an airport, airline movements served, environmental emission and noise, and other airport activity aspects are included into studies either as resources or as outputs of the business.

A range of quantitative methods used for airport benchmarking is reasonably wide. Productivity indicators (PFP and TFP), deterministic (DEA, FDH) and stochastic (SFA) frontier approaches are widely used. Partial productivity indicators (APM per employee, operational costs per WLU) are frequently used for initial analysis of airport efficiency, but reflect only a particular aspect of the business. Modern approaches to estimation of overall airport efficiency are based on the frontier concept. The majority of airport studies utilise deterministic frontier DEA approach to benchmarking, but during last three years number of stochastic SFA approach applications is increased significantly. We associate this interest to stochastic frontier applications with recent theoretical SFA developments, which allow taking into account a heterogeneous nature of airport production. Considering the complexity of the airport business, we can conclude a significant research field in this direction.

Discussions about competition among airports are also intensified last years. Despite several reasonable sceptical opinions about the existence of significant airport competition, there are a number of studies related to empirical evidences of competition. A structure of airport competition is composite. Airports compete for passengers, contracts with airlines, for arriving passenger traffic, for transferring traffic, for cargo transportation and others. Each component of airport competition can be considered as a separate topic of research, with its own features and problems. Spatial competition, based on locational interrelation between airports, is a special type of competition, which is addressed by several recent researches. The most popular spatial approach is based on the catchment area concept. This concept allows authors to estimate and analyse a level of spatial competition among airports. The theory of spatial competition is well-developed, but number of its empirical applications in the airport industry is very limited, which creates an extensive area for further researches.

Finally, an empirical relationship between spatial competition and efficiency of airports is also weakly researched. According to the mainstream economics, competition is the best way to force agents to improve their efficiency, but a power of this mechanism in the airport industry is almost unstudied. A small number of empirical studies don’t allow make a comprehensive conclusion about the subject. The methodological base of this kind of researches is also scanty, so influence of spatial competition on airports efficiencies is an extensive and complicated research topic. We seem that application of spatial econometrics to this area will enhance the methodological base of analysis and lead to practically important results.

References

1. European Commission. (1992). *Council Regulation on licensing of air carriers* (No 2407/92). Official Journal of the European Union (Legislation): The Publications Office of the European Union.
2. European Commission. (1992). *Council Regulation on access for Community air carriers to intra-Community air routes* (No 2408/92). Official Journal of the European Union (Legislation): The Publications Office of the European Union.
3. European Commission. (1992). *Council Regulation on fares and rates for air services* (No 2409/92). Official Journal of the European Union (Legislation): The Publications Office of the European Union.
4. Fu, X., Oum, T. H., Zhang, A. (2010). Air Transport Liberalization and Its Impacts on Airline Competition and Air Passenger Traffic. *Transportation Journal*, 49(4), 24–41.
5. European Conference of Ministers of Transport, Organisation for Economic Co-operation and Development, International Transport Forum. (2009). *Competitive interaction between airports, airlines and high-speed rail*. Paris: OECD/ITF.
6. Oum, T. H., Adler, N., Yu, C. (2006). Privatization, corporatization, ownership forms and their effects on the performance of the world's major airports. *Journal of Air Transport Management*, 12(3), 109–121.
7. Oum, T. H. (1992). Concepts, methods and purposes of productivity measurement in transportation. *Transportation Research Part A: Policy and Practice*, 26(6), 493–505.
8. Scotti, D. (2011). *Measuring Airports' Technical Efficiency: Evidence from Italy*, PhD thesis, University of Bergamo, Italy
9. Müller-Rostin, C., Niemeier, H. M., Ivanova, P., Müller, J., Hannak, I., Ehmer, H. (2010). Airport Entry and Exit: A European Analysis. In *Airport Competition: The European Experience* (pp. 27–46). England, Farnham: Ashgate Publishing Limited,
10. European Commission. (2006). *Commission Regulation laying down a common charging scheme for air navigation services Text with EEA relevance* (No 1794/2006). Official Journal of the European Union (Legislation): The Publications Office of the European Union.
11. Oum, T. H., Yu, C., Choo, Y. (2011). *ATRS Global Airport Performance Benchmarking Project, The Air Transport Research Society* Vancouver, Canada: *The Air Transport Research Society*.
12. Merkert, R., Pagliari, R., Odeck, J., Brathen, S., Halpern, N., Husdal, J. (2010). *Benchmarking Avinor's Efficiency, Møreforsking Molde AS, 1006.* Molde, Norway: Møreforsking Molde.
13. Civil Aviation Authority. (2000). *The Use of Benchmarking in the Airport Reviews.* London, UK: CAA.
14. O'Sullivan, A., Sheffrin, S.M. (2003). *Economics: principles in action*. Needham, Mass.: Prentice Hall.
15. Doganis, R. (1992). *The airport business*. London: Routledge.
16. Pels, E., Nijkamp, P., Rietveld, P. (2003). Inefficiencies and scale economies of European airport operations. *Transportation Research Part E: Logistics and Transportation Review*, 39, 341–361.
17. Zenglein, M. J., Müller, J. (2007). *Non-Aviation Revenue in the Airport Business–Evaluating Performance Measurement for a Changing Value Proposition*. Berlin, Germany: Berlin School of Economics.
18. Yu, M. (2004). Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environmental factors. *Journal of Air Transport Management*, 10(5), 295–303.
19. Pathomsiri, S., Haghani, A., Dresner, M., Windle, R. J. (2008). Impact of undesirable outputs on the productivity of US airports. *Transportation Research Part E: Logistics and Transportation Review*, 44(2), 235–259.
20. Liebert, V., Niemeier, H. M. (2011). Benchmarking of Airports-A Critical Assessment. In Proceedings of the 12th World Conference on Transport Research, 11–15 July 2010 (p. 46) Lisbon, Portugal: WCTRS.
21. Hirschhausen, C., Cullman, A. (2005). Questions to Airport Benchmarkers – Some Theoretical and Practical Aspects Learned from Benchmarking Other Sectors. In the German Aviation Research Society Workshop, 24–25 November 2005 (p.16). Vienna, Austria: German Aviation Research Society.
22. Abdesaken, G., Cullman, A. (2006). The Relative Efficiency of German Airports. In the GARS Amsterdam Student Workshop, 7 October 2006 (p. 36). Amsterdam: German Aviation Research Society.

23. Törnqvist, L. (1981). *Collected scientific papers of Leo Törnqvist.* Helsinki: Research Institute of the Finnish Economy.
24. Caves, D. W., Christensen, L. R., Diewert, W. E. (1982). Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers. *The Economic Journal*, 92(365), 73–86.
25. Nyshadham, E. A., Rao, V. K. (2000). Assessing Efficiency of European Airports: A Total Factor Productivity Approach. *Public Works Management & Policy*, 5(2), 106–114.
26. Gitto, S. (2008). *The measurement of productivity and efficiency: theory and applications.* PhD thesis, University of Rome "Tor Vergata," Rome, Italy.
27. Charnes, A., Cooper, W. W., Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, 2(6), 429–444.
28. Simar, L., Wilson, P. W. (2000). Statistical Inference in Nonparametric Frontier Models: The State of the Art. *Journal of Productivity Analysis,* 13(1), 49–78.
29. Simar, L., Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of econometrics*, 136(1), 31–64.
30. Barros, C. P. (2008). Technical efficiency of UK airports. *Journal of Air Transport Management*, 14(4), 175–178.
31. Ulku, T. (2009). *Efficiency of German Airports and Influencing Factors*. MSc thesis. Humboldt University, Berlin, Germany.
32. Gillen, D., Lall, A. (1997). Developing measures of airport productivity and performance: an application of data envelopment analysis. *Transportation Research Part E: Logistics and Transportation Review*, 33(4), 261–273.
33. Sarkis, J. (2000). An analysis of the operational efficiency of major airports in the United States. *Journal of Operations Management*, 18(3), 335–352.
34. Tapiador, F., Mateos, A., Marti-Henneberg, J. (2008). The geographical efficiency of Spain's regional airports: A quantitative analysis. *Journal of Air Transport Management*, 14, 205–212.
35. Martin, J. C., Roman, C. (2001). An application of DEA to measure the efficiency of Spanish airports prior to privatization. *Journal of Air Transport Management*, 7(3), 149–157.
36. Psaraki-Kalouptsidi, V., Kalakou, S. (2011). Assessment of efficiency of Greek airports. *Journal of Airport Management*, 5(2), 170–186.
37. Razali, S. R., Shah, M. Z. (2010). Performance Measurement of Malaysian Airports using DEA method. In Proceedings of Malaysian Universities Transportation Research Forum and Conferences, 21 December 2010 (pp. 487–493). Malaysia: University Tenaga Nasional.
38. Perelman, S., Serebrisky, T. (2010). *Measuring the technical efficiency of airports in Latin America*. Policy Research Working Paper WPS5339. Liege, Belgium: The World Bank.
39. Barros, C. P., Assef, A. (2009). *Productivity change in USA airports: the Gillen and Lall approach revisited.* Working Paper 22/2009/DE/UECE. Lisbon, Portugal: School of Economics and Management.
40. Barros, C. P., Assaf, A., Lipovich, G. A. (2010). *Productivity Analysis of Argentine Airports.* Working Paper. Lisbon, Portugal: School of Economics and Management.
41. Barros, C. P., Weber, W. L. (2009). Productivity growth and biased technological change in UK airports. *Transportation Research Part E: Logistics and Transportation Review*, 45(4), 642–653.
42. Barros, C. P., Peypoch, N. (2007). *A comparative analysis of productivity change in Italian and Portuguese airports.* Working Paper 006/2007/DE. Lisbon, Portugal: School of Economics and Management.
43. Barros, C. P., Peypoch, N., Villard, P. (2011). *Productivity changes in Canadian airports and technological change analysis.* Working Paper 05/2011/DE/UECE. Lisbon, Portugal: School of Economics and Management.
44. Kamp, V., Niemeier, H., Schmidt, P. (2004). Benchmarking of German Airports – Some first Results. In the GARS Research Seminar "How to Make Slot Markets Work" (p. 17). Bremen, Germany: GARS.
45. Kamp, V. (2007). Airport Benchmarking – An Empirical Research on the Performance Measurement of German Airports with Data Envelopment Analysis. *Aerlines e-zine edition*, 36, 1–4.
46. Adler, N., Liebert, V. (2011). *Joint Impact of Competition, Ownership Form and Economic Regulation on Airport Performance*. Bremen: Jacobs University.
47. Muller, J., Ulku, T., Zivanovic, J. (2009). *Privatization, restructuring and its effects on performance: A comparison between German and British airports.* German Airport Performance Project, Working Paper 16, Germany: GAP.
48. Curi, C., Gitto, S., Mancuso, P. (2009). *Managerial assessment of Italian airport efficiency: a statistical DEA approach.* Discussion Paper. Rome, Italy: University of Tor Vergata.

49. Gitto, S., Mancuso, P. (2010). *Airport efficiency: a DEA two stage analysis of the Italian commercial airports.* Paper 34366. Munich, Germany: MPRA.
50. Curi, C., Gitto, S., Mancuso, P. (2011). New Evidence on the Efficiency of Italian Airports: A Bootstrapped DEA Analysis. *Socio-Economic Planning Sciences*, 45(2), 84–93.
51. Barros, C. P., Dieke, P. (2007). Performance evaluation of Italian airports: A data envelopment analysis. *Journal of Air Transport Management*, 13(4), 184–191.
52. Malighetti, P., Martini, G., Paleari, S., Redondi, R. (2007). *Efficiency of Italian airports management: the implications for regulation*. Working Paper. Italy: University of Bergamo.
53. Malighetti, P., Martini, G., Paleari, S., Redondi, R. (2008). *The efficiency of European airports: Do the importance in the EU network and the intensity of competition matter?* Working Paper 04-2008. Bergamo, Italy: University of Bergamo, Department of Economics and Technology Management.
54. Malighetti, P., Martini, G., Paleari, S., Redondi, R. (2009). *The Impacts of Airport Centrality in the EU Network and Inter-Airport Competition on Airport Efficiency.* Paper 17673. Munich, Germany: MPRA.
55. Suzuki, S., Nijkamp, P., Pels, E., Rietveld, P. (2009). *Comparitive Performance Analysis of European Airports by Means of Extended Data Envelopment Analysis.* Discussion Paper 2009-024/3. The Netherlands: Tinbergen Institute.
56. Deprins, D., Simar, L., Tulkens, H. (1984). Measuring labor-efficiency in post offices. In *The Performance of Public Enterprises: Concepts and Measurement* (pp. 243–267). Amsterdam: North-Holland.
57. Holvad, T., Graham, A. (2000). Efficiency Measurement for Airports. In the Annual Transport Conference, Aalborg University, Denmark, 28–29 August 2000 (pp. 331–343). Denmark: Aalborg University.
58. Keeler, T. (1970). Airport Costs and Congestion. *The American Economist*, 14(1), 47–53.
59. Doganis, R., Thompson, G. (1974). Establishing Airport Cost and Revenue Functions. *Aeronautical Journal*, 78, 285–304.
60. Jeong, J. (2005). *An investigation of operating cost of airports: focus on the effect of output scale*. MSc thesis, The University of British Columbia, Canada.
61. Voltes, A. J. (2008). *Stochastic frontier estimation of airports' cost function.* PhD thesis, The University of Las Palmas de Gran Canaria, Spain.
62. Aigner, D., Lovell, C., Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, 6(1), 21–37.
63. Meeusen, W., van der Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Function with Composed Error. *International Economic Review*, 8, 435–444.
64. Greene, W. (2005). Reconsidering heterogeneity in panel data estimators of the stochastic frontier model. *Journal of Econometrics*, 126(2), 269–303.
65. Pels, E. (2001). Relative efficiency of European airports. *Transport Policy*, 8(3), 183–192.
66. Oum, T. H., Yan, J., Yu, C. (2008). Ownership forms matter for airport efficiency: A stochastic frontier investigation of worldwide airports. *Journal of Urban Economics*, 64(2), 422–435.
67. Barros, C. P., Marques, R. C. (2008). *Performance of European Airports: Regulation, Ownership and Managerial Efficiency*. Working Paper 25/2008/DE/UECE. Lisbon, Portugal: School of Economics and Management.
68. Barros, C. P., Managi, S., Yoshida, Y. (2008). *Technical Efficiency, Regulation, and Heterogeneity in Japanese Airports.* Working Paper 43/2008/DE/UECE. Lisbon, Portugal: School of Economics and Management.
69. Martín, J. C., Román, C., Voltes-Dorta, A. (2009). A stochastic frontier analysis to estimate the relative efficiency of Spanish airports. *Journal of Productivity Analysis*, 31, 163–176.
70. Pavlyuk, D. (2009). Spatial competition pressure as a factor of European airports' efficiency. *Transport and Telecommunication*, 10(4), 8–17.
71. Pavlyuk, D. (2010). Multi-tier spatial stocjastic frontier model for competition and cooperation of European airports. *Transport and Telecommunication*, 11(3), 57–66.
72. Malighetti, P., Martini, G., Scotti, D., Volta, N. (2010). *The impact of airport competition on technical efficiency: A Stochastic Frontier Analysis applied to Italian airports*. Paper 24648. Munich, Germany: MPRA.
73. Heymann, E., Vollenkemper, J., Frank, H. J., Walter, N. (2005). *Expansion of regional airports: Misallocation of resources.* Deutsche Bank Research, Germany.
74. Tretheway, M., Kincaid, I. (2005). Competition between airports in the new Millennium: what works, what doesn't work and why. In The 8th Hamburg Aviation Conference, 16–18 February 2005 (p. 18). Hamburg, Germany: InterVISTAS Consulting Inc.

75. Forsyth, P., Gillen, D., Müller, J., Niemeier, H. (2010). *Airport Competition: The European Experience.* England: Farnham: Ashgate Publishing Limited.
76. Forsyth, P. (2006). Airport competition: regulatory issues and policy implications. In *Competition policy and antitrust*, Vol. 1, (pp. 347–367). Amsterdam; Boston: Elsevier.
77. Barrett, S. (2000). Airport competition in the deregulated European aviation market. *Journal of Air Transport Management*, 6, 13–27.
78. Hancioglu, B. (2008). *The Market Power of Airports, Regulatory Issues and Competition between Airports.* Working Paper. German Airport Performance Project. Germany: GAP.
79. Czerny, A. I. (2006). Price-cap Regulation of Airports: Single-till Versus Dual-till. *Journal of Regulatory Economics*, 30(1), 85–97.
80. Starkie, D. (2002). Airport regulation and competition. *Journal of Air Transport Management*, 8, 63–72.
81. Bel, G., Fageda, X. (2009). Privatization, regulation and airport pricing: an empirical analysis for Europe. *Journal of Regulatory Economics*, 37, 142–161.
82. Dresner, M., Lin, J.-S., Windle, R. (1996). The Impact of Low Cost Carriers on Airport and Route Competition. *Journal of Transport Economics and Policy*, 30(3), 309–328.
83. Trzepacz, P. (2007). Spatial aspects of air transportation liberalization–changes in European airport hierarchy. *Bull. Geography*, 8, 163–177.
84. Pels, E., Njegovan, N., Behrens, C. (2009). Low-cost airlines and airport competition. *Transportation Research E*, 45, 335–344.
85. Competition Commission. (2008). *Stansted Airport Q5 price control review.* UK: Competition Commission.
86. Civil Aviation Authority. (2011). *Heathrow, Gatwick and Stansted Airports Q6 review.* UK: CAA.
87. Muller, J., Bilotkach, V., Fichert, F., Niemeier, H. M., Pels, E., Polk, A. (2010). *The economic market power of Amsterdam Airport Schiphol.* The Netherlands:The Netherlands Competition Authority.
88. Hotelling, H. (1929). Stability in competition. *The Economic Journal*, 39(153), 41–57.
89. D' Aspremont, C., Gabszewicz, J. J., Thisse, J.-F. (1979). On Hotelling's "Stability in Competition," *Econometrica*, 47(5), 1145–1150.
90. Salop, S. (1979). Monopolistic competition with outside goods. *The Bell Journal of Economics*, 10(1), 141–156.
91. Irmen, A., Thisse, J.-F. (1998). Competition in Multi-characteristics Spaces: Hotelling Was Almost Right. *Journal of Economic Theory*, 78(1), 76–102.
92. Van Dender, K. (2005). Duopoly prices under congested access. *Journal of Regional Science*, 45(2), 343–362.
93. Haskel, J., Iozzi, A., Valletti, T. M. (2011). *Market structure, countervailing power and price discrimination: the case of airports*. Discussion Paper 2011/03. London, UK: Imperial College.
94. Biscaia, R., Mota, I. (2011). *Models of Spatial Competition: a Critical Review*. Working Paper 411. Portugal: Department of Economics, University of Porto.
95. Department of Transport. (2004). *Regional and Small Airports Study*. TP 14283B. Canada: Department of Transport.
96. Starkie, D. (2009). The airport industry in a competitive environment: A United Kingdom Perspective. In *Competitive Interaction between Airports, Airlines and High-Speed Rail* (pp. 67–93). London, UK: OECD Publishing.
97. Civil Aviation Authority. (2011). *Catchment area analysis*. Working Paper. UK: Civil Aviation Authority.
98. Strobach, D. (2006). *Competition between airports with an application to the state of Baden-Württtemberg.* Working Paper 272/2006. Germany: University of Hohenheim.
99. Malina, R. (2006). *Competition and regulation in the German airport market*. Discussion Paper 10. Germany: Institute of Transport Economics.
100. Bel, G., Fageda, X. (2009). *Factors explaining charges in European airports: Competition, market size, private ownership and regulation.* Working Paper 2009-31. Madrid, Spain: Fundación de Estudios de Economía Aplicada.
101. Air Transport Group. (2002). *Study on Competition between Airports and the Application of State Aid Rules.* Final Report 2002/287. UK: ATG.
102. Borins, S., Advani, A. (2002). Managing airports: a test of the New Public Management. *International Public Management Journal*, 4(1), 91–107.

103. Gillen, D., Niemeier, H. M. (2006). Airport Economics, Policy and Management: The European Union. In the Fundación Rafael del Pino Workshop on Infrastructure Economics: a Comparative Analyses of the Main Worldwide Airports, Madrid, Spain (p. 53). Madrid, Spain: Rafael del Pino Foundation.
104. Jing, X. Y. (2007). *Benchmarking competitiveness of cargo airports*. MSc thesis, National University of Singapore, Singapore.
105. Adler, N., Liebert, V. (2010). Competition and regulation (when lacking the former) outrank ownership form in generating airport efficiency. In The GAP workshop "Benchmarking of Airports," Berlin, Germany, 25–26 November 2010 (p. 27). Berlin, Germany: GAP.
106. Anselin, L. (1988). *Spatial econometrics: methods and models*. Dordrecht: Kluwer Academic Publishing.
107. Arbia, G. (2006). *Spatial econometrics: statistical foundations and applications to regional convergence*. Berlin: Springer.

Transport and Telecommunication, 2012, Volume 13, No 2, 138–147
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0011-y

THE RESEARCH ON COMPETITIVENESS OF ROAD TRANSPORT ENTERPRISES: LITHUANIAN CASE

***Jonas Lazauskas*[1], *Gintautas Bureika*[2], *Valdas Valiūnas*[3], *Robertas Pečeliūnas*[4]**
***Jonas Matijošius*[5], *Saulius Nagurnas*[6]**

[1]*Dept of Transport Management, Vilnius Gediminas Technical University*
Plytinės St. 27, LT-10105, Vilnius, Lithuania

[2]*Dept of Railway Transport, Vilnius Gediminas Technical University*
J. Basanavičiaus St. 28, LT-03224, Vilnius, Lithuania

[3, 4, 5 ,6]*Dept of Automotive Transport, Vilnius Gediminas Technical University*
J. Basanavičiaus St. 28, LT-03224, Vilnius, Lithuania

Ph.: [1]*+37068141067;* [2] *+37068561950;* [3]*+37068611156;* [4]*+370 69818297;* [5]*+37068404169;* [6]*+37065402786*
E-mails: [1]*jonas.lazauskas@vgtu.lt;* [2]*gintautas.bureika@vgtu.lt;* [3]*valdas.valiunas@vgtu.lt*
[4]*robertas.peceliunas@vgtu.lt;* [5]*jonas.matijosius@vgtu.lt;* [6]*saulius.nagurnas@vgtu.lt*

In the paper, various opinions of Lithuanian and foreign authors of scientific publications are reviewed and the criteria for assessing competitiveness of road transport are discussed upon. On assessment of competitiveness of services provided by Lithuanian road transport enterprises, not only technical options are taken into account. It is proposed to assess competitiveness of enterprises upon taking into consideration the total set of services provided as well as their quality and the marketing level of the enterprise. In the paper, the factors impacting competitiveness of road transport are discussed upon and the research works required for objective assessment of competitiveness of road transport are foreseen. A model for assessing competitiveness of road transport enterprises realized by the authors is provided. In the end of the paper, conclusions and recommendations are provided.

