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Passenger transport by railway: evaluation of economic and social phenomenon

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Abstract

Transport activity depends on the development of other economic sectors, it is associated with the social and economic development of a country. Therefore, when forecasting economic development of a country, it is important to scrutinize and evaluate the direct and indirect influence of a transport system and its particular branches on social and economic sectors of a country or region. This article analyzes the methodological aspects of evaluating the social and economic influences of a passenger transport system. Passenger transport by railway is regarded not only as a business but also as a social function. In order to evaluate the relations of passenger transport by railway and the macroeconomic processes of a country or region, the macroeconomic social turnover indicators, that characterize the passenger transport activity, are chosen, the methods of economic statistical analysis are used. The interconnection of passenger railway transport's indicators and Lithuania's macroeconomic indicators are measured by calculation. The topic of interoperability installation in the Lithuanian railways is presented as well, and the benefits and costs of activities of the main stakeholders in railway transportation are projected.

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1. Introduction

In the markets of European Union states, there is a severe competition in the passenger transport sector between different types of transportation. Since the transportation sector plays an important role in each country's economy, it is vitally important to ensure its harmonious behavior and dynamic development.

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In order to reduce the negative (traffic jams, damage to the environment, noise, accidents) effect of a dominating road transport, the EU pays a lot of attention to the railway transport development. By 2020, the railway's market share in passenger transport is to be increased by 10 percent and the fuel emissions are to be reduced by 50 percent.

In the economic life of developed countries, transport has become an important factor of development instead of being a sidekick as it was in the past. Transport activity depends on the development of other economic sectors, it is associated with the social and economic development of a country. Therefore, when forecasting economic development of a country, it is important to scrutinize and evaluate the direct and indirect influence of a transport system and its particular branch on social and economic sectors of a country or region. Thus the EU seeks its goal – to create a transport system in accordance with the economic, social and environmental needs of the people and to pursue its sustainable development.

In the scientific literature, quite a few researches are presented regarding the connections between transport and economic social results estimation (A study, 2007; Butkevičius, 2009; EU energy, 2010; Directorate, 2010; Kalenoja, 1996; High speed, 2010, Wojewódzka-Król, 2011; Ottaviano, 2008; Toruński, 2009; Бразиа, 2010; Теплякова, 2001).

Macroeconomic, microeconomic and general equilibrium methods are used. They are applied subject to the goals set for the researchers, and subject to the importance and scope of these goals.

The nationwide influence of transport infrastructure is characterized by the macroeconomic effects of investments. When evaluating the efficiency of individual projects and transport activities, the microeconomic costs and benefits analysis is usually performed. The general equilibrium methodologies are applied when evaluating the changes in regional specialization.

In this article, indicators and economic calculation methods are chosen by which the influence of passenger transport by railway on a country's economic and social sector is measured. The interconnection of passenger railway transport's indicators and Lithuania's macroeconomic indicators are measured by economic calculation. The topic of interoperability installation in the Lithuanian railways is presented as well, and the benefits and costs of activities of the main stakeholders in railway transportation are projected.

2. The methodological aspects of evaluating the social and economic influences of a passenger transport system

Passenger transport by railway, especially the local, suburban routes, is regarded not only as a business but also as a social function. It is a part of the state program that ensures the public transportation required to satisfy the needs for work, daily, leisure and tourism communication. Therefore the railway transportation is usually supported by the state, and its role is important for the state's economic and social sector. An appropriately set infrastructure of passenger transportation encourages citizens' mobility, allows companies to disperse the production divisions in a rational way, allows to develop regional economic growth, specialization etc. This influences employee productivity, their living standards, in other words, a passenger transport system influences not only the economy but communities and their members as well.

Various sources present different social and economic effects of transport projects (Transport sector, 2007; Evaluation, 2009; How 2009; Lingaitis, 2009; Харитонова, 2009; Marginal, 2012). Summarizing the authors' suggestions, the passenger transport system's modernization effects can be grouped into the effects of transport systems changes and the effects of social economic changes that measure the interests of passengers, transport companies, regions and countries.

The following groups of evaluation indicators are proposed:

- the change of travelling time;
- the changes of technological costs of passenger transport;
- the changes of traffic and ecological safety;
- the changes of comfort level;
- the changes of a company's cohesion and economic development.

According to the experts, one of the most important indicators of passenger transport's economic social efficiency is the Value of Travel Time Savings. 30 to 80 percent of the overall transport project benefit is thought to come from the reduced traveling time during which a passenger does not participate in the creation process of added value. The

reduction of such time allows to increase gross domestic product, to use the personal time of a passenger more productively, to satisfy spiritual, cultural needs.

Therefore, when choosing the investment indicators of a passenger transport’s efficiency, the acceleration of passenger transportation is considered an important factor. The economy of total cost S , incurred by passengers and a carrier per trip, can be such an integral indicator:

$$S = S_k + S_v \rightarrow \min, \tag{1}$$

where: S_k – the costs of train passengers, EUR. They are related to waiting for a train, riding a train, train changing, comfort etc.;

S_v – the operating costs incurred by carriers (company), EUR.