Keywords: competitiveness of enterprises, competitiveness assessing, concordance, AHP method

1. Introduction

After joining of Lithuania to the European Union (EU) in the year 2004 and the subsequent changes of the business environment, the problems of competitiveness and foreign trade are becoming more and more topical, because the membership in the EU increases the importance of economic and institutional relations with other countries. In the period of economic recession, a considerable number of enterprises (in particular, those involved in providing transport services) could not hold out their position in the market and a still larger number of them obtained no profit from their activities because of the reduced level of consumption and needs in transport services. In course of the recovery of economy, effective using the competitive potential is of a great importance.

The key element of the competitive environment is enterprises. A competitiveness of an enterprise in the world market is bound with its ability to respond to immediate changes of the market and to hold out the position of the enterprise in it. The idea of competitive advantage starts from creation and distribution of the value. An enterprise is recognized competitively advantageous; when its influence predetermines economic changes in the market where it has a certain share [1]. The concept of economic equilibrium is interpreted as an ability of an enterprise to hold its end up and to withstand the negative impact of its rivals. So, an enterprise should be capable to overcome the barriers of strategic difficulties. According to scientist Piccoli, both its ability to defend its position of competitive advantage and an ability to provide a successful response to its rivals become the ones of a great importance [2]. The core of competition is a necessity to contend that is important for competition in the market. Researcher Lobanova emphasized that a market, as an open system (space or territory), cannot be imagined without organizations competing in the said space [3].

According to researcher Gerard de Villiers [4], commercial activities in competitive environment should be focused only to the spheres where they can preserve or obtain competitive advantage. Five factors of six traditional ones included in the service marketing mix (price, promotion, product, humans and process) leave a too little space for introduction of innovations.

According to scientists Marčinskas and Diskienė [5] in the complicated and ever-changing business environment, the ways of obtaining and preserving competitiveness by an organization vary as well; in scientific references, the said ways are assessed ambiguously. So, it may be stated that no universal ways of obtaining and preserving competitiveness by an enterprise exist. A majority of authors assent to the opinion that competitive advantage is obtained by those who:

1) may offer an exclusive and unique product or service highly appreciated by the consumer;
2) perfected their ability of a particularly sensitive response to the market and adaptation to it (earlier than other market players);
3) are the first in finding an access to the principal resources (when other market players cannot find it);
4) earlier achieve the highest level of results (as compared to other market players).

Competition is one of the key elements of the market. In each business sector, competition between market subjects takes place. Freight transporting and forwarding enterprises do not present an exception – competition between them takes place as well. However, it is not clear whether the said enterprises pay a great attention to striving to competitive advantage, i.e. improvement of the quality of services provided, assessment of actions of their rivals or control of certain spheres of the activities. So, it may be stated that the principal problem is incomplete using the competitive potential by Lithuanian enterprises involved in providing freight transportation services. In order to analyse the above-mentioned problem, the research work on assessment of an ability of Lithuanian road transport enterprises to compete in the market had to be made.

The aim of this research was to assess the competitiveness of Lithuanian road transport enterprises by using quality expertise multicriteria methods, especially AHP (*Analytic Hierarchy Process*) method.

2. Statistical Indicators of Road Transport Enterprises and Their Fluctuation

In the year 2010, export of services in Lithuania increased by 17.3%, or 1.56 billion LTL (the currency unit of Republic of Lithuania), as compared to the year 2009. Export of services of all principal types was growing, except of export of financial services that reduced by 3.5%. The said growing was mostly caused by export of transport services that increased by 21.6%, or 1.1 billion LTL, travel services – 7.6%, or 0.188 billion LTL, other business services – 22.1%, or 0.155 billion LTL, and building services – 34.2%, or 0.057 billion LTL.

In the early 2011, even a disproportion between transporting capacities and grown demand appeared. Undoubtedly, these factors also caused growing of export of forwarding, logistics and warehousing services: it grew by 276.6 million LTL, or 25.6%, as compared to the year 2009. Export of services in freight transportation by air transport increased by 71.6%, or 15.44 million LTL, by railways – by 1.2%, or 8.8 million LTL, as compared to the year 2009; however, export of services in freight transportation by sea reduced by 2.6%, or 8.7 million LTL. The structure of the sector of services in Lithuania in the year 2010 is shown in Fig. 1.

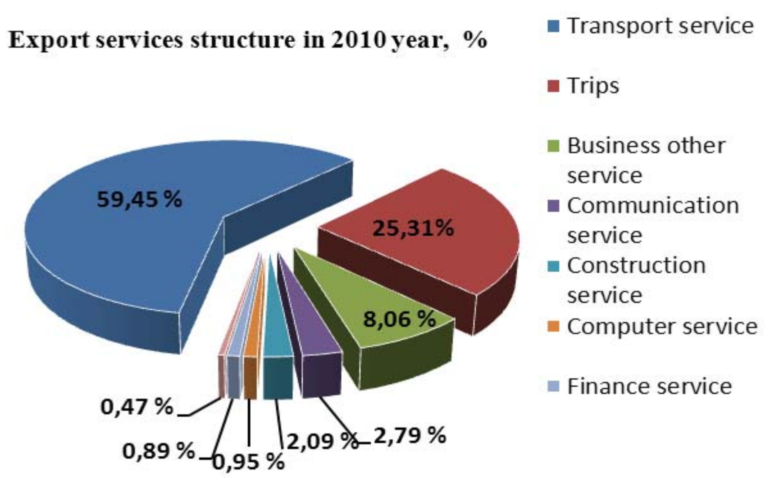


Figure 1. The structure of the export service's' sector in Lithuania in the year 2010,%
(http://www.verslilietuva.lt/files/files/PDF/elanalitinis_naujienlaiskis_paslaugos2010.pdf)

In the year 2008, when the economic crisis started, decrease of the annual sales in the road transport sector began earlier than in the whole national economy; in the middle 2009, it declined together with the economy – the income reduced by 27%. In respect of arrest of property, the transport sector was among the highest risk sectors. In the "peak" period that took place within January–April 2009, 1428 arrests of property at 586 enterprises (12.1% of enterprises) were registered.

In the lists of operating national transport enterprises, the below-mentioned enterprises do not exist anymore:

1) 45% of enterprises where an arrest of the property was registered within first four months of the year 2009;
2) 35% of enterprises where an arrest of the property was registered in early 2010.

Among enterprises with turnover over 4 million LTL, sales increased at 72% of the total number of enterprises. Among enterprises with turnover of 1–4 million LTL, sales increased at 69% of the total number of enterprises. In 2010, in the group of smallest enterprises, sales increased at 45% of enterprises; in addition, 8% new enterprises started their activities; however, 15% of small enterprises were liquidated.

The trends in different branches of Lithuanian road transport differ:

1) sales at freight transportation enterprise increased by 61%; in addition, 9% new enterprises appeared;
2) sales at urban passenger transportation enterprises reduced by 49%;
3) the activities of taxi were the most unsuccessful: within the year, 23% of enterprises were liquidated, and sales reduced at 58% of enterprises.

The competitive environment in road transport reduced. In the year 2010, 13% of enterprises terminated their activities and only 7% new enterprises appeared. For freight transportation enterprises, the following threats remain:

1) prices of oil increasingly grow; however, Lithuanian carriers can buy cheap fuel in East countries;
2) in the meanwhile, the growing wage-related expenses cause an inconsiderable impact upon freight transportation sector; however, a lack of employees is felt already;
3) in case of recovery of the national market, an equalization of flows of freights to Lithuania and from Lithuania may turn into a supplemental reserve for increasing the competitiveness;
4) in some segments, the situation may worsen: for example, from the 1st July of the current 2011 year, when flows of vehicles imported to CIS reduce, volumes of transportation by cars may reduce;
5) a negative impact may be caused by hardly predictable factors, such as disorders of ferry traffic, changes of road tolls in Poland and other states, a lack of permits for working in Russian market in the end of the year or possible sanctions of EU in respect of Belarus.

In spite of the obstructions, the perspectives for enterprises engaged in freight transportation by roads remain positive in the year 2011. Growing of road transport enterprises is limited by a shortage of equity capital or circulating funds; shortage of investments may appear in future as well.

The number of Lithuanian road transport enterprises in the years 2006–2011 is provided in Table 1. Changes of the number of freight-carrying vehicles in the years 2005–2010 are provided on Figure 2.

Table 1. The number of Lithuanian road transport enterprises in the beginning of the year (2006–2011).

Year	The number of transport enterprises in the beginning of the year
2006	4260
2007	4186
2008	4614
2009	4863
2010	4708
2011	4914

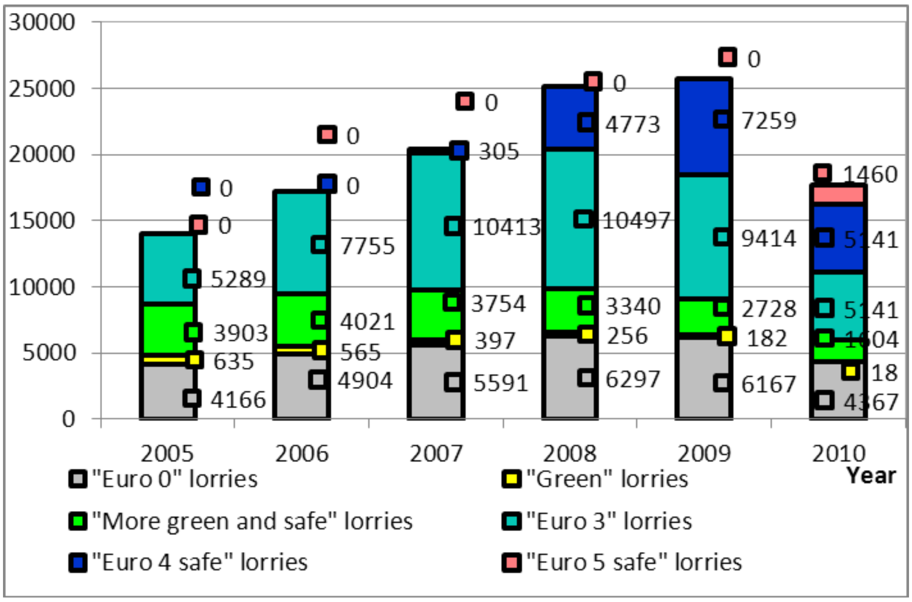


Figure 2. Distribution of Lithuanian freight-carrying vehicles involved in international transportations according to the certificates available (The Review on the Economical and Social Situation of Transport and Communication for the year 2009)

A gross negative impact to business of Lithuanian carriers was caused by the actions of Russian Federation customs service in respect of Lithuanian carriers. On 03 August 2009, intensified inspection of Lithuanian carriers began. It caused long queues of vehicles of Lithuanian carriers at borders with Russia. The strengthened control was applied to Lithuanian carriers only and it lasted for over 2 weeks. Because of this, a majority of consignors refused services of Lithuanian carriers. The introduction of toughened control by Russian customs in respect of Latvian carriers in December 2009 that caused long queues of vehicle at the borders between Latvia and Russia caused considerable losses to Lithuanian carriers as well.

3. The Factors Affecting the Competitiveness of Freight Transportation by Road Vehicles

In order to identify the factors affecting the competitiveness of freight transportation by road vehicles, a survey that involved 146 enterprises engaged in international freight transportation was carried out.

The obtained results show that a legal status of a majority of the surveyed enterprises (90%) are joint-stock companies limited, usually small, i.e. with a number of employees from 1 to 10, or medium-sized, with a number of employees from 21 to 50. A major part of the staff of surveyed enterprises (59%) is presented by drivers. As concerns to the duration of the activities of the enterprises, most of them (70%) were established before 3–5 years. So it may be stated that a major part of the enterprises are mature and stable.

Supplemental services offered by enterprises usually include management of freight-accompanying documents (100%) that is provided by all enterprises surveyed, management of the customs procedures (94%), choosing of the safest itinerary (91%) and consulting on transportation-related issues.

In the opinion of enterprises involved in international freight transportation, a consumer usually provides an advantage to enterprises that have own vehicles. Suppliers also suppose that enterprises with own vehicles are the strongest rivals. Some enterprises state that they feel no competition from the side of other enterprises. However, the opinion of clients on this problem was different: they provide an advantage to the properties of the service provided by enterprises, not to resources possessed by the enterprises.

The principal users of services provided by enterprises involved in freight transportation (in respect of the character of the activities) are forwarding (33%) and wholesale (49%) enterprises. They are the key clients using the said services. In addition, retail trade enterprises may be bracketed to the principal users as well (13%).

The opinions of clients and service providers on choosing the key criteria differed: clients identified the price and the delivery time as the key criteria, while transport enterprises singled out the quality of servicing and safety of transportation; the opinions of clients (companies) and service providers on exclusivity of a service were quite opposite: transport enterprises pay a great attention to it; however, in the opinion of clients, this property is not important.

The data of the research are reliable enough, because a majority of the respondents were heads of relevant enterprises or their subdivisions being perfectly aware of their activities.

Upon generalization of the research, the factors increasing competitiveness of road transport and the factors reducing competitiveness of road transport can be singled out. They are provided in the Table 2.

Table 2. The factors affecting competitiveness of road transport

The factors increasing the competitiveness	The factors reducing the competitiveness
The geographic situation of Lithuania is favourable for transportations from Central and Western Europe to Eastern Europe and Russia	A major part of stocks of Lithuanian road transport enterprises consists of lorries that conform to the standards Euro 0 and Euro 3
The well-developed network of roads; high quality of roads	Profitability of transport enterprises is mostly reduced by growing of taxes and prices of fuel
In Lithuania, promotion of transport sector is one of priorities of the national economy	In the year 2010, the average wages of road transport employees were the lowest as compared to other transport branches
The share of transport services in Lithuanian export of services equalled to 59.45% (2010)	Enterprises pay the greatest attention to searching and attracting new consumers and less attention to existing consumers
In the year 2010, the flow of direct foreign investments in Lithuania amounted to 1.6 billion LTL, i.e. it increased by 1.2 billion LTL, or increased by almost four times, as compared to the year 2009. Within the year 2010, direct foreign investments in Lithuanian transport sector were growing	As the survey of clients showed, they assess the price and the time of delivery as the key criteria, while only 55% of the surveyed companies consider pricing-related issues important and 6% of the surveyed companies settle the problems of optimisation of distribution
In the early 2011, total 4914 enterprises operated in the road transport sector of Lithuania; a larger number of operating enterprises was registered in the spheres of retail trade and real estate and construction	Freight transportation sector is affected by the shortage of employees (in particular, drivers) that began to be appreciable since the year 2011
Transport enterprises provide a large assortment of freight transportation services combining with each other all types of transport; in addition, a number of supplemental services are provided	–
In the year 2010, the volumes of freight transportation in Lithuania transport sector increased by 8.9%, as compared to the year 2009. In the year 2010, freight transportation by road vehicles increased by 12.6%, as compared to the year 2009	–
A major part of freight and income is contributed by road vehicles	–

4. The Model for Assessing a Competitiveness of Road Transport

For the survey of clients, only four questions were formulated striving to clear up how service receivers choose a service provider, what is their motivation, what properties of a service they single out as the key ones and what properties are out of their interest. For this purpose, a questionnaire of 4 questions was formed. The size of an enterprise, the number of its employees and other indicators were not taken into consideration; the key issue was a frequency of using road transport services. 150 questionnaires were sent by e-mail, and 128 of them were resent; the enterprises were chosen randomly, they were involved in retail and wholesale trade or manufacturing.

In the questionnaire, it was requested to specify one or more versions of choosing an enterprise involved in providing road transport services. The survey showed recommendations of colleagues to be the most effective marketing measure in this sphere: it was specified by 68 enterprises, i.e. almost a half of the respondents; personal sale is an effective marketing measure as well. The least effective measure is advertising in mass media – only enterprises transporting little freight specified it. In answers of large enterprises, recommendation of colleagues with actions and discounts and personal sales predominated. The above-described attests that enterprises try choosing a reliable carrier and look for lower prices (Fig. 3).

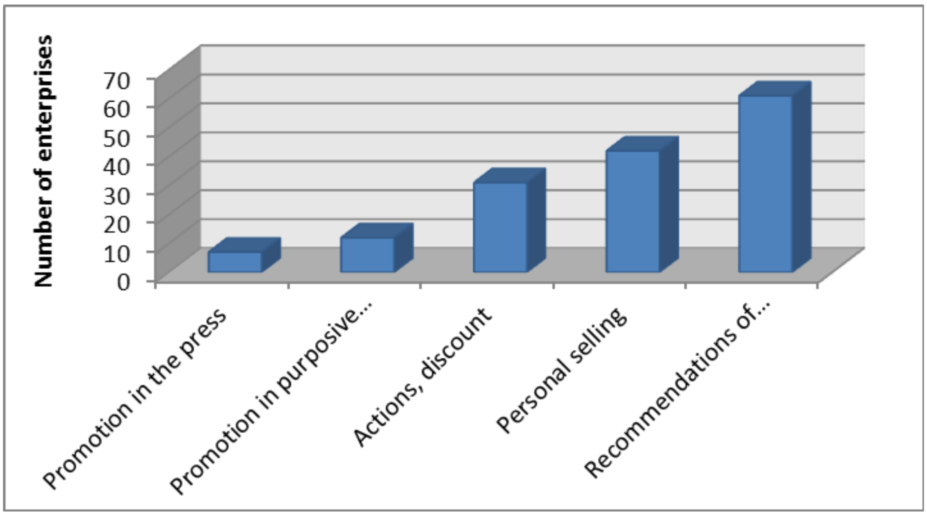


Figure 3. The service-promoting measures of enterprises that mostly affect a choice of clients

In addition, it was asked what criteria are taken into account by enterprises on choosing a carrier: 70% of enterprises pay the greatest attention to the properties (price, time of delivery, safety and so on), 16% of the respondents feel a greater concern about marketing features and only 14% of them – about resources of the carrier (the qualification of the employees, the available stock of vehicles).

Only enterprises transporting little freight took an interest in marketing policy; larger enterprises paid a greater attention to the properties of the services and resources of the carriers.

The fourth question was bound with assessment of importance of nine criteria from 1 to 9 (9 – the most important, 1 – the least important).

The weighted assessment S_{ev} is calculated according to the following formula:

$$S_{ev} = \frac{\sum_{j=1}^{n} Sk_j}{N}, \quad (1)$$

where S_{ev} – the weighted assessment , in scores; Sk_j – the assessment chosen by the enterprise, in scores; N – the number of participants of the survey.

The results of the calculations according to the formula (1) are provided in the Table 3.

Table 3. The weighted assessments (by clients) of the properties of the services offered by an enterprise

A criterion of the service	The weighted assessment, S_{ev}
Price	8.19
Time of delivery	7.52
Servicing	5.83
Safety	5.55
Service flexibility	5.19
Terms of payment	5.05
Promoting services	3.00
Innovativeness	2.52
Service exclusivity	2.14

Ranking is not the only method for object comparison. Experts may assess objects (indicators) in units of measurement of the scale of the objects; in percent; in any system of points; they also may assess the values of the weights by paired comparison methods, upon a consideration that the sum of the weights of the objects should be equal to one. If we wish to apply the coefficient of concordance *W* for establishing the level of consensus of opinion between experts, any assessment of the objects should be transformed into ranking. This task is easily accomplishable because any method establishes the order of importance of the objects as well [6]. For establishing the quantitative importance (weights) of the indicators, T. Saaty AHP (*Analytic Hierarchy Process*) paired comparison method was applied by Saaty [7] and was widely used by Maskeliūnaitė [8].

An example of the values of weights of indicators found on the base of the above-mentioned T. Saaty method upon using the questionnaire for paired comparison of indicators provided by one of the experts is shown in Table 4. In the same Table 4, the respective ranks of the indicators established according to decrease of the weights of the indicators are provided as well.

Table 4. The weights of indicators assessed by one of the experts and the respective ranks on establishing the impact of factors upon competitiveness

Ind.No	1	2	3	4	5	6	7	8	9
Weights	0.083	0.011	0.092	0.021	0.021	0.083	0.049	0.021	0.084
Ranks	10	1	13	3	3	10	7	3	12

Ind.No	10	11	12	13	14	15	16	17
Weights	0.011	0.049	0.049	0.043	0.099	0.092	0.092	0.100
Ranks	1	7	7	6	16	13	13	17

On applying T. Saaty AHP paired comparison method, the level of consensus is determined for each individual expert. In this case, the level of consensus for a group of experts upon applying the coefficient of concordance was determined by prior computation of Saaty weights of the indicators and following ranking of them in accordance with decrease of the weights. The method enables to determine the level of consensus for an individual expert. The level of consensus of 20 experts was acceptable because their consensus ratio was less than 0.1 [9].

It may be seen from the Table 3 that the most important property of enterprise's service is the price, then the time of delivery follows, while servicing, safety and service flexibility gained similar numbers of scores; innovativeness and service exclusivity remained in the end of the list of priority.

Upon singling out the key factors affecting competitiveness of road transport, a model for assessing the competitiveness of road transport, was developed (Fig. 4).

On the base of this model and a survey of experts, it is possible to assess competitiveness *K* of road transport with sufficient accuracy by assessing the impact of each factor upon competitiveness and the existing situation in scores and making calculations according to the formula:

$$K = \sum_{i=1}^{n} F_i \cdot k_i , \tag{2}$$

where: F_i – the assessment of the *i*-th factor in scores; k_i – the impact coefficient of the *i*-th factor.

Assessments of factors in scores and the impact coefficients of factors are established during a survey of experts applying the 100-score system, where an assessment of competitiveness is interpreted as follows: 1–10 scores – an absolutely non-competitive, 11–39 – non-competitive, 40–59 – moderately competitive, 60–89 – competitive, 90–100 – highly competitive branch.

The questionnaire was provided to heads of 20 transport enterprises and they were asked to assess the impact of each factor on competitiveness in scores from 1 to 10 (1 – almost no impact, 10 – very strong impact); in the second column, they ought to specify the character of the impact of the factor (positive, negative, neutral), and in the third column – to assess the existing situation of the factor in Lithuania in scores from 1 to 100 (1 – highly unfavourable situation, 50 – moderate situation, 100 – very favourable situation). The answers of the heads of all enterprises were obtained, their opinions were coordinated, and after processing the data provided in the questionnaires, the Table 5 was formed.

On applying multi-criteria methods, establishment of the weights of the criteria (indicators) is of a great importance. In calculation of the weights, the assessments provided by the experts are used as a base. The results are applicable in practice, if a sufficient consensus of opinion between experts takes place.

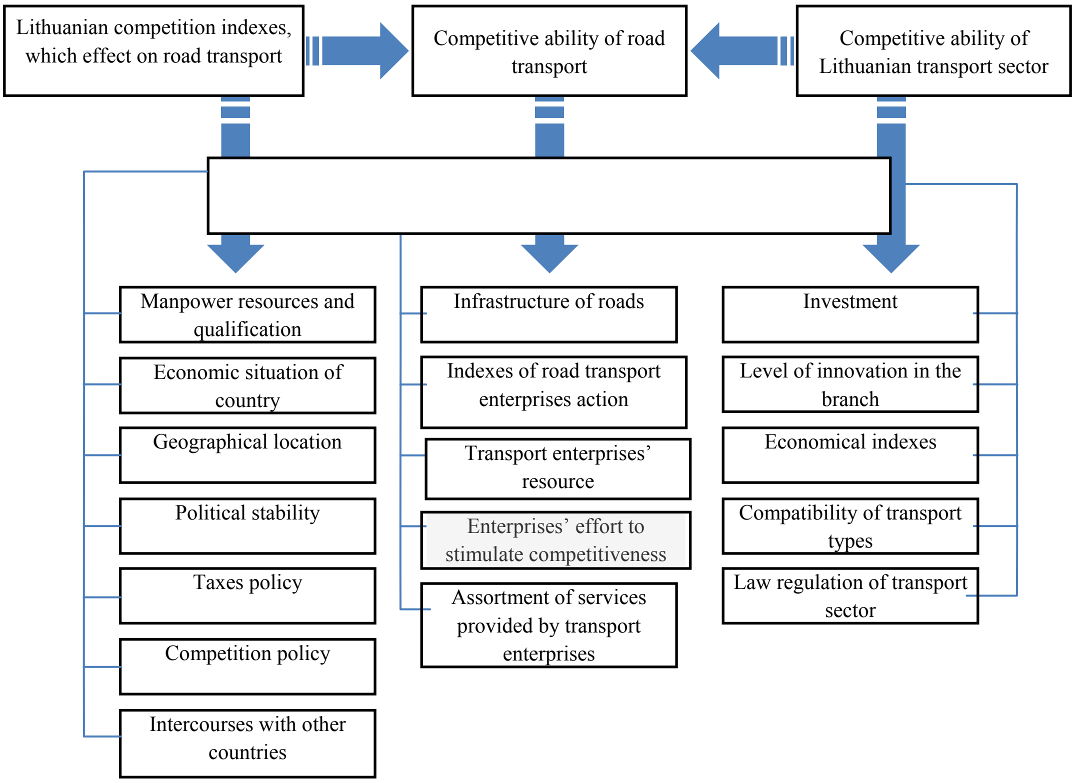


Figure 4. A model for assessing the competitiveness of road transport

It is shown by the coefficient of concordance that is computed on the base of ranking of comparable objects. The highest level of consensus is obtained when the direct ranking method is applied by Podvezko [6].

The definition of dispersive coefficient of concordance was provided by Kendall [10]:

$$W = \frac{12 \cdot S}{r \cdot m \cdot (m-1)}; \tag{3}$$

where S – the sum of standard (square) deviations; r – the number of experts; m – the number of indicators.

If the opinions of the experts coincide, the value of the coefficient of concordance W is close to one; if the opinions are very different, the value of W is close to zero. In assessing the impact of each factor on the competitiveness in the present research, the value of coefficient of concordance $W = 0.81$, and in assessing the existing situation – $W = 0.64$. These figures confirm a good level of consensus of opinion between experts.

The survey of experts shows the economic situation, political stability, tax policy, relations with other states, investments, economic indicators of the branch, compatibility of various kinds of transport and legal regulation of transport to be the key factors predetermining competitiveness of road transport, while the indicators of the activities of road transport enterprises and the assortment of services provided by them are of a less importance.

Table 5. The results of assessment of the competitiveness of road transport by the experts

Factor	Notation	Impact coefficient, $k_{1,2,3....17}$	Assessment of impact	Assessment, in scores
Manpower and its qualification	D_q	0.07	Neutral	60
Economic situation of the state	E_c	0.08	Negative	33
Geographic situation	G	0.04	Positive	69
Political stability	P_s	0.08	Negative	32
Tax policy	T	0.08	Negative	20
Competition policy	K_p	0.07	Neutral	44
Relations with other states	S	0.08	Positive	63
Investments	I	0.08	Positive	40
The level of innovations in the branch	I_{in}	0.04	Positive	34
Economical indicators of the branch	E_t	0.08	Positive	55
Compatibility of various kinds of transport	T_s	0.08	Positive	68
Legal regulation of transport	T_l	0.08	Neutral	61
Road infrastructure	K_i	0.05	Positive	70
Indicators of the activities of road transport enterprises	R_r	0.02	Neutral	49
Resources of enterprises	E_r	0.04	Positive	43
The activities of enterprises for promoting their competitiveness	E_{ks}	0.04	Neutral	56
The assortment of services offered by enterprises	S_a	0.02	Positive	67

Upon application of the formula (2) to the results provided, the following mathematical expression of competitiveness K is obtained:

$$\begin{aligned} K = {} & D_q \cdot k_1 + E_c \cdot k_2 + G \cdot k_3 + P_s \cdot k_4 + T \cdot k_5 + \\ & + K_p \cdot k_6 + S \cdot k_7 + I \cdot k_8 + I_{in} \cdot k_9 + E_t \cdot k_{10} + \\ & + T_s \cdot k_{11} + T_l \cdot k_{12} + K_i \cdot k_{13} + R_r \cdot k_{14} + E_r \cdot k_{15} + \\ & + E_{ks} \cdot k_{16} + S_a \cdot k_{17} . \end{aligned} \tag{4}$$

The value of assessment of competitiveness K of road transport calculated according to the formula (4) is $K = 50.94$. So, it means that competitiveness of road transport in Lithuania is of a middling level. This indicator is mostly worsened by the political and economic situation of the state, its tax policy and a low level of investments in the branch. According to the experts, there are no highly favourable factors. Some factors, such as manpower and its qualification, geographical situation of the state, relations with other states, compatibility of various kinds of transport, legal regulation of transport, road infrastructure and the assortment of services offered by enterprises, were assessed as the ones of a higher than a middling level.

5. Conclusions

1. Upon applying the methodology for assessing competitiveness of Lithuanian road transport offered by the authors, it was found that: competitiveness of road transport is of a middling level (50.94); competitiveness is mostly worsened by the political and economic situation of the state, its tax policy and a low level of investments in the branch.
2. Wide-ranging and detailed assessments of enterprise competitiveness methods are usually time-intensive. This reduces the flexibility and effectiveness of the competitiveness evaluation: not always possible to obtain quickly the latest information and fidelity respond to changes therein.

3. Clients consider the price and the delivery time AS the most important criteria for choosing an operator, while road transport enterprises singles out the quality of servicing and safety of transportation as the most important ones. The opinions of clients and service providers on an exclusivity of the service were quite opposite: transport enterprises pay a great attention to it, while clients consider it to be out of importance.
4. Enterprises increasingly carry out analysis of pricing and prices, search for way of attracting new potential consumers, make efforts for concluding contracts as efficiently as possible, optimising their vehicle fleet and logistics systems.
5. According to the data of this survey of clients of Lithuanian road transport enterprise, they usually choose an operator following recommendations of their colleagues, not the marketing strategy of the operator.
6. Striving to preserve their competitive advantage, transport enterprises two times per year should carry out an analysis of the needs of the clients on a regular basis and adapt the properties (peculiarities) of the service to the needs of the clients.
7. Providers of international freight transportation services should use more competently the support from EU Structural Funds for renewing and updating the fleet of vehicles.
8. Striving for attracting a larger number of clients, enterprises involved in rendering transport services should, first of all, care about improvement of a reliability of the service and the reputation of the enterprise.

References

1. Baublys, A., Griškevičienė, D., Lazauskas, J., Palšaitis, R. (2003). *Transport economics*. Vilnius: Technika.
2. Piccoli, G. (2005). Review: IT-dependent strategic initiatives and sustained competitive advantage: a review and synthesis of the literature. *MIS Quarterly*, 29(4), 747–776.
3. Lobanova, L. (2001). Model of competitiveness: quality of human resources potential. *Management of Enterprises*, 20, 125–155.
4. De Villiers, G. (2002). Transport, logistics and supply chain management. Civil Engineering. *Magazine of the South African Institution of Civil Engineering*, 10(1), 16–23.
5. Marčinskas, A., Diskienė, D. (2001). The determinants of enterprise competitiveness. In *Economics: research works,* vol. 55–56 (pp. 57–88). Vilnius.
6. Podvezko, V. (2005). Compatibility of Expert Estimates. *Technological and economic development of economics,* 11(2), 101–107.
7. Saaty, T. L. (2001). *Fundamentals of the analytical hierarchy process*. Pittsburg: RWS Publications.
8. Maskeliūnaitė, L., Sivilevičius, H., Podvezko, V. (2009). Research on the quality of passenger transportation by railway. *Transport*, 24(2), 100–112.
9. Saaty, T. L. (1980). *The Analytical Hierarchy Process: Planning, priority setting, resources allocation*. London: McGraw-Hill.
10. Kendall, M. (1970). *Rank Correlation Methods*. London: Griffin.

Transport and Telecommunication, 2012, Volume 13, No 2, 148–158
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0012-x

MULTIPLE-CRITERIA ANALYSIS AND CHOICE OF TRANSPORTATION ALTERNATIVES IN MULTIMODAL FREIGHT TRANSPORT SYSTEM

Eugene Kopytov, Dmitry Abramov

Transport and Telecommunication Institute
Lomonosova str. 1, Riga, LV-1019, Latvia
Ph.: (+371)67100614. E-mails: kopitov@tsi.lv, dmitrijs_abramovs@yahoo.com

In the paper the multimodal freight transportation system with a finite number of known alternatives, defined by the routes and modes, is considered. The objective of research is to suggest the approach for evaluation and choice the alternatives of cargo transportation. The following main tasks are considered: choice of indices characterizing efficiency of multimodal transportations, formation of optimization criteria of the multimodal freight transportation, construction of the model of the multimodal transportation system, calculation the performance criteria of cargo transportation. The study presents the Analytic Hierarchy Process (AHP) as the most suitable approach for comparative evaluation of different routes and modes of cargo transportation.

Keywords: multimodal freight transportation, logistic system, business-process, criteria of optimization, route, Analytic Hierarchy Process

1. Introduction

The demand for cargo transportation in Latvia has experienced high growth rates. From 1998 to 2010 the main indices of freight transport in Latvia increased significantly (see Fig. 1): cargo volume by 34.9 % and cargo turnover by 62,4 % [1]. Current trends of development of the Latvian system of freight transportation are characterized by essential increase of multimodal transportation in total amount of cargo transportation. Usage of several types of transport in multimodal transportation makes the management, loading and warehousing processes, in which various executors and various facilities are involved, significantly more complicated. Thus, considering great transportation volumes, miscalculations in the organization and management of these processes lead to considerable material and financial losses. The growth of cargo transportation claims for higher optimization of the transportation process. In practice we have to answer on two basic questions: what route to choice and what transport mode to use, and there are different methods which provide the decision-maker (DM) with a satisfactory solution.

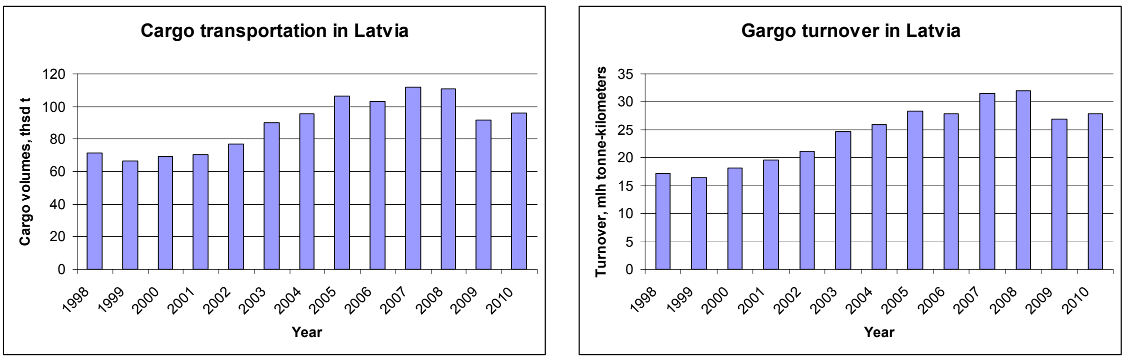


Figure 1. Main indicators of cargo transportation in Latvia in 1998–2010

As a rule, for the each multimodal freight transportation the decision-maker can offer several alternatives for cargo delivery determined by different routes or/and modes. Search for the best solution or finding a set of good alternatives in realization of multimodal freight transportation should be based on a set of the initial data, considering logistic principles, and be done using modern mathematical methods and computer engineering [2, 3]. Solving this problem we have to take in account such important factors as: a complicated structure of multimodal transportation, high dynamics and rapidity of transport processes, the random factors influencing these processes and geographical dispersion of participants of the transportation. There are a number of researches for evaluation and choice the alternatives of cargo transportation (for example, see analysis in [4]), and a lot of them are based on the cost criterion. In some papers the authors propose the multiple-criteria approach for transportation system evaluation, but for the alternative choice they include these criteria into generalized cost criteria (for example, see [5]). Multiple-criteria method is realized in the work [4], where three criteria for route choice (shipping time, shipping price, shipping safety) are applied, but in practice there exist more different indices which determine the efficiency of cargo transportation.

The objective of our paper is to suggest the multiple-criteria approach for evaluation and choice the alternatives of cargo transportation. We consider the multimodal transportation system with finite number of known alternatives defined by the routes and modes of transportation. Each alternative is represented by its performance in multiple criteria. In the presented research, the following main tasks, which require solutions in multimodal freight transportation system, are highlighted:

- construction of a mathematical model of the multimodal transportation system;
- choice of a set of indices, characterizing efficiency of multimodal transportation, and formation of an optimization criteria of the multimodal transportation system on their basis;
- development of a method for evaluation and selection of cargo transportation routes and modes.

2. Model of Multimodal Transportation System

Multimodal freight transportation system is a classic logistic system (LS) [3]. For the description of multimodal transportation system it is possible to use two approaches: functional and process.

Functional approach was the first for describing business-systems. It considers usage decomposition of the system, which includes three basic steps. On the first step logistic system is divided into a set of subsystems. On the next step subsystems are presented as a set of logistic functions (LF). On the final step, each logistic function is presented as a set of logistic operations (LO), which are characterized by their own set of indices.

The main disadvantage of the functional approach is dissociation of separate logistic functions and insufficient interaction among them. However, an ultimate goal of formalization of the transportation process description is not only calculation of efficiency indices, but also development of the approach to efficient control system of multimodal transportation. The last is difficult for implementing using the functional approach.

The process *approach* has found wide application recently only [6]. Thus the model of logistic system, realised at the functional approach, joins additional processes level. This level in hierarchy of the system precedes functions level. Logistic process is considered as a set of logistic functions, however in certain cases logistic process (LP) can consist of one LF. The main task of this approach is elimination of lack of the functional approach, which is noted above, and consists in absence of interaction between various LF within the limits of one system.

In the present paper the process approach is used for the description of multimodal freight transportation system. For presentation of the multimodal freight transportation system the decomposition of logistic systems $\mathbf{LS}$ are executed (see Fig. 2). The process of decomposition includes the following four steps:

1) the logistic system LS_j is divided into a set of *subsystems* $\mathbf{LT} = \{LT_1, LT_2, ..., LT_g\}$;
2) each subsystem LT_k is presented as a set of *logistic processes* $\mathbf{LP} = \{LP_1, LP_2, ..., LP_z\}$;
3) each logistic process LP_m is presented a set of *logistic functions* $\mathbf{LF} = \{LF_1, LF_2, ..., LF_r\}$;
4) each function LF_q is presented as a set of *logistic operations* $\mathbf{LO} = \{LO_1, LO_2, ..., LO_h\}$, which are characterized by own sets of indices.

The constructed system of sets allows making calculations of LS efficiency, taking in account different indices, first of all cost indices and time indices [3]. Besides, these calculations are made “bottom-up” starting from the bottom level (level of LO) and finishing by the top level (level of LS). So, the calculation process can be presented by the chain $\mathbf{LO} \to \mathbf{LF} \to \mathbf{LP} \to \mathbf{LT} \to \mathbf{LS}$.

It is necessary to underline that cost indices at the next level of hierarchical bottom-up system are calculated by simple summation of corresponding indices of the previous level. Then cost index $E(LS_j)$ for logistic system LS_j is calculated by the formula:

$$E(LS_j) = \sum_{LT_i \in LS_j} E(LT_i) = \sum_{LT_i \in LS_j} \sum_{LP_m \in LT_i} E(LP_m) = \sum_{LT_i \in LS_j} \sum_{LP_m \in LT_i} \sum_{LF_h \in LP_m} E(LF_h) =$$
$$= \sum_{LT_i \in LS_j} \sum_{LP_m \in LT_i} \sum_{LF_h \in LP_m} \sum_{LO_p \in LF_h} E(LO_p), \tag{1}$$

where $E(S)$ is cost index for the item S.

However, calculation of time indices in the transportation system involves severe difficulties. It is necessary to take into account factors like shifts of separate operations, functions and processes for fixed moments of time, parallel and consecutive performance of separate elements of logistic system and so forth. With this aim, methods of network planning are used [7]. In considered task LO, LF, LP and LT are presented by the weighed graphs (see Section 5) in which edges are corresponding elements of appropriate hierarchy level (i.e. LO, LF, LP and LT accordingly), when time indices of functions, processes and subsystems are been calculated.

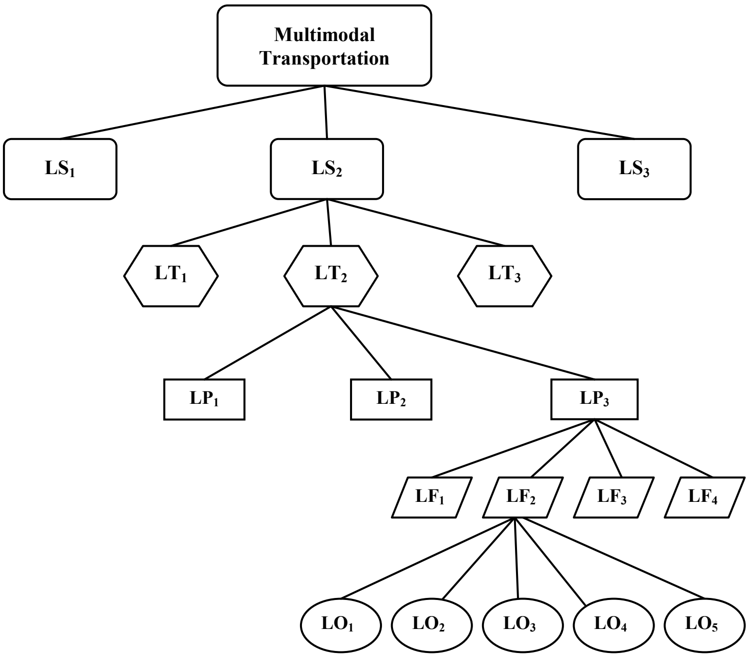


Figure 2. Decomposition of logistic system

3. Performance Criteria of the Transportation System

As it was mentioned above, we can find several alternatives for cargo delivery determined by different routes and modes, which are characterized by a set of indices for each multimodal freight transportation. To estimate the efficiency of possible transportation alternatives the system of indices, including cost, time, reliability of transportation of cargo and its safety, was offered and considered by authors in [8]. In the present research an ecological index "environmental impact from transportation" has been added to the system of criteria. It is easy to notice that the suggested indices have the various physical natures and are measured by different physical magnitudes. The part of indices is deterministic, the part is stochastic. Additional difficulties for estimating the system's indices are related to the fact that a part of indices has quantitative nature and a part has qualitative nature. For example, cost and durations of transportation are quantities, but reliability, safety and environmental impact, estimated by experts, are qualitative parameters. For conversion of qualitative indices into quantitative several approaches are offered to use, including comparative scales (for example, "Pairwise comparison scale 1–9" [9, 10]), non-comparative scales (for example, Continuous rating scale, when experts rate items by placing a mark from zero to 100), Harrington's desirability function [3], etc.

In general case a set of chosen indices is used for evaluating alternatives and searching the optimal decision in the freight transportation task, and two approaches of efficiency criteria formation can be used: mono-criterion and multiple-criteria approaches.

The *mono-criterion approach* assumes usage of one generalized optimization criterion and recognizes that various indices (delivery time, reliability of delivery, safety of cargo, etc.) can be estimated in one expression in terms of value. It allows constructing a generalized criterion of total costs E_Σ for realization of multimodal transportation, which unites a set of local criteria, among them:

- direct cost for freight transportation, i.e. expenses for cargo transportation, reloading and warehousing, customs operations, documentation, etc.;
- losses appearing as a result of delay in delivery schedule (including penalties for non-fulfilment of the delivery terms and the lost and-or half-received profit);
- losses from cargo loss, and deterioration of its consumer properties (partial or full damage of cargo which reduces its cost);
- expenses for capital freezing (they are defined taking into account cost of transported cargoes and time of delivery);
- losses related to currencies' exchange rates fluctuations;
- expenses for additional insurance of cargo;
- expenses for stock holding in case of irregular deliveries;
- losses related to environmental impact from freight transport.

At the same time, the given criterion can be supplemented with new components, considering concrete transportation system.

In general case total cost $E_\Sigma(LS_j)$ for realization of multimodal transportation of logistic system LS_j will be calculated by the following formula

$$E_\Sigma(LS_j) = \sum_{i=1}^{n} E_i \,, \tag{2}$$

where n is quantity of components (items), which form total cost for realization of multimodal transportation; E_i is a value of i-th component of expenses for realization of multimodal transportation (for example, direct cost for freight transportation; losses appearing as a result of delay in delivery schedule etc).

In this case the problem of search of optimal multimodal freight transportation system LS_{opt} on the basis of finite set of possible logistic systems $\mathbf{LS}$ has the following view:

$$E_\Sigma(LS_{opt}) = \min_{LS_j \in \mathbf{LS}} [E_\Sigma(LS_j)]\,. \tag{3}$$

In number of cases the constraints on used resources (time, technique, means etc.) are additionally introduced:

$$p_k(LS_j) \le p_k^{\max}, \quad k = 1, 2, ..., m; \ \forall LS_j \in \mathbf{LS}, \tag{4}$$

where $p_k(LS_j)$ is the value of k-th index of the logistic system LS_j; $p_k^{\max}$ is the maximum possible value for k-th index for the given multimodal transportation; m is a quantity of indices on whose constrains are imposed.

For the fixed number of variants of the systems, determined by a set $\mathbf{LS}$, the choice of an optimum variant LS_{opt} by criterion (3) consists of checking conditions (4) and calculations of total cost for realization of multimodal transportation for $\forall LS_j \in \mathbf{LS}$.

The *second approach* considers a *multiple-criteria* problem of multimodal transportation, when the system of q various criteria $C_1(LS_j), C_2(LS_j), ..., C_q(LS_j)$ is used. These criteria have the various physical natures and are measured by different physical magnitudes.

A part of criteria is minimised (for example, cost and time), and a part is maximised (for example, safety of transportation, safety of cargo). In this case we have a *vector optimisation* problem of a kind:

$$C_l(LS_{opt}) \to \underset{LS_j \in \mathbf{LS}}{extremum}, l = 1,2,...,q; LS_{opt} \in \mathbf{LS}, \tag{5}$$

where *extremum* for separate criteria corresponds to a minimum, for others – to a maximum.

In the process of the criteria system formation the authors have been focused on four groups of criteria: cost of cargo delivery, time of delivery, reliability of cargo transportation and ecological impact (or environmental impact from transportation). As a result of investigation 22 criteria were selected. The list of criteria using in the given research is presented in Table 1.

Table 1. Criteria for cargo transportation evaluation

Name of group	Criteria
Cost of cargo delivery	Costs for transportation; costs for handling; seasonal fluctuation of tariffs, costs for documentation processing; penalties (missing delivery terms); possible additional costs during transportation; additional insurance (insufficient safety)
Time of delivery	Time for transportation; time for border crossing; time for customs clearance; exchange rate fluctuation during delivery time
Reliability of cargo transportation	Exceed of delivery time; cargo safety (loss, damage of cargo); availability of transport units; safety (theft, unauthorized access to cargo); reliability of transport means
Ecological impact	Emission of CO2; emissions of harmful substances; noise and vibration; accidents and disasters from the ecological point of view; death and traumatism of people

4. Selection of the Method for a Choice of the Best Solution

There are currently various methods that have been developed and implemented to analyze and choose from a range of alternatives. These methods include multiple-criteria decision making (MCDM), multiple-criteria decision analysis (MCDA), and multiple attribute decision making (MADM) [11]. The existence of this variety of methods makes the issue of choosing the most suitable one rather difficult [12]. The authors have analysed the possibility of employing two of the most popular MCDA methods to solve the problem of choosing the best route and mode of freight transportation: the Analytic Hierarchy Process (AHP) method [9, 10] and ELECTRE method [13].

When implementing the ELECTRE method, the authors faced the problem of arranging the alternatives in the criteria table (assigning the weights). The use of a large number (22) of criteria, belonging to different professional knowledge areas resulted in an inadequate estimation of each criterion's significance. With the help of invited experts, the authors were only able to competently evaluate certain criteria which they know well. The estimations of other criteria have been arrived at by guess-work. Since the assigned weights of criteria have a great impact on the alternative choice, the authors have come to the conclusion that this method would result in largely inaccurate results.

The AHP seems to be a more attractive choice in this context since it allows structuring the choice procedure as a hierarchy of several levels. It allows the distribution of the criteria by several groups, and evaluates the significance of each group's components. Consequently, the different groups of criteria have been evaluated by different experts. For instance, the economists have assessed the cost criteria; the transport technologists have evaluated the reliability and ecological criteria, while the managers have estimated the time criteria. The opportunity of the pairwise comparison of a smaller number of criteria in every group allows the experts to determine better weighted values according to these criteria. The authors have concluded that the optimal number of criteria in each considered group should be from 3 to 7. The estimation of the significance of the criteria groups was determined by the experts with greater qualification. The AHP method also allows the possibility of controlling the consistency of the experts' judgements, making it possible to increase the reliability of estimation. In summary, the multi-criteria analysis determined the AHP as the most suitable method for comparative evaluation of different alternatives of the cargo transportation.

In the judgment of the authors, AHP method [9] is the most efficient for choice of optimal logistic system. The method allows arranging the alternatives of trasportation in the order of their efficiency and showing their difference in the given set of criteria.

5. Calculation of Delivery Cost and Delivery Time

To illustrate the offered approach, the multimodal freight transportation from Shanghai to Moscow by five alternative routes is considered. The suggested routes are the following:

- Shanghai – Hamburg – Riga – Tver – Moscow;
- Shanghai – Vladivostok – Rail Terminal in Moscow – Warehouse in Moscow;
- Shanghai – Hamburg – Kotka – Tver – Moscow;
- Shanghai – Hamburg – Klaipeda – Tver – Moscow;
- Shanghai – Alashankou – Dostyk – Rail Terminal in Moscow – Warehouse in Moscow.

Let us consider each route in details.

1. *Shanghai – Hamburg – Riga – Tver – Moscow.* This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Riga. In Riga container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

2. *Shanghai – Vladivostok – Railway terminal in Moscow – Warehouse in Moscow.* Cargo in container is delivered from Shanghai to Vladivostok by vessel, where customs clearance is being done. Further the container is loaded onto rail platform and delivered to rail terminal in Moscow. At the terminal the container is being reloaded on truck and delivered to the warehouse of consignee.

3. *Shanghai – Hamburg – Kotka – Tver – Moscow.* This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Kotka. In Kotka container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

4. *Shanghai – Hamburg – Klaipeda – Tver – Moscow.* This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Klaipeda. In Klaipeda container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

5. *Shanghai – Alashankou – Dosty – Almaty.* Cargo in container is delivered from Shanghai to Alashankou by short see vessel. In Alashankou container is reloaded onto railway platform and further delivered to Dostyk, Chinese/Kazakhstan border point. In Dostyk the container is reloaded onto railway platform of Kazakhstan railways (changing the gauge). Further the container is being delivered to rail terminal in Moscow, where customs clearance is done. After customs clearance the container is reloaded on truck and delivered to the warehouse of consignee.

Actually we are considering five logistic systems presented by the graph on Figure 3. The edge of the graph corresponds to a logistic subsystem (or to a route stage).

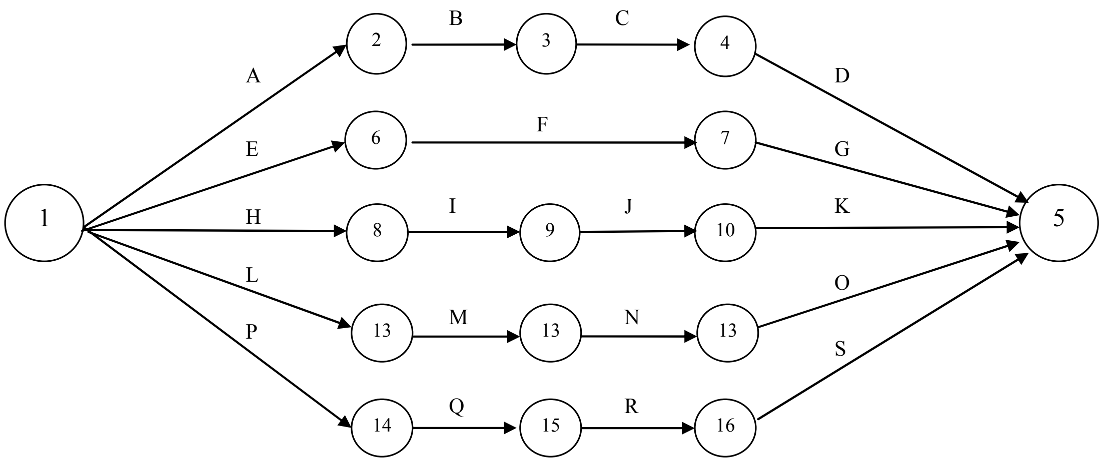


Figure 3. Logistic Systems

Description of routes LS_j, $j = 1,2,..,5$ is presented in Table 2.

Further the first route LS_1 (Shanghai – Hamburg – Riga – Almaty) will be considered in more detail. It is presented by vertexes 1-2-3-4-5 (or by edges A-B-C-D) on the graph on Figure 3. As it can be seen, logistic system LS_1 includes four subsystems (stages of routes):

stage A – cargo transportation in container from Shanghai to Hamburg, unloading of container at port of Hamburg;

stage B – loading of container onto feeder vessel, delivery from Hamburg to Riga, unloading of container at port of Riga;

stage C – loading of container on truck at port of Riga, delivery from Riga to Almaty terminal;

stage D – delivery from customs terminal to warehouse in Moscow.

Table 2. Subsystems (stages) of routes

LS_j	**Stage** LT_k	**Description of stage**
LS_1	A	Cargo transportation in container from Shanghai to Hamburg. Unloading of container at port of Hamburg
	B	Loading of container onto feeder vessel, delivery from Hamburg to Riga, unloading of container at port of Riga
	C	Loading of container on truck at port of Riga, delivery from Riga to customs terminal in Tver. Customs clearance
	D	Delivery from customs terminal to warehouse in Moscow
LS_2	E	Cargo transportation in container from Shanghai to Vladivostok. Unloading of container at port of Vladivostok. Customs clearance
	F	Loading of container onto rail platform, delivery from Vladivostok to rail terminal in Moscow, unloading of container at the terminal
	G	Loading of container onto truck, delivery from rail terminal to warehouse of consignee
LS_3	H	Cargo transportation in container from Shanghai to Hamburg. Unloading of container at port of Hamburg
	I	Loading of container onto feeder vessel, delivery from Hamburg to Kotka, unloading of container at port of Kotka
	J	Loading of container on truck at port of Kotka, delivery from Kotka to customs terminal in Tver. Customs clearance
	K	Delivery from customs terminal to warehouse in Moscow
LS_4	L	Cargo transportation in container from Shanghai to Hamburg. Unloading of container at port of Hamburg
	M	Loading of container onto feeder vessel, delivery from Hamburg to Klaipeda, unloading of container at port of Klaipeda
	N	Loading of container on truck at port of Klaipeda, delivery from Klaipeda to customs terminal in Tver. Customs clearance
	O	Delivery from customs terminal to warehouse in Moscow
LS_5	P	Cargo transportation in container from Shanghai to Alashankou. Unloading of container at port of Alashankou
	Q	Loading of container onto rail platform in Alashankou. Rail transportation Alashankou – Dostyk, unloading of container at Dostyk border terminal
	R	Loading of container onto Kazakhstan rail platform at Dostyk terminal, delivery to rail terminal in Moscow. Customs clearance
	S	Loading of container onto truck, delivery from rail terminal to warehouse of consignee

Each subsystem (stage) consists of one or several logistic processes. Let us in detail consider stage C which consists of three logistic processes, shown on Figure 4: transhipment of container, customs clearance and transportation.

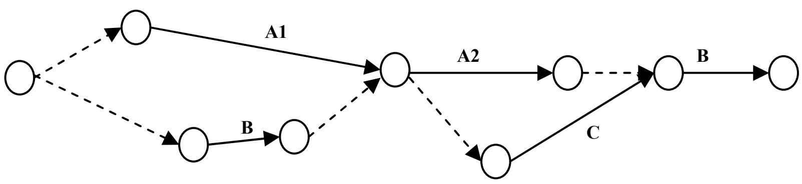


Figure 4. Logistic processes of the stage C

Each edge on Figure 4 corresponds to one process of the stage: A1 – customs clearance of incoming container; B – transhipment of container, A2 – customs clearance of outgoing container, C – cargo transportation. By dashed lines the edges used for marking “fictitious processes” (shift in time, parallel performance of processes, etc.) are shown.

Further we will make decomposition of processes into logistic functions. Let us show it on an example of process of container transhipment at port of Riga. In the offered statement of a problem, at the level of detailed elaboration accepted by us, we will allocate the following logistic functions for transhipment process:

- handling of incoming container;
- storage;
- handling outgoing container;
- processing of documents.

Schematically this process is presented on Figure 5. Each edge of the graph corresponds to a concrete function: A – handling of incoming container; B1 – processing of documents for incoming container, B2 – processing of documents for outgoing container, C – storage, D – handling of outgoing container.

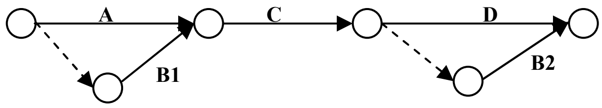


Figure 5. Process of container transhipment at port of Riga

Decomposition of the functions is shown on example of LF „Handling of outgoing container”. This function consists of a set of the following logistic operations:

- receiving truck number and sending the truck for loading;
- registration of loading in IT system of terminal;
- generating PIN code for loading;
- loading of container.

Schematically function “Handling of outgoing container” is presented on Figure 6. Each edge of the graph corresponds to the concrete logistic operation: A – receiving truck number and sending the truck for loading, B – registration of loading in IT system of terminal, C – generating PIN code for loading, D – loading of container.

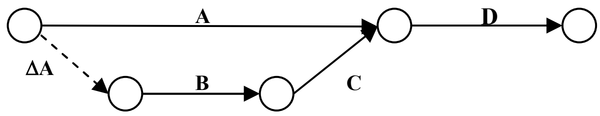


Figure 6. Logistic Function «Handling of outgoing container»

Decomposition of all elements of logistic system (route) has been similarly executed, which has allowed to define cost of transportation of cargo, using the formula (1), and to calculate time of cargo transportation from vertex 1 till vertex 5 (see Fig. 2), having defined a critical way of the obtained graph of logistic operations.

As an example, let us consider the calculation of performance duration of separate logistic function «Handling of outgoing container». The performance durations of separate operations of the function are presented in Table 3. Using the graph on Figure 6 we can find the critical way AD, it is equal 140 minutes.

Table 3. The duration of separate operations of the function “Handling of outgoing container”

Logistic Operations	Duration, minutes
A – receiving truck number and sending the truck for loading	60
ΔA – waiting time	10
B – registration of loading in IT system of terminal	15
C – generating PIN code for loading	10
D – loading of container	80

In a similar way, a critical ways for all functions, processes, subsystems and logistic system as a whole are calculated. Results of calculations of two basic indices of efficiency of the chosen routes of freight transportation (transportation cost and delivery time) are presented in Table 4. As evident from the table the decision-maker can not get a clear answer on the question what route to choice. On the one hand 1^{st} route has the lowest cost of cargo transportation, but its delivery time is 15 days greater then smallest time. On the other hand 2^{nd} route, which has the smallest delivery time, is more expensive (the cost is 19% greater). For the choice of route the priority between cost and delivery time should be chosen or multiple-criteria decision method should be applied (see Section 6).

Table 4. Efficiency indices of logistic systems

Route LS_j	**Transportation cost, USD**	**Delivery time, days**
1	6300	40
2	7500	25
3	6600	40
4	6800	42
5	9000	40

6. Multiple-Criteria Choice Using the AHP Method

As discussed in Section 4, the AHP method [10] has been chosen for evaluating the efficiency of the alternatives of cargo transportation from Shanghai to Moscow taking into consideration 5 possible routes suggested in Section 5. The chosen criteria for the routes and modes efficiency are described in Section 3. The created hierarchical structure of the criteria is shown on Figure 7.

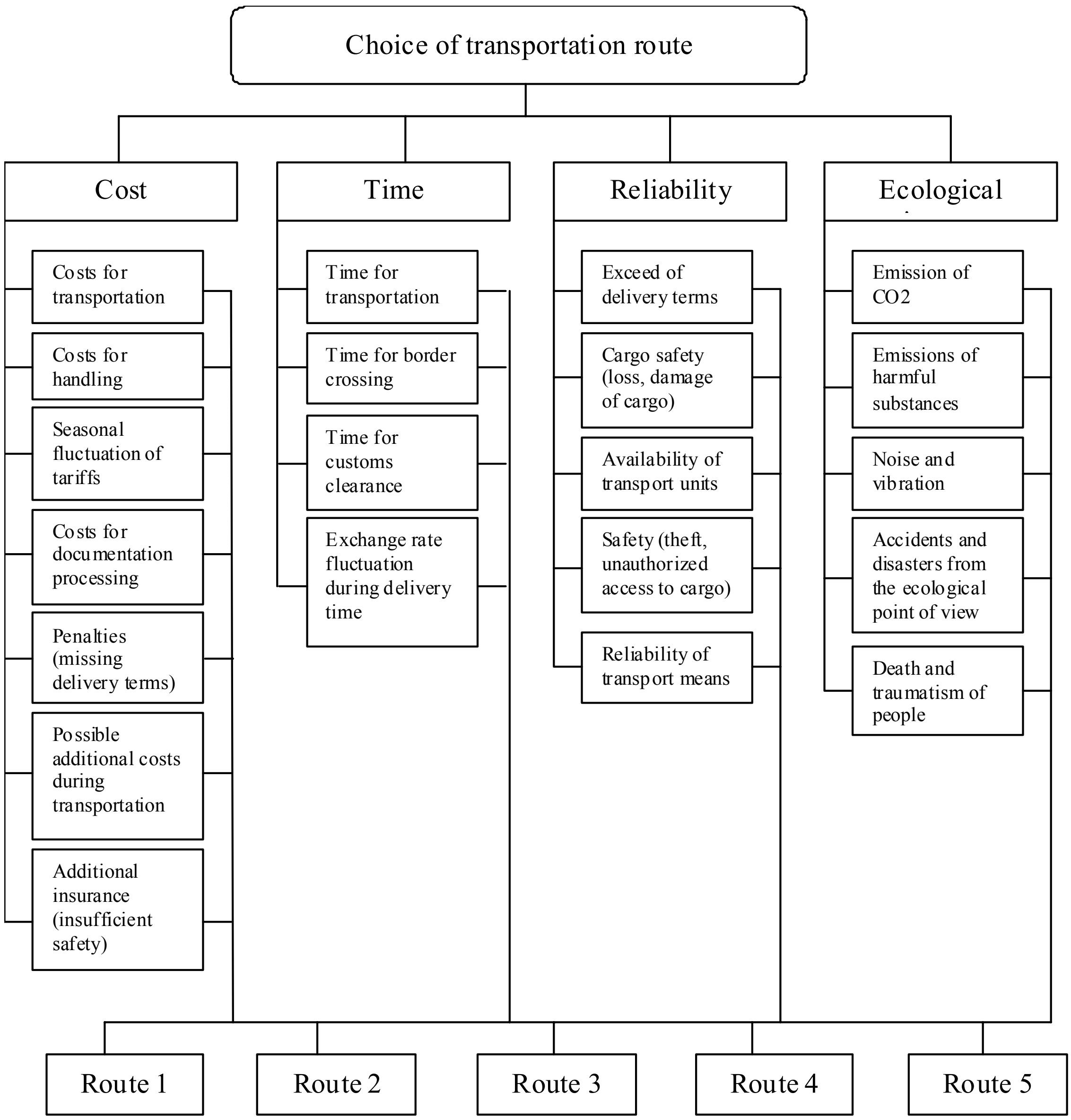


Figure 7. Hierarchy of the criteria for evaluating the routes of cargo transportation

To perform the calculations of criteria, the authors have used standard algorithms of the AHP method with the commonly used pairwise comparison scale 1–9. This scale proposed by Saaty [10] has the following values: 1 – if two alternatives **A1** and **A2** are equal in importance; 3 – if **A1** is weakly more important than **A2**; 5 – if **A1** is strongly more important than **A2**; 7 – if **A1** is very strongly more important than **A2**; 9 – if **A1** is absolutely more important than **A2**; and 2, 4, 6, and 8 are intermediate values between the two adjacent judgments. The summary data of the pairwise comparisons for the criteria of the first hierarchy level for each group are presented in Table 5. The importance of the criteria is evident from the evaluation of the criteria priority vector. It is easy to notice that "Cost" criteria with value 0,5813 of priority vector are more important for the multimodal freight transportation.

Table 5. Paired comparisons matrix for criteria (first hierarchy level)

Criteria	Cost	Time	Reliability	Ecological impact	Priority vector
Cost	1	4	5	6	0,581288
Time	1/4	1	2	5	0,220842
Reliability	1/5	1/2	1	5	0,147686
Ecological impact	1/6	1/5	1/5	1	0,050185

We have calculated the matrices of the evaluations of the priority vector for the suggested routes based on the evaluation of the criteria priority vector of two levels of the hierarchy. Table 6 gives an example of the results of pairwise comparisons and a normalised evaluation of the criterion "Costs for transportation" and Table 7 presents an example of calculating the priorities of the second level criteria "Cost". Similar calculations were made for the second level criteria Time, Reliability and Ecological impact.

Table 6. Paired comparisons matrix and results of a normalised evaluation of the criterion "Costs for transportation"

	Route 1	Route 2	Route 3	Route 4	Route 5	Priority vector
Route 1	1	4	2	2	6	0,388889
Route 2	1/4	1	1/3	1/3	4	0,100583
Route 3	1/2	3	1	1	5	0,233552
Route 4	1/2	3	1	1	5	0,233552
Route 5	1/6	1/4	1/5	1/5	1	0,043424
Total	2,4167	11,2500	4,5333	4,5333	21,0000	1,000000

Table 7. Matrix of evaluations of the vector of the criteria priorities of the "Cost" group

Alternatives	Criteria							Priorities in group "Cost"
	Costs for transportation	Costs for handling	Costs for documentation processing	Seasonal fluctuation of tariffs	Possible additional costs during transportation	Additional insurance (insufficient safety)	Penalties (missing delivery terms)	
	Numerical value of priority vector							
	0,435534	0,104360	0,024950	0,085610	0,077539	0,064833	0,207172	
Route 1	0,388889	0,346426	0,339458	0,285322	0,219304	0,083582	0,152554	0,292452
Route 2	0,100583	0,062969	0,068448	0,081937	0,052682	0,399669	0,488307	0,190261
Route 3	0,233552	0,206030	0,206514	0,285322	0,456028	0,083582	0,161589	0,227056
Route 4	0,233552	0,346426	0,339458	0,285322	0,219304	0,083582	0,152554	0,224798
Route 5	0,043425	0,038150	0,046121	0,062097	0,052682	0,349586	0,044995	0,065433

The evaluations of the vector of the global alternatives priorities are shown above in Table 8. The results of the evaluations show that route 2 has the highest value of priority 0,291997 and will be selected for cargo transportation from Shanghai to Moscow.

Table 8. Evaluating result for freight transportation from Shanghai to Moscow

Alternatives	Criteria				Global priorities
	Cost	Time	Reliability	Ecological impact	
	Numerical value of priority vector				
	0,581288	0,220842	0,147686	0,050185	
Route 1	0,290658	0,079618	0,125299	0,063250	0,208218
Route 2	0,194134	0,487666	0,371898	0,329346	0,291997
Route 3	0,226390	0,121666	0,108371	0,074537	0,178212
Route 4	0,223518	0,068267	0,135682	0,067550	0,168433
Route 5	0,065299	0,242783	0,258749	0,465317	0,153140

7. Conclusions

The constructed model of multimodal transportation system allows calculating total cost for freight transportation and total delivery time over considered routs. The received results allow choosing the most favourable route for which the criterion of system's efficiency has the optimal value.

The AHP seems to be the most attractive multiple-criteria method in this context since it allows structuring the choice procedure as a hierarchy of several levels. It allows for the distribution of criteria into several groups and the evaluation of the significance of every group's component. Consequently, the different group's criteria have been evaluated by different experts with proper qualification.

Further guidelines of the current research are the following: to find an optimal solution of the transportation problem using the simulation approach; to consider the cases with different optimization criteria.

References

1. Latvian Statistics. Retrieved Febrary 1, 2012 from http://www.csb.gov.lv/statistikas-temas/transports-datubaze-30099.html.
2. Ghiani, G., Laporte, G., Musmanno, R. (2004). *Introduction of Logistic Systems Planning and Control*. England: John Wiley and Sons.
3. Lukinsky, V. (2008). *Models and methods of the theory of logistic: the Manual*. St. Petersburg: Piter. (In Russian)
4. Gursoy, M. (2010). A method for transportation mode choice. *Scientific Research and Essays*, 5(7), 613–624.
   Available online, retrieved August 4, 2010 from http://www.academicjournals.org/SRE
5. Ivanova, O., Toikka, T., Hilmola, O. (2006). *Eurasian Container Transportation Market: Current status and future development trends with consideration of different transportation modes*. Finland, Lappeenranta: Lappeenranta University of Technology. Research Report No 179.
6. Repin, V. V. (2004). *Process Approach to Business Process Modelling Management*. Moscow: Standarti i Kachestvo. (In Russian)
7. Novitsky, N. (2004). *Network planning and production management.* Moscow: Mir. (In Russian)
8. Kopytov, E., Abramov, D. (2010). Modelling of multimodal freight transportation system using process approach. In Proceedings of the 13th International Conference on Harbour Maritime Multimodal Logistics Modelling and Simulation, September 12–14, 2011 (pp. 46–51). Rome, Italy: I3M2011.
9. Saaty, T. L. (2001). Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World. Pittsburgh, PA: RWS Publications.
10. Saaty, T. L. (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. New York: McGraw-Hill.
11. Köksalan, M., Wallenius, J., Zionts, S. (2011). *Multiple Criteria Decision Making: From Early History to the 21st Century*. Singapore: World Scientific.
12. Triantaphyllou, E. (2000). *Multi-criteria decision making methods: A comparative study*. London: Kluwer Academic Publishers.
13. Figueira, J., Mousseau, V., Roy, B. (2005). ELECTRE Methods. In J. Figueira, S. Greco, M. Ehrgott (Eds.), *Multiple criteria decision analysis: state of the art surveys, Springer's International Series,* (pp. 133–162). New York: Springer Science & Business Media, Inc.

Transport and Telecommunication, 2012, Volume 13, No 2, 159–166
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0013-9

DEVELOPMENT TRENDS OF AIR PASSENGER TRANSPORT SERVICES AND SERVICE DISTRIBUTION CHANNELS

***M. Rebezova*[1], *N. Sulima*[2], *R. Surinov*[3]**

[1]Transport Clearing House, Bolshaja Gruzinskaja 59, Moscow 123056, Russia
Ph.: +007(495)7881215. E-mail: rebezova@tch.ru

[2]Exigen Services Latvia, Strelnieku 9/3, Riga, LV-1010, Latvia
Ph.: (+371)671505515. E-mail: sulima@gmail.com

[3]Rosaviaconsorcium, Kadashevskij per. 2, Moscow 119180, Russia
Ph.: +007(495)2322516. E-mail: surinov@rosaviaconsorcium.ru

Alongside their core service, i.e., passenger transportation, air carriers are nowadays providing numerous extra services, which are not directly related to transport. On the one hand, airlines are enlarging the scope of paid services provided on board an aircraft by, among other ways, splitting the air ticket fee and singling out the costs of such services as catering on board, checked-in luggage, airport check-in, etc. On the other hand, airline companies tend to provide mass services to their sales partners – ground transportation, car rental, insurance, hotel booking, etc.

Provision of both the core and the extra services is closely connected with computerized reservation systems and the corresponding agent and customer access networks. These systems and networks form the basis of IT channels of service distribution.

The present paper analyses the indicators and development trends of air transport services in combination with the development of service distribution channels and the information technologies lying at the basis of such channels. The paper also describes the structure and IT support of distribution channels. The authors have paid attention to the potential qualitative changes in the structure and possibilities of distribution of air passenger transportation services in view of the Next Generation Network (NGN) concept whose implementation has been started in the world.

Keywords: passenger air transport services, Computer Reservation System, Global Distribution System, Information Technology, Next Generation Network

1. Introduction

Despite the positive trends in the passenger transportation indicators, world's commercial air passenger transport (civil aviation), is going through serious financial difficulties that are caused, to a certain degree, by subjective reasons, but mostly – by objective reasons, of which there are enough: remember, e.g., terrorist acts in New York and Domodedovo, volcanic eruption in Island, the earthquake and the explosion at the nuclear power station in Japan, etc. These are added to by the continuously growing aviation fuel prices, monopoly of airports and air traffic control (ATC) companies, price pressure on the part of the Global Distribution System (GDS) providers, etc. The above allows formulating the problem as follows: over the last couple of decades, the airlines "accumulated" tens of billions of losses. Many of them – the world leaders in passenger transportation – were forced to merge or to take a creditor protection procedure in order to reorganise the business and cut the expenses. Yet, the comprehensive solution to this problem lies in the implementation of additional fee-based services, both related and not related to transport. Development of the core and extra services requires diversification and optimization of distribution channels, putting forward new demands to the information technologies lying at the basis of such channels.

The objective of this research has been to analyze, through a critical overview of numerous publications, the development trends of air-passenger transportation services, and to make a connection between the development problems of the range of core and extra services and those of the distribution channels and the required IT support.

2. World's Air Passenger Transportation Indicators

The commercial air passenger transport has reached the pre-crisis level in the last years; 2.8 billion passengers were transported in 2011 [1, 2]. The following operation indicators (rounded) were reached in 2011 (cargo transportation included): income and loss – $590 billion and $575 billion accordingly; weight load factor – over 0.6; staff positions – 32 000 000; passenger load factor – approx. 0.8.

At the same time, the rate of air accidents was reduced to one per 1 400 000 flights. The carriers paid about $54 billion to the providers (airports, air traffic control (ATC), global distribution systems (GDS), etc.). However, the world air transport is burdened by the debts accumulated over the preceding decades, the total amount exceeding $50 billion. The aviation safety costs borne by the airlines and their passengers are also high – over $7 billion.

It took three years to restore the income that had decreased by $22 billion (6%) in financial year 2001. In financial year 2009, right after the world financial crisis of 2008, the income dropped again, this time by 14% ($82 billion), making $482 billion. This drop, however, was also compensated – in 2010, when the overall income of the branch went up to $554 billion, and the airlines got the $18 billion profit.

The branch restructuring that took place in the "noughties" facilitated the increase in airlines' income and flexibility in the conditions of a crisis.

Table 1.1, based on the data of [2], shows the air-passenger transportation statistics across the years; Table 1.2 shows the income before interest and taxes (passenger and cargo flights and extra services).

Table 1.1. Number of passengers transported in the world (billions of passengers)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Number of passengers (billions)	1.63	1.65	1.75	1.85	2.0	2.15	2.35	2.35	2.25	2.4	2.5

Table 1.2. Profit of the world's commercial airlines ($ billions)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Profit (loss), $ billions	(13)	(11)	(7)	(6)	(4)	3	13	(16)	(10)	8	5

In the longer term, civil aviation should be prepared *to transport 16 billion passengers annually* by 2050 [1].

In our opinion, the following circumstances remain as the key *reasons for the substantial growth of airlines' expenses and losses,* both now and in the near future:

- terrorist acts and systematic increase in the airline's expenses for anti-terrorism measures;
- climate changes (hurricanes, snowfalls, floods) and natural disasters (volcanic eruptions, earthquakes) increasingly often affecting flight schedules, causing cancellations and delays;
- the growing tension in the world, caused by the wars in the Persian Gulf and Afghanistan, "colour revolutions" in North Africa;
- unstable financial and economic situation, especially in the Euro zone;
- high prices for aviation fuel, no decrease being expected;
- monopoly of companies providing services to carriers (airports, ATC, GDS, etc.).

In the shorter term, the airlines' expenses will also increase – due to the EU decision regarding CO2 emission charge to be paid when flying through its member states; this promises the world's airlines an annual loss of tens of millions of dollars.

3. Main Projects Implemented by International Organizations and Airlines to Reduce Transportation Costs

International organisations (ICAO, IATA), state governments, and airlines themselves are implementing serious *programmes and measures* to reduce air transportation costs, e.g.:

- IATA *Vision 2050* concept [1], based on four key principles: stable income, effective infrastructure, effective technologies, loyal customers;
- IATA programme *Simplifying the Business* [3, 4], promising the annual 18-billion-dollar reduction of airlines' expenses thanks to the simplification of pre-boarding procedures in airports and more efficient information technologies;
- IATA programme *Checkpoint of the Future*, entitled to substantially reduce the security check time by dividing the passengers into three groups depending on the information available from the existing database, and organizing their passing through one of the three corridors – "Known Traveller", "Normal", and "Enhanced Security" [5, 6];
- liberalization of international regulations, aimed at the implementation of the open skies principle, and the introduction of notification procedure for the use of air space;
- structuring, aimed at the elimination of branch fragmentation (including, e.g., reduction of the number of airline companies);

- additional safety measures implemented at the expense of state budgets and reducing, to a significant extent, the carriers' expenditure in this sphere;
- straightening of air routes, which has saved the environment from 71 400 000 tonnes of CO_2 emission since 2004, and helped to cut the world's fuel expenses by $14.7 billion [7];
- modernization of the air traffic management system: giving up radars and passing over to the new generation ATM system – based on GPS and known as NextGen – that allows navigating by satellite signals instead of radio ranges, thus saving time and fuel, and, as the final result, raising the airports' capacity [8];
- extensive application of the *low cost* strategy, not only by the discount airlines, but also by the classic airline companies;
- struggle against Internet fraud (world's airlines' loss from cyber crime amounts to billions of dollars) [9];
- launching the electronic ticketing technology, which has already saved up to $3 billion for airlines in the world [3];
- launching the electronic multi-purpose document technology, which allows selling additional services on board the air transport, etc.

On their part, the airlines implement considerable projects to reduce costs by raising the decade's performance by 72%, fuel efficiency – by 21%, and cutting the expenses for service distribution channels by 33% [3].

4. Development Trends of Extra Services on Air Transport and Revenue Raising

Airlines' performance cannot be improved by *expense-cutting* alone – *revenue-raising* is what ensures development of airlines in the first place.

The main trend in the sphere of raising the revenue of the world's *civil aviation* is the *provision of extra services* conditionally divided into two groups:

- extra services directly related to passenger transportation or own activity of the airline companies;
- intermediary services related to re-sale of goods and services of other providers.

The typical *extra services of group one* are the following services provided by an airline company to other carriers: ground processing, technical maintenance, material and technical support, consulting, charters, on-board catering supplies, duty-free trade, etc.

In the last decade, group one was supplemented with passenger services directly related to transportation yet singled out from the basic fee. The fee is being split, and the "fractioned" services are paid according to a separate price-list. The large losses the companies encountered after 11 September 2011 were the main imperative reason for the development of this type of services [10]. It was then that many US air carriers started charging their passengers for on-board catering, luggage processing, window seats, etc. Thus, the companies could offer a lower transportation fee, yet increase their income from fees of other services the passengers wished to purchase.

Extra services of group two are services that are not directly related to transportation. Those are usually a part of a separate business not related to the airlines' core activity. Such services include selling various goods and services of other providers through the carrier's distribution channels.

As a result, the airline companies started resembling "flying supermarkets", and a *new airline revenue management strategy* appeared, which was more characteristic of the discount airlines. The essence of this strategy is that the *passenger load factor is more important than revenue from transportation sales*. The more passengers there are on board, the more extra services can be sold on the flight. The lower the transportation fee, the less service it includes.

Ryanair, with its super-cheap flights and a very wide range of extra services, is the most promoted airline *on the European market* [11]; already at the end of 2001, its Director General Michael O'Leary formulated the concept of extra revenue – *revenue from air ticket sales replaced by revenue from extra services*. The general success formula is as follows:

<more partners> + <millions of website visitors> + <millions of passengers> + <aggressiveness> = <high additional revenue>.

Ryanair's website is unique for the aviation branch [12]. It rather presents supportive commerce than transportation itself. The company is a leader by additional income, aggressive marketing, and the scope of commercial activity. For the purposes of this research, we introduce a simplified classification of services presented on *Ryanair's* website into the following main groups:

- services related to air transportation (sightseeing packages; VIP lounges in airports; airport transfer by minibuses; car rental; hotel, guest house and hostel booking; amusement parks and theme parks; railway express to/from Stansted airport (London); guided tours);
- consumer services (foreign currency exchange; home insurance; life insurance; property abroad; resort cottages for sale; Ryanair MasterCard; tourist insurance options);

- entertainment (Internet services and online games; instant lottery tickets; theatre, concert, and sports events tickets);
- retail trade (catalogue retailing on board; paid advertising; advertising tourist and leisure destinations).

In addition to the above-listed paid services (IdeaWorks analysis [13]), *Ryanair* collects the following fees according to the price-list:

- card payment fee for all payments made by debit card via Internet or the airline's call centre (except for *Visa Electron*);
- priority boarding fee (priority boarding is free for passengers booking their flights via Internet);
- airport check-in fee;
- fee for the first, second, and third piece of checked-in luggage;
- excess luggage fee (per 1 kg).

Diversification of airline services has led to the long-term trend of *frequent flyer* programmes evolving into *frequent buyer* programmes [14] based on the accumulation of "miles" not only for flights but also for purchase of extra services.

The classic airlines and discount airlines use modern IT to manage their revenue ("*Yield* Management"/ "Revenue Management") [15]. IT are meant to maximize the income by forecasting customer behaviour and demand, segmenting the market, optimizing the prices of various types of services, etc.

Yield Management – one of the basic revenue management tools used in the sphere of air-passenger transport [16–17]. The term was introduced by R.Crandall (American Airlines), who also considered this information technology to be the most important one for transport management in the period of deregulation in the USA [18–20]. Thus, thanks to using the *Yield Management* technology, *American Airlines* got an additional revenue of 1.4 billion US dollars within three years at the end of 1980-s.

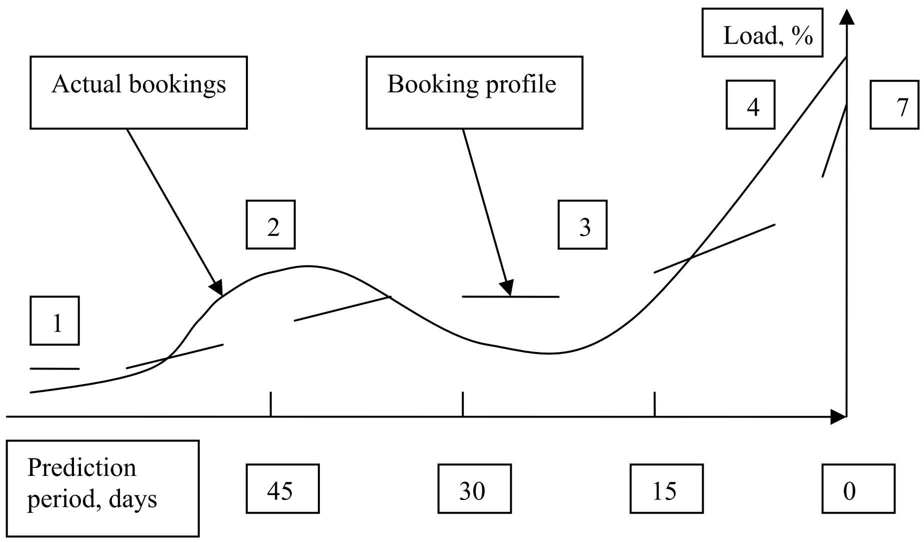


Figure 1. Example of an average and actual booking profile

The essence of *Yield Management* marketing model is in the following [21]:

Sell the "right" seat to the "right" passenger at the "right" moment for the "right" price.

Figure 1 [22] illustrates the "ideology" of one of such technologies used for seat booking. Being an example of room booking technology in hotel business, it also reflects, in our opinion, the general picture of booking passenger flights.

It is necessary to make the airlines' core and extra services available to the final consumer, i.e., the passenger. This creates another important revenue-raising task for airlines – to *diversify distribution channels* of such *services* (enlarge the range of channels).

The "booking profile" line shows the average number of bookings per each interval up to the date for which the booking is made. The "actual bookings" line shows the existing status of bookings as at the date set. The correlation of the two lines characterises the customer behaviour. The two lines moving apart, the management should immediately take certain measures:

- provide discounts or use any other alternative marketing strategy, for it is still a substantially long time till the date for which the booking is made (area 1), or the number of returned seats and non-confirmed booking is large (area 3);
- sell tickets for full price only, to maximize revenue in the conditions of high demand (area 2) or of substantial increase in the number of actual bookings (area 4).

5. Diversifying Distribution Channels of the Core and Extra Services of Air Passenger Transport

We have systematized *the channels of distribution of air-passenger transport services* and delivery of the services to customers, i.e., passengers, as shown in Figure 2. Marked out are the *direct channels (zero level channels)*, i.e., the channels with no intermediaries involved, and *multi-level channels* that may involve one or more intermediaries.

Zero level channel presupposes that the carrier sells its services through its own bureaus and representative offices in the online and offline modes. The online distribution it carried out through the carrier's homepage or web-portal. A web-portal is a complex website providing multi-services to customers.

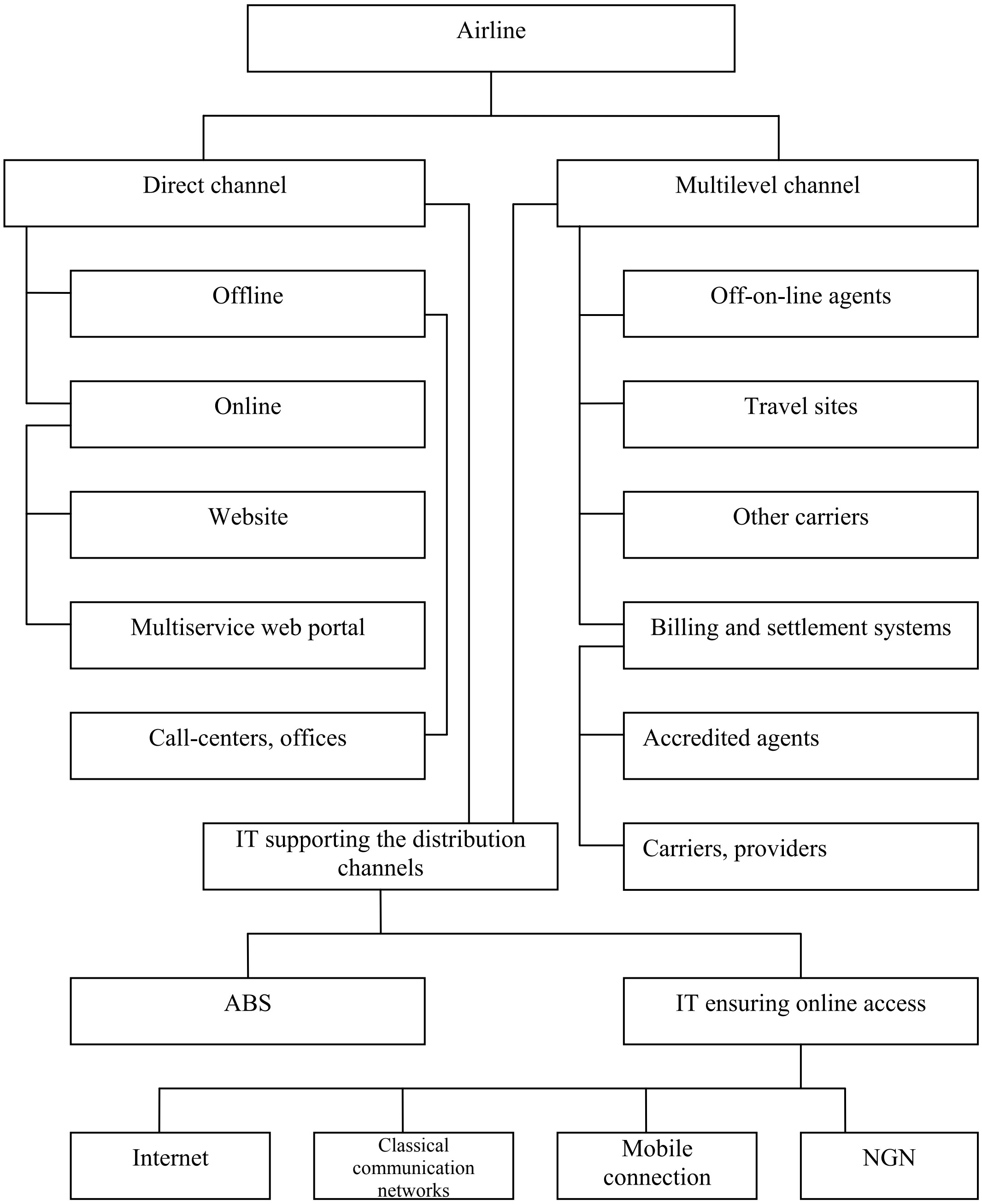


Figure 2. Distribution channels of airline services and IT sales

The *multi-level channels* include the traditional logistic chains of a carrier's sales network – "offline agents": <agent>; <agent – sub-agent>; <general agent – agent – sub-agent>. An agent's part may be played by another carrier with whom the first carrier has concluded an interline agreement on modal and multi-modal transportation, and who uses his own distribution channels to sell the first carrier's services. It should be noted that agents usually have their own multi-level channels for distribution of their own services.

"The online agents" are those selling flights and extra services only through travel sites. *Expedia, Orbitz, Travelocity* are among the largest ones.

The travel-site business is developing dynamically. According to forecasts, the volume of travel services booked online in the USA will grow from $86.6 billion (2011) to $110.7 billion (2014) [23].

Due to the development of the carriers' online sales, the number of agent businesses started decreasing all over the world. Thus, the number of travel agencies in the USA decreased from 27 700 (2001) to 15 000 (2011). However, direct online booking is becoming less attractive for many Americans. People have no one to turn to for assistance in planning a complex route; besides, the danger of cyber-fraud is growing, which makes people go back to the traditional "offline" and "on-off-line" agents. Thus, in prospect, the traditional agents' business will remain in demand, yet with the tendency towards reduction and enlargement.

In different chains of a carrier's multilevel distribution channel, the *carrier's original documents* (now including electronic tickets and multipurpose documents) are used alongside billing and settlement systems (BSS) for the processing of flight and extra service sales.

In the last two decades, the *world billing and settlement systems* have become the most important distribution channels for the services of carriers and other travel industry providers: ARC (Airlines Report Corporation) – mostly in the USA; IATA (International Air Transport Association) BSP (Billing and Settlement Plan) – in the world, except for the USA; CBBT (Air Transport Settlement System managed by the Transport Clearing House) – mostly in the CIS [24]. The BSS are overwhelmingly more important than other distribution channels, for they distribute among the accredited (own) agencies the services of its members – multiple carriers and other providers of travel and tourism services, as well as ensure settlements between all the members for all the core and extra services sold.

The BSS provide the accredited agents and member-airlines with their original *standard carriage documents* (SCD) for the processing of transportation and extra services sold; the SCD are now 100% electronic and accepted by all BSS members.

The *automated booking systems* (ABS) and the *IT ensuring online access* to ABS form the basis of the IT-based distribution channels.

ABS are divided into the carriers' *Inventory systems* and the *Global distribution systems* (GDS), the latter being independent from the carriers. GDS are an extremely powerful distribution channel, but the virtually monopolistic prices they ask for their services contradict the airlines' expense-cutting policy. Therefore, the airlines, having no potential possibility to waive the GDS services due to the high level and diversity of the service range they offer, counterbalance this disadvantage by enlarging their own service range through own inventory systems and trying to limit the agents' access through GDS to their full content (e.g., American Airlines Direct Connect technology [25]). It is, however, impossible for airline companies to refuse the GDS services. The ABS products of the airlines are not yet at the same level as the individual offers and point-of-sale packages of GDS. For this reason, it is unlikely that the volume of GDS services used by airlines will reduce in future, all the more so because even the discount airlines – such as, e.g., *EasyJet, AirTran, JetBlue, Air Berlin* – have now turned to GDS (though on different price conditions) [26, 27].

Another future-oriented project is *Google's* intention to concentrate the Internet travel sales in its "hands", offering more advantageous and comfortable conditions thanks to combining the possibilities of its Internet search engine with one of the best airline fare tracking systems – ITA Software [28]. However, the leading online agents (*Expedia* and others) are lining up against this project, accusing *Google* of the breach of anti-monopoly laws.

Access to ABS is ensured both by the classical communication means (ABS units, booking through airlines' and agencies' call-centres and bureaus), and via Internet. It is now also possible to purchase flights and extra services via *mobile phones*, tickets and documents being drawn up electronically.

6. Prospects of Distributing Air Passenger Transport Services in the Global Information Society (GIS) – Using NGN Applications

IT tools, including CRS and GDS, online products, Internet, mobile connection, now also NGN, on the one hand, and carriers, agents with their ticket offices and call-centres, and BSS, on the other hand, open vast possibilities to distribute the core and extra services of air transport through a wide range of channels and respective supportive tools. CRS-providers and GDS invest considerable resources to ensure that the developing range of services offered by their customers – airlines and the large circle of subscribers accordingly – can be booked. Even discount airlines have become GDS subscribers, for the latter offered the necessary products for an acceptable distribution price. Such a progressive and, in a way, rapid development of forming, booking, and selling technologies, in combination with the development of the IT-tool range, has led to a certain successive overlap of all these elements [29]. Taking into account the splitting of basic services and fees, mass appearance of new extra services and fees, variety of sales categories and revenue management algorithms, new business models of discount airlines, it can be stated that no entity of the aviation sphere could single-handedly make the whole set of its core and extra services available to the customer.

Basically, the above answers the question why both the growth of online sales and the reduction in the number of traditional agents have slowed down or even stopped. The customer "got lost" in the avalanche of potential possibilities offered by websites. Online booking and purchase of return flight with the whole package of extra services would in most cases be optimal as far as the price is concerned. However, in the case of connecting flights, especially those operated by different airlines with their own sets of extra services, it becomes virtually impossible to optimize the purchase by the price/quality criterion. The customer needs advice, which so far is only available offline, in a traditional agency, from highly professional operators.

In our opinion, the main development trends of airline business will depend on how effectively the following problems are solved: optimization of the structure, diversification and combined use of various distribution channels, adjustment of distribution channels to the ever expanding range of extra services in addition to the core services. New possibilities in this direction are opened by the "information and communication technologies (IT&T)" that are "one of the most important factors shaping the 21st century society", as stressed by the Okinawa Charter on Global Information Society passed by the G8 leaders in 2000 [30]. GIS throws out new challenges to the developers of information and communication services in all spheres of human activity, including air passenger transport.

NGN (Next Generation Networks) will form the basis of info-communication services in Global Information Society. The essence of NGN is partly explained by the following formula: all kinds of IT&T services for the user – "from one socket" (integration and multi-service approach) [31].

In our view, the solution to the problem of online sales tempo growth lies in the usage of NGN in combination with an "electronic consultant" (as an IT-application) for multimedia booking of air passenger transport services via CRS and GDS. In other words, the Customer, when booking and purchasing the flight and extra services, is not just "communicating" with the "electronic engine" of the carrier's or agent's website, but also using multimedia products, such as NGN applications for online consulting, ensuring the best choice of services.

7. Conclusions

1. There is a substantial trend of growth in the volumes of passenger transportation and airlines' income from all types of services in the world. The trend of growth in the airlines' expenses surpasses the income growth, which creates the negative profit trend; no loss of airlines has accumulated in the world yet. For this reason, international organizations (ICAO, IATA), state governments, and airlines themselves are implementing a complex of programmes and measures to substantially reduce the airlines' expenses related to passenger transportation.

2. Provision of various extra services, both original and offered by other providers, is one of the main trends of the world's air passenger transport in the revenue-raising sphere. This increases the importance of diversification of distribution channels for such services and the IT supporting those channels. The development of online IT-products is facilitated not only by the transition of the whole branch to a fully electronic ticketing procedure within passenger transportation, but also by the transition to electronic multi-purpose documents for the processing of sales of extra services.

3. New "players" are appearing at the air-passenger service distribution market, such as *Google*, which intends to concentrate the Internet travel sales in its "hands" by combining the possibilities of its Internet search engine with one of the best airline fare tracking systems – ITA Software.

4. We believe that in the near future one should expect the appearance of "electronic consultants" and other multimedia products in the form of NGN IT-applications, meant for booking of air passenger transport services via CRS and GDS.

5. The main development trends of airline business will depend on how effectively the following problems are solved: optimization of the structure, diversification and combined use of various distribution channels, adjustment of distribution channels to the ever expanding range of extra services in addition to the core services.

References

1. *Speech presented by IATA Director General Giovanni Bisignani at 66th IATA Annual General Meeting and World Air Transport Summit in Berlin on 7 June 2010*, from official website of IATA: www.iata.org
2. Source: Centre for Asia Pacific Aviation, IATA.
3. *Speech presented by IATA Director General Giovanni Bisignani at the press briefing in Beijing in February 2011*, from official website of IATA: www.iata.org
4. *Fast Travel Programme IATA – Simplifying the Business,* from http://www.iata.org/whatwedo/stb/Documents/Fast%20Travel%20Programme%20Strategy%.pdf
5. Pavlovsky, A. (2011). Checkpoint of the Future. *CNN*, 7 June 2011.
6. Press Releases No.: 35. 07.06.2011 IATA Reveals Checkpoint of the Future, from http://www.iata.org/pressroom/pr/pages/2011-06-07-01.aspx
7. Arnolt, S. Flightglobal. (2010, February 16).
8. Lindsay, C. Aviation is the engine of economy. (2011, January 31). New York Times.
9. Jones, C. Stolen Mile. (2010, October, 05). USA Today.
10. "Gold Rush" in the air and on the ground. (2010, February). Airline Weekly.
11. An Offer You Cannot Refuse, from http://www.traveldailynews.gr;
12. http://www.ryanair.com
13. http://www.ideaworkscompany.com
14. Plank, W. *The Wall Street Journal online*. 5 February 2010
15. Cross, R. (1997). *Revenue Management: Hard-Core Tactics for Market Domination*. New York: Broadway Books.
16. http://books.google.com/books?id=bXsyO06qikEC&pg=PA207&dq=overbooking&hl=ru&cd=7#v=onepage&q=overbooking&f=false
17. http://archive.ite.journal.informs.org/Vol3No1/NetessineShumsky/ Introduction to the Theory and Practice of Yield Management. Serguei Netessine. The Wharton School University of Pennsylvania. Robert Shumsky. W. E. Simon Graduate School of Business Administration University of Rochester
18. Wardell, David J. *Understanding Yield Management*, from http://www.wardell.org/understanding_yield_management.htm.
19. Best Practice Pricing, from http://bestpracticepricing.blogspot.com/ 8 July 2008
20. Netessine, S., Shumsky, R. (2002). Introduction to the Theory and Practice of Yield Management. *INFORM Transactions on Education,* 3(1).
21. Randall Beard, Nielsen IAG. What Advertisers Can Learn from the Airlines? Retrieved November 12, 2009, from http://blog.nielsen.com/nielsenwire/online_mobile/yield-management-what-advertisers-can-learn-from-the-airlines/Yield Management
22. http://www.rea.ru/hotel/it/metod/Text/ym.htm
23. All Kinds of Agents Are Useful. (2010, November 15). USA Today.
24. Basics of Air transport settlement system. (2011). In E. Maharev (Ed.), Transport and Telecommunication Institute Study Guide (pp. 67-75). Riga: TTI.
25. Retrieved 2011, March 23 from http://www.aa.com/i18n/agency/General/aa_direct_connect.jsp.
26. Bemer, J. Indicator of Maturity. (2010, June 1). Business Travel News.
27. Kinbi, D. Whose Nerves are Stronger, or what is behind the Conflict between American Airlines and Orbitz. (2011, January 5). Travel Daily News.
28. Lidtke, M., Tessler, D. Google Enters the Battle. (2011, February16). Canadian Business.
29. Kobi, P. One dead, the other gone insane. (2011, March). Airline Business.
30. Okinawa Charter on Global Information Society. (2000). *Diplomatic Newsletter*, 8, 52.
31. Baklanov, I. (2008). *NGN: Build-up and Organisation Principles,* Y. Chernyshev (Ed.). M.: Eko-Trends.

Transport and Telecommunication, 2012, Volume 13, No 2, 167–173
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.2478/v10244-012-0014-8

TRAFFIC FLOW SIMULATION ON DISCRETE RATE APPROACH BASE

Mihails Savrasovs

Transport and Telecommunication Institute
Lomonosova str. 1, Riga, LV-1019, Latvia
Ph.: +371 29654003. E-mail: mms@tsi.lv

The classical scientific literature dedicated to transport modelling has emphasised three levels of detail on which traffic models could be created. These levels are: microlevel, mesolevel and macroscopic level. Microscopic and macroscopic modelling are well known and widely used. The term 'mesoscopic modelling' has been interpreted by different scientists in different ways. In general, mesoscopic traffic flow models are understood to be models where traffic flow is described with a high level of detail, but at the same time flow behaviour and flow interactions are presented with a low level of description. The previously proposed new simulation approach (called 'mesoscopic simulation') was applied to traffic flow simulation. All the described models were implemented using Microsoft Excel and VBA. However, the practical application concerns that to construct more sophisticated models Microsoft Excel and VBA could not be used, because of programming complexity.

The main goal of this paper is to present examples of the application of the discrete rate approach of ExtendSim simulation software for traffic flow simulation. A literature survey has shown that the discrete rate approach is mainly used in logistics, but not in the area of transport area. So the tasks of this paper are to present the main techniques of model implementation using a discrete rate approach and to apply this approach to traffic flow simulation.

Keywords: Discrete rate, mesoscopic models, traffic flow

1. Introduction

Many new mathematical models for traffic systems have been developed. Almost all of them can be categorized as macroscopic or microscopic models. Macroscopic models [1] use differential equations and describe the behaviour of traffic flows. In such models long periods of time (days, hours) can be observed. Microscopic models use standard simulation models based, among other things, on discrete events [2] and cellular automats [3]. Models of this class are used to model short periods of time with a very high level of detail. In [4, 5] a new class of so called mesoscopic models has been described. The purpose of this model class is to take advantage of the two traditional approaches to modelling flow systems while avoiding their disadvantages such as the amount of time and labour involved in creating and implementing microscopic models.

The basic principles of mesoscopic modelling can be described as 'algorithmic management and analytical calculation' and 'discrete time and continuous quantities'. The second phrase shows that the philosophy of mesoscopic modelling has similarities with macroscopic modelling with differential equations. However, this analogy can only be observed in the presentation of numerical results. Results are presented as process graphs with the time step Δt. In mesoscopic models, relationships between variables are often implemented as complex algorithms and not as concrete formulas. This is a characteristic of microscopic simulation.

A mesoscopic model uses mathematical formulae to calculate the results as continuous quantities in every step Δt of the discrete modelling time. In contrast to the microscopic approach, the mesoscopic approach monitors quantities of objects that belong to a logical group instead of individual flow objects (e.g. customers in queuing systems). In contrast to macroscopic models, any number of groups of objects can exist at the same time in mesoscopic models, and interactions between them can be implemented.

In [5] it has been shown that 'multichannel funnels' can be effectively used as the main structural component of mesoscopic models. The process of product accumulation and processing can be modelled with this component. Flow processing is done through different strategies of resource usage.

The advantages of the mesoscopic approach are the high degree of flexibility it allows in the preparation of input data for the simulation, the universal and simple structure of its internal model data, the fact that no restrictions for modelling complex control algorithms exist, its high level of performance for computing the model code and its clear presentation of simulation results.

An example of using the mesoscopic approach for modelling a controlled crossroads is demonstrated in reference [6]. Reference [7] shows the validation of mesoscopic models on the basis of microscopic models. These references deal with using mesoscopic simulation to model a crossroads or a small group of crossroads. Unfortunately further investigation [7] shows that to model more complex transport objects such as transport corridors, Microsoft Excel with VBA cannot be used, due to issues of programming complexity. Research into possible alternatives to Microsoft Excel reveals that ExtendSim simulation software can be used. ExtendSim has a special library called ‘Rate’ approach. The description of this approach fully complies with the described mesoscopic approach to traffic simulation.

2. Discrete-Rate Approach Comparison with Traditional Approaches

The discrete rate approach is a new advanced simulation technology presented in 2009 by Imagine That, Inc. at the Winter Simulation Conference [8]. The mainly discrete rate approach is focused on logistics and manufacturing problems and used for material flow simulation. The difference between the traditional approaches (system dynamics, agent-based simulation and discrete event simulation) must be described. This description can be done on different levels.

General comparison of approaches

All the mentioned above simulation approaches (discrete rate, discrete event, system dynamics and agent-base simulation) could be separated into groups. The separation could be based on the level of detail. Discrete event simulation and agent-based simulation are mainly used at the microscopic level. The system dynamics approach can be applied at the macroscopic level. And finally, the discrete rate approach deals with the mesoscopic level. The figure below shows the relations between the levels from the point of view of input and output data.

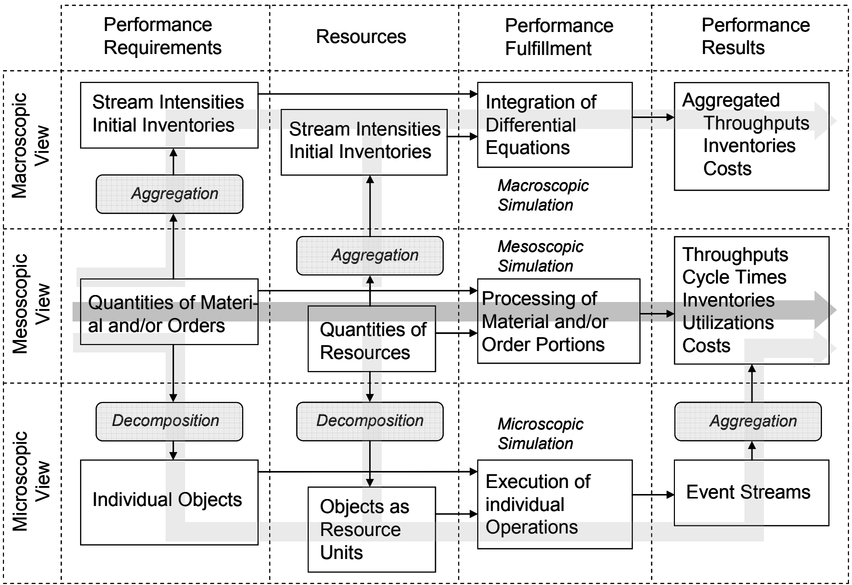


Figure 1. Relationships between levels

Figure 1 shows that application of macroscopic approaches is often connected with such operations as aggregation of data. This can explain why final results often are not very exact. The application of microscopic approaches is connected with decomposition operations. For this reason, model construction is a time-consuming process.

Detailed comparison of approaches

The following table shows a detailed comparison of the different approaches [9]. The first column is a comparison factor, the next 4 next columns present different approaches. The factors selected for comparison are: What is modelled; What causes a change in state; Time steps; Characteristics of what is modelled; Ordering; Routing; Statistical detail; Typical uses.

Table 1. Comparison of simulation approaches

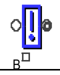
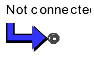
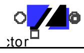
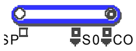
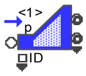
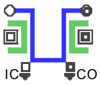
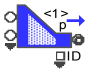
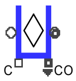
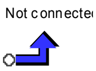
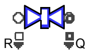
Factor	System Dynamics	Discrete event	Discrete rate	Agent-based
What is modelled	Values that flow through the model	Distinct entities (‘items’ or ‘things’)	Bulk flows of homogeneous material, or flows of otherwise distinct entities where sorting or separating is not necessary	Distinct active entities
What causes a change in state	A time change	An event	An event	An event and a time change
Time steps	Interval between time steps is constant. Model recalculations are sequential and time dependent	Interval between events is dependent on when events occur. Model only recalculates when events occur	Interval between events is dependent on when events occur. Model only recalculates when events occur	In some models the time step is a constant and could be defined as very small value. In some models events define the time intervals
Characteristics of what is modelled	Track characteristics in a database or assume the flow is homogeneous	Using attributes, items are assigned unique characteristics and can then be tracked throughout the model	Track characteristics in a database or assume the flow is homogeneous	Using attributes, items are assigned unique characteristics and behaviour
Ordering	FIFO	Items can move in FIFO, LIFO, Priority, time-delayed, or customized order	FIFO	Could be given customized order if necessary
Routing	Values need to be explicitly routed by being turned off at one branch and turned on at the other (values can go to multiple places at the same time)	By default, items are automatically routed to the first available branch (items can only be in one place at a time)	Flow is routed based on constraint rates and rules that are defined in the model (flow can be divided into multiple branches)	The routing is done based on agent behaviour
Statistical detail	General statistics about the system: amount, efficiency, etc.	In addition to general statistics, each item can be individually tracked: count, utilization, cycle time	In addition to general statistics, effective rates, cumulative amount	Information about each agent. Average characteristics across all agents or groups of agents
Typical uses	Scientific (biology, chemistry, physics), engineering (electronics, control systems), finance and economics, System Dynamics	Manufacturing, service industries, business operations, networks, systems engineering	Manufacturing of powders, fluids, and high speed, high volume processes. Chemical processes, ATM transactions. Supply chains	Social processes, biology, traffic flows

As can be seen from Table 1, the discrete rate approach is very close to the system dynamics approach. The difference between them is hidden in the ‘What causes a change in state’ factor. In the case of system dynamics there is a predefined time change, in the case of the discrete rate, the events cause a change of the state of the system. A more detailed comparison of the system dynamics approach and the discrete rate approach can be found in [8].

3. Discrete-Rate Library

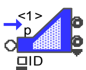
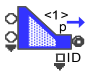
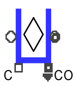
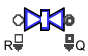
The discrete rate approach is presented in the ExtendSim library by 11 blocks, which can be used for model construction. As was mentioned before, the discrete rate approach is mostly used to simulate material flows. This is why each block can execute predefined operations with the flow. The following description can be given for each block [10].

Table 2. Rate library blocks

Block	Block name	Description
	Bias	Prioritizes the flow going through it.
	Catch Flow	This block catches flow sent by Throw Blocks or Diverge blocks
	Change unit	Changes the flow unit of measurement.
	Convey Flow	Delays the movement of flow from one point to another.
	Diverge	Distributes the input flow to two or more outputs.
	Interchange	The Interchange block represents a tank, or holding area, where flow can interact with items generated by discrete event blocks.
	Merge	Merges flows from multiple inputs into one output.
	Sensor	Reports the potential upstream supply rate and potential downstream demand rate.
	Tank	Acts as source, intermediate storage, or sink. As a residence type block, the Tank has the capacity to hold defined amounts of flow as time advances.
	Throw flow	This block sends flow received by Catch Blocks or Merge blocks even though the blocks.
	Valve	Controls, monitors, and transfers flow.

As can be seen, some of blocks can be treated as the main blocks (Valve, Tank etc.) of the library, while some of the blocks are used as a helpers (at example Interchange). Of course blocks from other ExtendSim libraries could be used in the discrete rate models. To simulate transport flow, not all the described blocks are used. The following table could be constructed to show the main role of the blocks in a transport model (Table 3). As can be seen from Table 3, we need only 6 main blocks to construct a transport model. Of course additional ExtendSim blocks could be involved to collect and visualise output data.

Table 3. Main role of blocks in a transport model

Block	Block name	Main role in transport model
	Convey Flow	Can be used to simulate a movement between two geographical points (for example between two crossroads).
	Diverge	Can be used to simulate a splitting of the transport flow into different direction (for example at a crossroads: turning left, turning right, moving forward).
	Merge	Can be used to merge traffic flows together.
	Sensor	Can be used as the main source of information for controlling flows and controlling flow interaction.
	Tank	Can be used as a source and sink. Also can be used to represent the capacity of the road.
	Valve	Controls, monitors, and transfers traffic flow.

4. Modelling and Source Data Description

As the simulation object we have selected a transport corridor. A transport corridor is a (generally linear) tract of land in which at least one main line is provided for transport. This could be a road, rail or canal facility. In this paper, by ‘transport corridor’ we mean a road which connects two or more geographical points. The need for research and analysis into transport corridors is mainly connected with the wish to locate corridor bottlenecks estimate their different characteristics (for example, the average speed along the corridor, the average travel time etc). The main idea of a transport corridor can be represented in Figure 2.

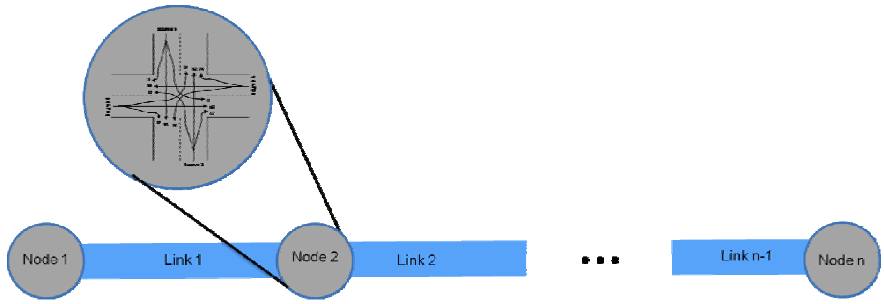


Figure 2. Schema of transport corridor

As can be seen, the structure of the transport corridor can be presented in node-link notation. The only thing which should be taken into account is a detailed simulation of the nodes. Let us assume for our example that we are going to model a transport corridor which consists of homogeneous symmetric crossroads. The number of crossroads is 3. A detailed conceptual model could be constructed (Figure 3). Nodes 1 and 2 have 3 inputs as their sources of traffic, while node 2 has only 2 inputs of traffic. The length of the links is defined: link 1 length is 100 m; link 2 length is 200 m. The structure of the crossroads in each node is the same. All crossroads are controlled by traffic lights. In this example the cycle duration for all crossroads is 50 seconds (20s+5s+20s+5s). All directions of movement are allowed. The two opposite sources have their green phase at the same time. During this time the two remaining sources have their red phase. This means that they do not interfere with each other. Transport flows are given and measured in PCUs (passenger car units). As we only want to demonstrate the general example of using a discrete rate approach for traffic flow simulation, the intensity of traffic input flow was chosen randomly.

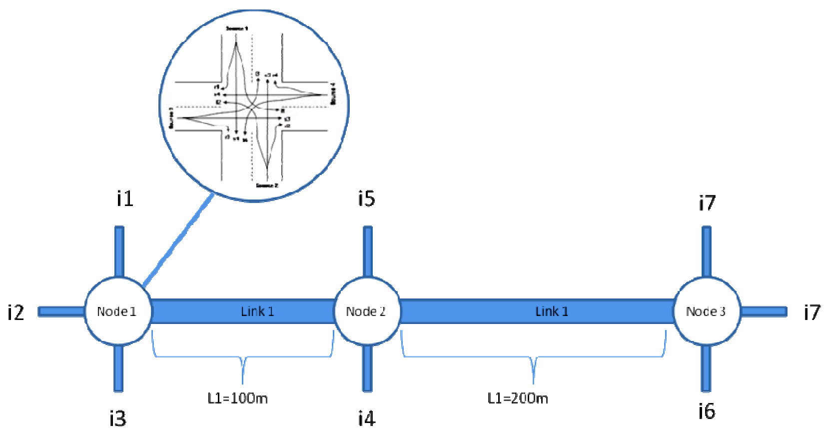


Figure 3. Simulation object

The simulation model was constructed using ExtendSim software. Because all crossroads have the same structure, the user defined object called Node was implemented. This object presents one crossroads. Using this object the following model was constructed (see Figure 4).

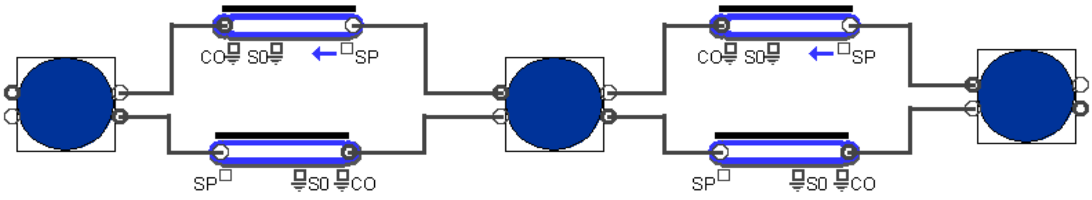


Figure 4. High level model constructed using ExtendSim

To connect Node objects to the transport corridors, a standard ExtendSim block Convey Flow was used. Each Convey Flow represents the direction and the opposite direction of the link. To connect a Convey Flow block with a Node block, 2 input and 2 output ports were implemented for the Node block. Each node block has almost the same structure; defined in terms of standard blocks. The figure below demonstrates a part of the Node block.

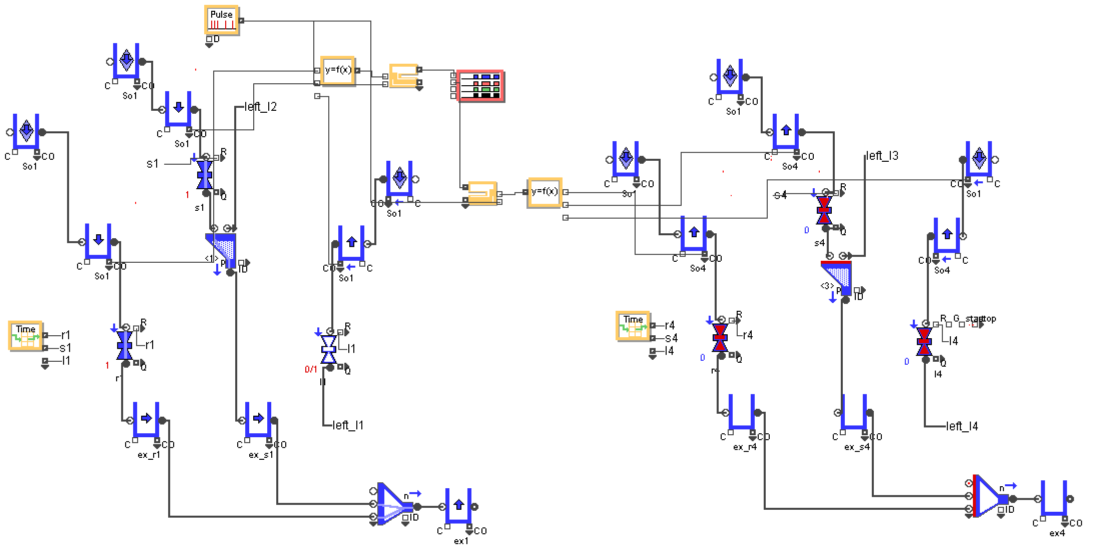


Figure 5. A part of the Node block

As can be seen for the Node object construction, only standard blocks from the Discrete-Rate library plus some additional blocks from other libraries were used.

The main output results of the simulation can be presented in the form of graphs which show different statistics such as:

- maximum queue length,
- average queue length,
- minimum queue length,
- maximum and average waiting time,
- the loading level of each crossroads in terms of crossroads utilisation.

5. Conclusions

- Because of the disadvantages of microscopic simulation and the disadvantages of macroscopic simulation, a new mesoscopic approach for traffic modelling is proposed in this article.
- Earlier attempts to demonstrate the potential of this new approach used Microsoft Excel and VBA. Unfortunately, owing to the large number of simulation objects, the complexity of the programming increased substantially. Therefore it was decided to use ExtendSim simulation software. A discrete rate approach realised with this software fully realised all the key components of mesoscopic simulation.
- The ExtendSim discrete rate library is proposed for material flow simulation. Consequently, this is mainly orientated towards logistics and production.

- This article demonstrates how the discrete rate approach can be used to simulate transport corridors. The analysis of the block set of the library showed that only 6 of 11 blocks could be used for traffic flow simulation. These 6 blocks fully cover the required functionality needed to construct the model.
- A comparative analysis was conducted to show the differences between the discrete rate approach and classical approaches such as discrete events, system dynamics and agent-based simulations.
- Unfortunately, during the final analysis of the model, the following inaccuracies were found: the proposed model does not take into account that the running link length could become shorter because of growing queues before a crossroads; also, the growing queues do not influence the incoming flow (the incoming traffic flow can still pass the crossroads). These problems lead to inaccurate simulation results. Possible future research could examine how to bypass these disadvantages.
- This article demonstrates only a general approach towards using the Discrete-Rate approach, but the constructed model should be validated using existing models. This could also be the subject of future work.

Acknowledgments

The article is written with the financial assistance of the European Social Fund. Project Nr. 2009/0159/1DP/1.1.2.1.2/09/IPIA/VIAA/006 (The support in Realisation of the Doctoral Programme 'Telematics and Logistics'of the Transport and Telecommunication Institute).

References

1. Kühne, R. D., Rödiger, M. B. (1991). Macroscopic simulation model for freeway traffic with jams and stop-start waves. In Proceedings of the Winter Simulation Conference, 8-11 December (pp. 762-770). USA Phoenix, AZ: ACM Press.
2. Yatskiv, I., Yurshevich, E., Savrasov, M. (2007). Investigation of Riga Transport Node Capacity on the Basis of Microscopic Simulation, In Proceedings of the 21st European Conference on Modelling and Simulation (ECMS 2007), Prague, Czech Republic, 4-6 June (pp. 584-589). Prague, Czech Republic: Curran Associates, Inc.
3. Esser, J., Schreckenberg, M. (1997). Microscopic simulation of urban traffic based on cellular automata. *Int. J. Mod. Phys*. C 8(5), 1025-1036.
4. Tolujew, J., Alcalá, F. (2004). A Mesoscopic Approach to Modelling and Simulation of Pedestrian Traffic Flows. In G. Horton (Ed.), Proceedings of the 18th European Simulation Multi-Conference, SCS International, Ghent, 13-16 June (pp. 123-128). Magdeburg, Germany: International SCS Publishing House.
5. Savrasov, M., Toluyew, Y. (2007). Application of Mesoscopic Modelling for Queuing Systems Research. In I. V. Kabashkin, I. V. Yatskiv (Eds.), *Reliability and Statistics in Transportation and Communication* (pp. 94-99). Riga: Transport and Telecommunication Institute.
6. Tolujew, J., Savrasov, M. (2008). Mesoscopic approach to modelling a traffic system. In Proceedings of the International Conference Modelling of Business, Industrial and Transport Systems, 7-10 May (pp. 147-151). Riga: Transport and Telecommunication Institute.
7. Savrasov, M., Toluyew, Y. (2008). Transport system's mesoscopic model validation using simulation on microlevel. In Proceedings of the 8th International Conference, Reliability and Statistics in Transportation and Communication, 15-18 October (pp. 297-304). Riga, Latvia: Transport and Telecommunication Institute.
8. Krahl, David. (2009). ExendSim advanced technology: discrete rate simulation. In Proceedings of the 2009 Winter Simulation Conference, 13-16 December (pp. 333-338). Austin, TX, USA: WSC
9. Official webpage of ExtendSim, 04.04.2012 from www.extendsim.com
10. Imagine that, ExtendSim User Guide. Imagine that, 04.04.2012 from http://www.extendsim.com/support_manuals.html. ISBN: 978-0-9825040-0-0

Transport and Telecommunication, 2012, Volume 13, No 2
Transport and Telecommunication Institute, Lomonosov 1, Riga, LV-1019, Latvia

Authors' index

Abramov, D.	148
Bureika, G.	138
Griskeviciene, D.	108
Griskevicius, A.	108
Griskeviciute-Geciene, A	108
Kopytov, E.	148
Labanauskas, G.	101
Lazauskas, J.	138
Matijošius, J.	138
Nagurnas, S.	138
Palšaitis, R.	101
Pavlyuk, D.	123
Pečeliūnas, R.	138
Rebezova, M.	159
Savrasovs, M.	167
Sulima, N.	159
Surinov, R.	159
Valiūnas, V.	138

Igor V. Kabashkin (born in Riga, August 6, 1954)

- Vice-rector for Research and Development Affairs of Transport and Telecommunication Institute, Professor, Director of Telematics and Logistics Institute
- Ph.D in Aviation (1981, Moscow Institute of Civil Aviation Engineering), Dr.sc.habil. in Aviation (1992, Riga Aviation University), Member of the International Telecommunication Academy, Member of IEEE, Corresponding Member of Latvian Academy of Sciences (1998)
- **Publications:** 390 scientific papers and 67 patents
- **Fields of research:** information technology applications, operations research, electronics and telecommunication, analysis and modelling of complex systems, transport telematics and logistics

Irina V. Yatskiv (born in Krasnoyarsk, Russia)

- Vice-Rector of Transport and Telecommunication Institute, Professor of Computer Science Department
- **Education:** Riga Civil Aviation Engineering Institute, studied computer science and obtained an engineer diploma in 1982
- **Scientific and university degrees:** Candidate of Technical Science Degree (1990), Riga Aviation University, Dr.sc.ing. (1992)
- **Scientific activities:** Member of Classification Society of North America, Member of Latvian Simulation Modelling Society, Director of Latvian Operation Research Society, the leader of project BSR INTERREG III B Programme InLoC, and projects connected with transport system simulation in Latvia
- **Publications:** more than 70 scientific papers and teaching books
- **Fields of research:** multivariate statistical analysis, modelling and simulation, decision support system

Eugene A. Kopitov (born in Lignica, Poland, December 5, 1947)

- Dr.habil.sc.ing, Professor, Transport and Telecommunication Institute, Member of International Telecommunication Academy
- Director of Programs "Master of Natural Sciences in Computer Science" and "Master of Engineering Sciences in Management of Information Systems" (Transport and Telecommunication Institute)
- **University study**: Riga Civil Aviation Engineering Institute (1966–1971); Candidate of Technical Science Degree (1984), Kiev Civil Aviation Engineering Institute); Dr.sc.ing. (1992) and Dr.habil.sc.ing. (1997), Riga Aviation University
- **Publications:** 276 publications, 1 certificate of inventions
- **Fields of research:** computer science and information technology applications, mathematical and computer modelling, system analysis, modern database technologies

Gintautas Labanauskas (born in Silute, Lithuania, June 19, 1963)

- Head of State Enterprise „Lithuanian Inland Waterways Authority", lecturer at Aleksandras Stulginskis University, lecturer at Kaunas University of Technology
- **Scientific and university degrees:** Syzran High Military Aviation College for Pilots, pilot engineer, 1986; Kaunas University of Technology, Faculty of Informatics, Master's degree in Computer Engineering, 2004; Vilnius Gediminas Technical University, Doctorate 2010
- **Publications:** author of 10 scientific publications
- **Fields of research:** development of transport infrastructure, logistics

Ramūnas Palšaitis

- Doctor habil., Professor (1997) of Transport Management Department Vilnius Gediminas Technical University
- **Publications:** author or co-author of 200 scientific publications, including monograph "Planning of operational and strategic activities of transport in the system of the logistics" (1994), manuals "Transport Economics" (1996), "Marketing and Quality Management in Transport" (1997), "Logistics .Terms and abbreviations" (2001), Fundamentals of business logistics (2003). Logistics management (2003), Fundamentals of Logistics management (2004, 2005, 2008), Contemporary logistics (2010), Transport and logistics service of international business (2011)
- He has participated in a number of National and EU-funded projects as team leader, senior researcher, local expert. Participated in many national and international projects and studies concerning national transport masterplan in Lithuania, national and regional transportation studies, international and national logistics projects and studies concerning intermodal transport, overall transport models for goods transport

Daiva Griskeviciene (born in Vilnius, Lithuania, January 23, 1950)

- Associated Professor in Department of Transport Management of Vilnius Gediminas Technical University
- **Education:** Construction engineer in urban planning and transport (1973); PhD student in Urban Engineering (1975–1978, Vilnius Engineering Construction Institute (VISI)); Candidate of Technical Science Degree (1982, Moscow Institute of Civil Engineering (MISI)); Doctor of Technical Sciences (1993, Lithuanian Academy of Sciences, nostrification)
- **Publications:** more than 60 scientific papers and teaching books
- **Fields of research:** analysis on passenger public transport market demand; support of passenger public transport system; forecast and planning of passenger and freight transportation; possibilities of infrastructure development and project assessment; transport development strategy; applied economy of transport

Algirdas Juozapas Griskevicius (born in Zarasai, Lithuania, April 21, 1944)

- Associated Professor in Department of Transport Management of Vilnius Gediminas Technical University
- **Education:** Engineer-economist in industrial economy and organization (1967, Kaunas Polytechnic Institute (KPI)); PhD student in Economic Institute of Academy of Sciences (1972–1976); Candidate of Economic Science Degree (1976, Lomonosov Moscow State University); Doctor of Social Sciences (1993, Lithuanian Academy of Sciences, nostrification)
- **Publications:** more than 60 scientific papers and teaching books
- **Fields of research:** capital market research; assessment of efficiency of investment appliance; improvement of legislation on regulation of investment processes; development of investment mechanism; attraction of investment to transport sector; improvement of transport charge systems

Ausrine Griskeviciute-Geciene (born in Vilnius, Lithuania, April 26, 1981)

- Assistant in Department of Urban Engineering of Vilnius Gediminas Technical University
- **Education**: Master Degree of construction engineer in urban Engineering and Transport. Ph.D student in Science of Technology, Urban engineering (2008–2012, Vilnius Gediminas Technical University)
- **Publications:** more than 10 scientific papers
- **Fields of research:** sustainable urban development; development of urban and road transport infrastructure, assessment of investment projects

Jonas Lazauskas (born in Švenčionėliai, Lithuania, June 13, 1953)

- Associate Professor of Dept. of Transport Management, Vilnius Gediminas Technical University
- **Education:** Vilnius Gediminas Technical University studied Transport economics and management and obtained an Engineer-Economist diploma in 1976
- **Scientific and university degrees:** Candidate of Social Science Degree (1984), Moscow Road Transportation Institute, Dr.social.sc. (1993)
- **Publications:** more than 50 scientific papers and teaching books
- **Fields of research:** Economy of Transport, Finance of Transport Enterprises, Cargo Transportation, Analysis of Enterprises Activity

Gintautas Bureika (born in Kaunas, Lithuania, on June 21, 1964)

- Assoc Professor at Department of Railway Transport of Vilnius Gediminas Technical University (VGTU)
- **Scientific and university degrees:** Doctor of Technical Sciences (1997, Vilnius Gediminas Technical University), Master of Engineering (1992, VGTU), Engineer Mechanic (1990, VGTU)
- **Scientific activities:** Member of Scientific Committee of International Congress of „KONES" in Poland (since 2006), Member of the Editorial Board of journal "Transport" (since 2009), Member of European Rail Researchers Association "EURNEX" (since 2009), Member of Technical Committee "Safety of Trackless Land Vehicles" at Lithuanian Department of Standardization (since 2010)
- **Publications:** more than 60 scientific papers, 4 teaching books and 1 patent
- **Fields of research:** transport innovative technologies, vehicles exploitation effectiveness, transport traffic safety, renewable energy resources and environment, transport energy efficiency

Valdas Valiūnas (born in Klaipėda, Lithuania, on May 5, 1952)

- Associate Professor of Vilnius Gediminas Technical University, Department of Automobile Transport
- **Education:** at Vilnius Gediminas Technical University studied Mechanical Technology and obtained an Engineer-mechanic Diploma in 1975
- **Scientific and university degrees:** Candidate of Technical Science Degree (1983), Moscow Road Transportation Institute, Dr Tech. Sc. (1992)
- **Publications:** more than 50 scientific papers and teaching books, 3 patents
- **Fields of research:** designing of internal combustion engines, ensuring effective exploitation of vehicles, transport infrastructure and logistics, traffic safety problems, transport ecology

Robertas Pečeliūnas (born in Panevėžys, Lithuania, May 21, 1975)

- Associate Professor of Vilnius Gediminas Technical University, Department of Automobile Transport
- **Education:** Vilnius Gediminas Technical University, studied transport engineering and obtained a master diploma in 1999
- **Scientific and university degrees:** Defended Doctor Degree Technological Science field, Transport Engineering direction and obtained Doctor of Science Degree, Vilnius Gediminas Technical University, 2005
- **Publications:** more than 50 scientific papers and teaching books
- **Fields of research:** roads traffic safety problems research, automobile dynamics, transport infrastructure and logistics, traffic accidents expertise

Jonas Matijošius (born in Vilnius, Lithuania, 21th August, 1981)

- Lector of Vilnius Gediminas Technical University, Department of Automobile Transport
- **Education:** Vilnius Gediminas Technical University, studied mechanical engineering an engineer-mechanic bachelor diploma in 2003, Vilnius Gediminas Technical University, studied mechanical engineering an engineer-mechanic master diploma in 2005
- **Scientific and university degrees:** PhD of Technological Sciences – Transport Engineering field (03T) (2012), Vilnius Gediminas Technical University
- **Publications:** more than 15 scientific papers
- **Fields of research:** designing of internal combustion engines, biofuels, transport ecology, alternative energy in transport

Saulius Nagurnas (born in Vilnius, Lithuania, September 2, 1976)

- **Assoc. professor of Department of Automobile Transport, Vilnius Gediminas Technical University.**
- **Education:** Transport Engineering Bachelor, Vilnius Gediminas Technical University, 1998, Transport Engineering Master Degree, Vilnius Gediminas Technical University, 2000, Doctor of Technological Science, Vilnius Gediminas Techni`cal University, 2005
- **Publications:** more than 26 scientific papers
- **Fields of research:** automobile diagnostics, reliability of transport machinery, roads traffic safety problems

Dmitry V. Pavlyuk (born in Saratov, Russia, July 6, 1980)

- Docent of Mathematical Methods and Modelling Department
- **Education:** Saratov State University, Department of Mechanics and Mathematics, Information Systems (in Economics) (2002)
- **Scientific and university degrees:** Candidate of Economic Science Degree (2005) on Mathematical Methods in Economics
- **Publications:** 34 scientific papers
- **Fields of research:** econometric analysis (stochastic frontier models; spatial models), statistics

Mihail M. Savrasov (born in Daugavpils, November 5, 1982)

- Head of Research and Development Department of the Transport and Telecommunication Institute
- Ph.D student (speciality – Transport Telematics and Logistics) in Transport and Telecommunication Institute
- **Publications:** 21 scientific papers
- **Scientific activities:** applied statistical analysis, modelling and simulation

Marina Rebezova (born in Moscow, 30 April 1972)

- Head of department at Transport Clearing House
- **University study**: State institution of higher professional education – Moscow Aviation Institute (State University of Airspace Technology): Systems engineer
- **Publications**: materials for study guide, 3 intra-branch ATSS standards
- **Fields of research**: billing and settlement systems and technologies

Nicholai Sulima (born in Riga, October 1981)

- Systems architect at Exigen Services Latvia JSC
- **University study**: Riga Aviation University: Mg.sc.ing.
- **Publications**: 1 publication
- **Fields of research**: IT, programming

Roman Surinov (born in Moscow, November 1983)

- Chairman of the Board of Directors of JSC FPG Rosaviaconsortium
- **University study**: State institution of higher professional education – Moscow Aviation Institute (State University of Airspace Technology): Mathematics engineer
- **Publications**: 7 publications
- **Fields of research**: Air sales proceedings; IT

CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, Volume 13, No 2, 2012 (Abstracts)

Labanauskas, G., Palšaitis, R. Investment Risk Management and Economic Aspects of Transport Infrastructure Development, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 101–107.

The major causes of investment riskiness into transport infrastructure relate to international economy instability, lack of clearly defined and accurate information on the overall processes of international intermodal transportation, absence of objective information due to inconsequent market research as regards interpretation of economic, political and other aspects.

Assessment of objective integrated investments into public transport sector as a very specific branch of economy should necessarily be evaluated as multiple indicators affecting different spheres of community, and the final solution should be drawn when all multi-criteria indicators are well appraised. Economy based grounding of the optimal choice from all possible variants when solving specific tasks of the transport sector, depends on the economic expediency of the constructed subject. The main factors of effective usage of investments become apparent in the process of solving the task of road or railway network development optimisation.

Keywords: transport, infrastructure, investments, efficiency, risk

Griskeviciene, D., Griskevicius, A., Griskeviciute-Geciene, A. A New Approach to Assessment of Infrastructure Projects on Urban Transport Systems, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 108–122.

The scientific analysis of currently used assessment principles of the development on urban transport systems; subsystems on vehicles, passenger and freight transportations, special public services, pedestrian and bicyclists has been carried out. Each subsystem needs technical infrastructure, the set of informational and traffic control means. Moreover quantitative and qualitative development of transport infrastructure is necessary for appropriate operating of whole communication system. Unfortunately an increase in the level of automobilization, growing transport flows in urban territories and decreasing investment for the development of transport infrastructure are the main barriers for urban development. An uncontrolled increase in automobilization changed the character of the usage of urban territories, urban structure, stimulated the process of agglomeration and formed new problems.

The results of expert evaluation and statistical analysis highlighted the influence of each subsystem on the sustainable development of whole urban transport system by technical, traffic safety, social-economic, environmental and other specific aspects. Objects of technical infrastructure that should be treated as infrastructure of urban road transport system were identified. The results of statistics analysis allowed determine features of separate objects necessary to evaluate; assess and adjust separate stages, key principles and quantitative and qualitative criteria of assessment of the development on urban transport systems infrastructure.

Keywords: sustainable development, urban transport systems, project assessment, statistical analysis, expert survey

Pavlyuk, D. Airport Benchmarking and Spatial Competition: a Critical Review, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 123–137.

During the last two decades the European airport industry is liberalised and turned to competitive market environment. This fact attracts an increasing scientific and practical interest to analysis of airport efficiency and its determinants, as well as different aspects of airport competition. This paper contains a critical review of existing researches in these two areas – airport efficiency and spatial competition among airports. We analysed modern approaches to airport benchmarking, their advantages and shortcomings, and systematised a wide range of related academic studies. We paid special attention to empirical researches of spatial competition as a factor affecting airport efficiency. Despite the fact of a well-developed theory of spatial competition and signs of its growing effects in the airport industry, we discovered a lack of studies devoted to the relationship between airport efficiency and spatial competition.

Keywords: airport efficiency, benchmarking, spatial competition

Lazauskas, J., Bureika, G., Valiūnas, V., Pečeliūnas, R., Matijošius, J., Nagurnas, S. The Research on Competitiveness of Road Transport Enterprises: Lithuanian Case, Vol. 13, No 2, 2012, pp. 138–147.

In the paper, various opinions of Lithuanian and foreign authors of scientific publications are reviewed and the criteria for assessing competitiveness of road transport are discussed upon. On assessment of competitiveness of services provided by Lithuanian road transport enterprises, not only technical options are taken into account. It is proposed to assess competitiveness of enterprises upon taking into consideration the total set of services provided as well as their quality and the marketing level of the enterprise. In the paper, the factors impacting competitiveness of road transport are discussed upon and the research works required for objective assessment of competitiveness of road transport are foreseen. A model for assessing competitiveness of road transport enterprises realized by the authors is provided. In the end of the paper, conclusions and recommendations are provided.

Keywords: competitiveness of enterprises, competitiveness assessing, concordance, AHP method

Kopytov, E., Abramov, D. Multiple-Criteria Analysis and Choice of Transportation Alternatives in Multimodal Freight Transport System, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 148–158.

In the paper the multimodal freight transportation system with a finite number of known alternatives, defined by the routes and modes, is considered. The objective of research is to suggest the approach for evaluation and choice the alternatives of cargo transportation. The following main tasks are considered: choice of indices characterizing efficiency of multimodal transportations, formation of optimization criteria of the multimodal freight transportation, construction of the model of the multimodal transportation system, calculation the performance criteria of cargo transportation. The study presents the Analytic Hierarchy Process (AHP) as the most suitable approach for comparative evaluation of different routes and modes of cargo transportation.

Keywords: multimodal freight transportation, logistic system, business-process, criteria of optimization, route, Analytic Hierarchy Process

Rebezova, M., Sulima, N., Surinov, R. Development Trends of Air Passenger Transport Services and Service Distribution Channels, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 159–166.

Alongside their core service, i.e., passenger transportation, air carriers are nowadays providing numerous extra services, which are not directly related to transport. On the one hand, airlines are enlarging the scope of paid services provided on board an aircraft by, among other ways, splitting the air ticket fee and singling out the costs of such services as catering on board, checked-in luggage, airport check-in, etc. On the other hand, airline companies tend to provide mass services to their sales partners – ground transportation, car rental, insurance, hotel booking, etc.

Provision of both the core and the extra services is closely connected with computerized reservation systems and the corresponding agent and customer access networks. These systems and networks form the basis of IT channels of service distribution.

The present paper analyses the indicators and development trends of air transport services in combination with the development of service distribution channels and the information technologies lying at the basis of such channels. The paper also describes the structure and IT support of distribution channels. The authors have paid attention to the potential qualitative changes in the structure and possibilities of distribution of air passenger transportation services in view of the Next Generation Network (NGN) concept whose implementation has been started in the world.

Keywords: passenger air transport services, Computer Reservation System, Global Distribution System, Information Technology, Next Generation Network

Savrasovs, M. Traffic Flow Simulation on Discrete Rate Approach Base, *Transport and Telecommunication,* Vol. 13, No 2, 2012, pp. 167–173.

The classical scientific literature dedicated to transport modelling has emphasised three levels of detail on which traffic models could be created. These levels are: microlevel, mesolevel and macroscopic level. Microscopic and macroscopic modelling are well known and widely used. The term 'mesoscopic modelling' has been interpreted by different scientists in different ways. In general, mesoscopic traffic flow models are understood to be models where traffic flow is described with a high level of detail, but at the same time flow behaviour and flow interactions are presented with a low level of description. The previously proposed new simulation approach (called 'mesoscopic simulation') was applied to traffic flow simulation. All the described models were implemented using Microsoft Excel and VBA. However, the practical application concerns that to construct more sophisticated models Microsoft Excel and VBA could not be used, because of programming complexity.

The main goal of this paper is to present examples of the application of the discrete rate approach of ExtendSim simulation software for traffic flow simulation. A literature survey has shown that the discrete rate approach is mainly used in logistics, but not in the area of transport area. So the tasks of this paper are to present the main techniques of model implementation using a discrete rate approach and to apply this approach to traffic flow simulation.

Keywords: Discrete rate, mesoscopic models, traffic flow

TRANSPORT and TELECOMMUNICATION, 13.sējums, Nr.2, 2012 (Anotācijas)

Labanauskas, G., Palšaitis, R. Investīciju riska menedžments un transporta infrastruktūras attīstības ekonomiskie aspekti, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 101.–107. lpp.

Investīciju transporta infrastruktūrā riska galvenie cēloņi attiecas uz starptautiskās ekonomikas nestabilitāti, skaidri noteiktas un precīzas informācijas par starptautiskiem kombinētiem pārvadājumiem trūkums, kā arī objektīvas informācijas izpalikšana līdz ar nekonsekvento tirgus izpēti. Ekonomika, balstīta uz optimāla izvēles pamata, no visiem iespējamiem variantiem, risinot īpašos transporta sektora uzdevumus, ir atkarīga no konstruēto tēmu ekonomiskās lietderības. Investīciju efektīvas izmantošanas galvenie faktori kļūst redzami, jau risinot ceļu un dzelzceļa tīkla attīstības optimizācijas procesu.

Atslēgvārdi: transports, infrastruktūra, investīcijas, efektivitāte, risks

Griskeviciene, D., Griskevicius, A., Griskeviciute-Geciene, A. Jauna pieeja novērtējumam infrastruktūras projektiem par pilsētas transporta sistēmām, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 108.–122. lpp.

Autore ir veikusi pašreizējā momentā lietotu novērtēšanas principu zinātnisku analīzi par pilsētas transporta sistēmas attīstību: transportlīdzekļu apakšsistēmas, pasažieru un kravu pārvadājumi, īpašie sabiedriskie pakalpojumi, gājēji un riteņbraucēji. Ikvienai apakšsistēmai ir nepieciešama tehniskā infrastruktūra, informatīvais un satiksmes kontroles līdzekļu pakete.

Automobilizācijas nekontrolētā palielināšanās mainīja pilsētas teritorijas izmantošanas raksturu, pilsētas struktūru, veicināja aglomerācijas procesu, un līdz ar to veidoja jaunas problēmas.

Statistikas analīzes rezultāti ļāva noteikt atsevišķu objektu pazīmes, kas nepieciešamas, lai novērtētu; novērtēt un piemērot atsevišķus posmus, galvenos principus un kvantitatīvos un kvalitatīvos novērtēšanas kritērijus pilsētas transporta sistēmas infrastruktūras attīstībā.

Atslēgvārdi: ilgtspējīgā attīstība, pilsētas transporta sistēmas, projekta novērtēšana, statistiskā analīze, eksperta pārskats

Pavļuks, D. Lidostu efektivitātes salīdzinoša novērtēšana un telpas konkurence: kritisks apskats, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 123.–137. lpp.

Divas pēdējās desmitgades laikā Eiropas lidostu nozare tiek liberalizēta un nokļūst konkurējošā tirgus vidē. Šīs pārmaiņas piesaista pieaugošo zinātnisku un praktisku interesi uz lidostu efektivitātes un tās noteicošo faktoru analīzi, kā arī uz dažādiem lidostu konkurences aspektiem. Šis raksts satur lidostu efektivitātes un telpas konkurences pastāvošu pētījumu kritisku apskatu. Mēs analizējām mūsdienu lidostu efektivitātes novērtēšanas pieeju priekšrocību un nepilnību un sistematizējām lielu saistītu pētījumu daudzumu. Mēs pievērsām īpašu uzmanību empīriskiem lidostu telpas konkurences kā efektivitātes noteicošu faktora pētījumiem. Neraugoties uz labi attīstītu telpas konkurences teoriju un šās konkurences palielināšanās pazīmes, mēs atklājām lidostu efektivitātes un telpas konkurences sakarības pētījumu trūkumu.

Atslēgvārdi: lidostu efektivitāte, salīdzinošā novērtēšana, telpas konkurence

Lazauskas, J., Bureika, G., Valiūnas, V., Pečeliūnas, R., Matijošius, J., Nagurnas, S. Autotransporta uzņēmumu konkurētspējas izpēte: Lietuvas piemērs, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 138.–147. lpp.

Autori rakstā parāda autotransporta konkurētspējas novērtēšanas kritērijus, pamatojoties uz lietuviešu un aizrobežu zinātnieku pētījumu rezultātiem. Pakalpojumu konkurētspējas novērtēšanā raksta autori iesaka neaprobežoties tikai ar tehniskām iespējām, bet gan analizēt visu piedāvāto pakalpojumu paketi, to kvalitāti un uzņēmuma mārketingu.

Rakstā tiek parādīti faktori, kas ietekmē autotransporta konkurētspēju. Bez tam tiek pētīti faktori, kas ietekmē autotransporta pakalpojumu izvēli. Rakstā tiek piedāvāts modelis autotransporta uzņēmuma konkurētspējas novērtēšanai, ko ir aprobējuši Lietuvas autotransporta eksperti.

Atslēgvārdi: uzņēmuma konkurētspēja, konkurētspējas novērtēšana, saskaņa, *AHP* modelis

Kopitovs, J., Abramovs, D. Transportēšanas alternatīvu vairākkārtēju kritēriju analīze un izvēle multimodālā kravu transporta sistēmā, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 148.–158. lpp.

Dotajā pētījumā tiek izskatīta multimodālā kravu transportēšanas sistēma ar noteiktu skaitu zināmo alternatīvu, kuras nosaka maršruti un veidi. Pētījuma mērķis ir piedāvāt pieeju kravu transportēšanas novērtēšanai un alternatīvu izvēlei. Tiek izskatīti sekojoši galvenie uzdevumi: indeksu izvēle, kas raksturo multimodālo pārvadājumu efektivitāti; optimizācijas kritēriju veidošana multimodālo kravu pārvadājumiem; multimodālo pārvadājumu sistēmas modeļa konstruēšana; kravu pārvadājumu izpildes kritēriju aprēķins. Pētījums prezentē AHP (Analītisks Hierarhijas Process) kā vispiemērotāko modeli dažādu maršrutu un kravu transportēšanas veidu salīdzinošai novērtēšanai.

Atslēgvārdi: multimodālā kravu transportēšana, loģistiska sistēma, biznesa process, optimizācijas kritēriji, maršruts, Analītisks Hierarhijas Process

Rebezova, M., Sulima, N., Surinovs, R. Lidmašīnu pasažieru pārvadājumu pakalpojumu un pakalpojumu izplatītāju kanālu attīstības tendencies, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 159.–166. lpp.

Paralēli saviem pamata pakalpojumiem, kā pasažieru pārvadāšanas serviss, tā arī gaisa satiksme nodrošina papildu ekstra pakalpojumus, kas bieži vien nemaz tieši neattiecas uz pārvadāšanas pakalpojumiem. No vienas puses, aviolīnijas palielina sniegtos maksas pakalpojumus lidmašīnā un, no otras puses, aviobiļetes cenā iekļauj ēdināšanu reisa laikā, bagāžas pārbaudi, reģistrēšanos lidostā, etc. Bez tam tiek piedāvāta arī viesnīcu noma, automašīnas noma, apdrošināšana u.c. pakalpojumi.

Šādu pakalpojumu sniegšana prasa datorizētu rezervēšanas sistēmu un atbilstošu aģentu un klientu piekļuvi tīkliem. Šīs sistēmas un tīkli veido IT pakalpojumu izplatītāju kanālu bāzi.

Dotais raksts analizē gaisa pārvadājumu pakalpojumu attīstības rādītājus un virzienus. Autori rakstā parāda struktūru un izplatītāju kanālu IT atbalstu. Tiek vērsta uzmanība uz potenciālajām kvalitatīvajām izmaiņām struktūrā un pasažieru pārvadājumu pakalpojumu sadales iespējām, ņemot vērā *Next Generation Network* konceptu (nākotnes paaudzes tīkla koncepts), kura ieviešana pasaulē jau ir sākusies.

Atslēgvārdi: pasažieru pārvadājumu pakalpojumi, kompjuterizētā rezervācijas sistēma, globālā sadales sistēma, informācijas tehnoloģijas, nākotnes paaudzes tīkls

Savrasovs, M. Satiksmes plūsmas simulācija, balstoties uz diskrētās likmes pieeju, *Transport and Telecommunication,* 13.sēj., Nr.2, 2012, 167.–173. lpp.

Klasiskā zinātniskā literatūra, kas veltīta transporta modelēšanai, uzsver trīs līmeņu detalizācijas, kurās satiksmes modeļi varētu tikt radīti. Šie līmeņi ir sekojoši: mikrolīmenis, mezolīmenis un makroskopiskais līmenis. Mikroskopiskā un makroskopiskā modelēšana ir labi zināma un plaši pielietota. Terminu 'mezoskopiskā modelēšana' dažādi zinātnieki interpretē dažādi un dažādos veidos. Kopumā mezoskopiskie satiksmes plūsmas modeļi tiek saprasti kā modeļi, kur trafika plūsma tiek aprakstīta ļoti detalizēti, bet tajā pašā laikā plūsmas uzvedība un plūsmas mijiedarbība tiek parādīta ar zema līmeņa aprakstu. Jaunā modelēšanas pieeja, t.s. 'mezoskopiskā modelēšana', par kuru tika iepriekš runāts, ir pielietota trafika plūsmas modelēšanā. Visi aprakstītie modeļi tika ieviesti, pielietojot Microsoft Excel un VBA. Tomēr praktiskais pielietojums rada bažas, ka, konstruējot sarežģītākus modeļus, Microsoft Excel un VBA lietot nevar programmatūras sarežģītības dēļ.

Dotā raksta mērķis ir prezentēt piemērus, modelējot satiksmes plūsma, ar ExtendSim modelēšanas programmatūras diskrētās likmes pieejas pielietošanu. Pēc dotās literatūras, varam spriest, ka diskrētās likmes pieeja tiek lietota galvenokārt loģistikā, bet ne transporta jomā. Tādējādi šī raksta mērķis ir parādīt modeļu ieviešanas galvenās tehnikas, pielietojot diskrētās likmes pieeju, un pielietot šo pieeju satiksmes plūsmas modelēšanā.

Atslēgvārdi: diskrētā likme, mezoskopiskie modeļi, satiksmes plūsma

TRANSPORT & TELECOMMUNICATION

ISSN 1407-6160 & ISSN 1407-6179 (on-line)

All articles are reviewed.
Articles can be presented in the journal in English.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)67100594. Fax: (+371)67100535.
E-mail: transport.journal@tsi.lv, http:// www.tsi.lv

TRANSPORT and TELECOMMUNICATION, 2012, Vol. 13, No 1
ISSN 1407-6160
The journal of Transport and Telecommunication Institute (Riga, Latvia).
The journal is being published since 2000.

The papers published in Journal “Transport and Telecommunication” are included in
SCOPUS (since 2008, Vol. 9, No 1), **Elsevier Database**
www.info.scopus.com
www.elsevier.com

FAILURE TO COMPLY WITH THESE INSTRUCTIONS MAY RESULT IN YOUR PAPER BEING RETURNED AND CAUSE A DELAY IN PUBLICATION

PREPARATION OF CAMERA-READY TYPESCRIPT: TRANSPORT AND TELECOMMUNICATION

1. In order to format your manuscript correctly, see the Page Layout Guideline for A4 (21 cm x 29,7 cm) paper size. Page Layout should be as follows: Top – 3 cm, Bottom – 3 cm, Left – 3 cm, Right – 3 cm.
2. Maximum length for the article is **10 pages**.
3. **Using of other Styles with the exception of Normal is not to be allowed!**
4. ***Articles*** should be Times New Roman typeface, single-spaced.
5. The article should include:
   - title;
   - author's name(s) and information (institution, city, country, the present address, phones, and e-mail addresses);
   - abstract (100-150 words);
   - keywords (max. 6);
   - introduction – clear explanation of the essence of the problem, previous work, purpose of the research and contribution;
   - description of the research;
   - conclusion section (this is mandatory) – should clearly indicate the advantages, limitations and possible applications;
   - references.

   Attention! First name, last name, the title of the article, abstract and keywords must be submitted in the English and Latvian languages (in Latvian it is only for Latvian authors) as well as in the language of the original (when an article is written in different language).
6. The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (***British English***), headings and the style of referencing.
7. ***The title of the article*** – 14 point, UPPERCASE, style Bold and centred.
8. ***Author's names*** – centred, type size 12 point, Upper and lower case, style Bold Italic.
9. ***Author's information*** – 10 point, Upper and lower case, style Italic, centred.
10. ***Abstract and keywords*** – 8 point size, style Normal, alignment Justify.
11. ***The first level Headings*** – 11 point, Upper and lower case, style Bold, alignment Left. Use one line space before the first level Heading and one line space after the first level Heading.
12. ***The second level Headings*** – 10 point, Upper and lower case, style Bold, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the second level Heading.
13. ***The third level Headings*** – 10 point, Upper and lower case, style Italic, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the third level Heading.
14. ***Text*** of the article – 10 point, single-spaced, alignment Justify.
15. The set of ***formulas*** on application of fonts, signs and a way of design should be uniform throughout the text. The set of formulas is carried out with use of editors of formulas MS Equation 3.0 or MathType. The formula with a number – the formula itself should be located on the left edge of the text, but a number – on the right one. Font sizes for equations are the following: 11pt – full, 7pt – subscripts/superscripts, 5pt – sub-subscripts/superscripts, 16pt – symbols, 11pt – subsymbols.
16. All ***Figures*** – must be centred. Figure number and caption always appear below the Figure, type size 8 point.

Figure 1. This is figure caption

Diagrams, Figures and Photographs – must be of high quality, in format *.TIFF, *.JPG, *.BMP with resolution not less than 300 dpi. Also formats *.CDR, *.PSD are possible. Combination of Figures in format, for instance, *.TIFF with elements of the in-built Figure Editor in MS Word is prohibited.

17. ***Table Number and Title*** – always appear above the Table. Alignment Left. Type size 8 point. Use one line space before the Table Title, one line space after the Table Title and 1/2 line space after the Table.

Table 1. This is an example of a Table

Heading	**Heading**	**Heading**
Text	Text	Text
Text	Text	Text

18. ***References*** in the text should be indicated by a number in square brackets, e.g. [1].
    References should be numbered in the order cited in the manuscript. The correct format for references is the following:

Article: Author(s). (Year of publication). Article title, *Journal title (in Italics)*, volume and issue number, inclusive pages.

Example: 1. Amrahamsson, M., Wandel, S. (1998). A Model of Tearing in Third – Party Logistics with a Service Parts Distribution Case Study, *Transport Logistics*, Vol. 1, No 3, pp. 181–194.

Book: Author(s). (Year of publication). *Book title (in Italics)*. Place of publication: Publisher. Whole pages.

Example: 2. Kayston, M. and Fried, W. R. (1969). *Avionic Navigation Systems*. New York: John Wiley and Sons Inc. 356 p.

Conference Proceedings: Author(s). (Year of publication). Title of an article. In: *Proceedings (in italics)*; title of a conference, date and place of a conference (concrete pages). Place of publication: Publisher.

Example: 3. Canales, Romero J. (2003). A First Step to Consolidate the European Association of Aerospace Students in Latvia (Presented by the Munich Local Group). In: *Research and Technology – Step into the Future: Programme and Abstracts. Research and Academic Conference, Riga, Latvia, April 7–11, 2003 (pp. 20–29)*. Riga: Transport and Telecommunication Institute.

Report: Author(s). (Year of publication). *Title*. Place of publication: Publisher. (Report number)

Example: 4. Osgood, D. W., & Wilson, J. K. (1990). *Covariation of adolescent health problems*. Lincoln: University of Nebraska. (NTIS No. PB 91-154 377/AS)

Government publication: Institution name. (Year of publication). *Title*. Place of publication: Publisher.

Example: 5. Ministerial Council on Drug Strategy. (1997). *The national drug strategy: Mapping the future*. Canberra: Australian Government Publishing Service.

19. ***Authors Index***
    Editors form the author's index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.

20. ***Acknowledgements***
    Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper. The first page of the contribution should start on page 1 (right-hand, upper, without computer page numbering). Please, paginate the contributions in the order they are to be published. Use simple pencil only.

21. **Articles poorly produced or incorrectly formatted may not be included in the proceedings**.

Finally, please, ensure you have returned the **PUBLISHING AGREEMENT** form, which was sent to you with these instructions. Copies may be obtained from our web site, via the Internet (http://www.tsi.lv/Transport-and-Telecommunication/Preparation_of_publication.pdf).