Summarizing the components of passenger costs S_k that are analyzed in the literature (Бразиа, 2010), the following mathematical expression for this indicator is proposed:

$$S_k = \sum_{i=1}^n P_i T C_v / 2 + \sum_{i=1}^n P_i L_v C_v / V, \tag{2}$$

In this formula: n – the number of train stops on a trip,

P_i – the number of passengers that board the train in the i stop; passengers

T – time interval between trains on a route; hours

C_v – the value of one passenger’s hour, EUR, V - average train speed, km/h, L_v – average travel distance per passenger, km/pass.

The formula uses the average financial equivalent of one passenger’s hour C_v which is calculated as the gross domestic product per one hour of the working population. During the initial calculations, this indicator can be used in a certain range depending on the social structure of a passenger flow.

In order to evaluate the operating costs of a carrier on a trip, a mathematical model is proposed by (Dailydka, 2011) from which we get the following mathematical expression:

$$S_v = \left[I_{inf} + \sum_i I_i K_v \right] K_t \sum_k l_k, \tag{3}$$

where: I_{inf} – infrastructure fee, EUR/train. Km; I_i – passenger transport cost number i (expenditures for fuel, lubricants, wages, materials, repairs, depreciation etc., $i = 1-7$); K_v – relative number of wagons deriving from approximation of empirical data; K_t – traction coefficient (electric traction – 1, thermal power plant – 1.44, railcar – 1.06); k – the way station's number, l_k – the length of the way station number k , km.

Since the number of passengers on the same trip varies and often falls to just 50 percent halfway, the average cost per passenger increases accordingly. In order to equalize the situation, the means of passenger transport – the number of wagons, traction measures, their combinations – should be optimized. Thus a mathematical model is made – the nonlinear programming method is applied when searching the optimal solutions, all expenditure components are to be optimized, economically rational routes, passenger transport vehicles, organizational solutions are to be chosen. The “fmincon” routine of the MATLAB program is chosen for the calculations, it is intended for the search of the lowest values when solving nonlinear equations with many variables and limitations (Čiočys & Jasilionis 1990).

The research has shown that, if passenger trains were formed for individual Lithuanian railway routes according to the optimized version of this model, the passenger transport losses could be reduced four times, and the passenger transport could be profitable for the trips filled with passengers (Dailydka, 2011).

Regarding the passenger transport process and influence of railway infrastructure’s modernization on the economy, it is important to evaluate the general effect achieved outside the transport system. Its size can often surpass the positive result (benefit) that is achieved inside the transport sector. Such effect consists of:

$$\Delta E_{ent} = \Delta E_{soc} + \Delta E_{sv} + \Delta E_{eko}, \quad (4)$$

where: E_{soc} - passenger social effect achieved after the increase of service quality;

E_{sv} – the effect related to the damage to passengers' health and to the reduction of losses due to accidents.

E_{eko} – the effect of reducing the negative impact to the environment.

The social effect related to the passenger service E_{soc} is proposed to be measured using a peer review. For this purpose, there can be used such qualitative indicators as: traveling time, traveling safety, reliability, comfort, transport vehicle's reach, service quality in the stations, information service etc.

The traffic accident cost model E_{sv} usually consists of 5 components. It includes such individual areas: people's health, damage to property, investigation, rescue works, loss of productivity. Such cost calculation model is used for the purpose of standardizing the cost comparison system in various types of models. The cost of traffic accident consists of both direct and indirect costs. Direct costs are those that can be directly evaluated and calculated for the damage done to a person, property and environment during the traffic accident, also the expenses for various investigations and expertise required to identify, evaluate and calculate the causes and outcomes of the traffic accident. We cannot directly measure the indirect expenses but they have a subsequent negative influence and are calculated according to various methodologies. Such costs can consist of a loss of transport vehicle efficiency.

Regarding E_{eko} – the effect of reducing negative impact on the environment, it can be said that the main negative factors of transport activity are the following:

- air pollution from a variety of harmful substances;
- noise;
- water pollution;
- the use of energy (non-renewable) resources (waste);
- (new) infrastructure's impact on a landscape;
- traffic accidents;
- traffic jams in the roads;
- occupation of territories.

The studies show that there are no positive values. Therefore a conclusion can be made that transport can be neutral to the environment at best. In all other cases, its impact is regarded as negative. Of all the types of transport, road transport causes the biggest negative effect (Evaluation, 2009).

Table 1. Comparison of the impact on the environment caused by various types of transport (Likert scale, pollution- indexes)

Transport type	Air pollution (indexes)	Water pollution	Soil pollution	Noise	Use of land
Road	100	-1	-3	-2	-3
Railway	46	-1	-2	-2	-2
Internal water	47	-3	-1	0	-1

To summarize the research conclusions, the impact of passenger transport projects on the environment is measured as the sum of effects achieved by reducing the damage regarding the pollution of water and soil, the pollution of flora and fauna, the use of territories for roads and other infrastructure.

The cost of transport impact to the environment in the European Union is regarded as 1,1 percent. Studies show that railway is an environmentally friendly type of transport. This is due to a relatively lower energy consumption, lower air pollution and smaller required territory (Wojewódzka-Król, 2011). The energy intensity of a train is 1,9 times lower than that of a car whereas carbon dioxide emissions, area intensity - almost 3 times lower. As a result of this, the external non-transport sector costs, related to transportation activity and which reach up to 4 percent of GDP in individual EU states, are in the railway sector 3,3 times lower than in the car sector, according to UIC data. When transporting the same number of passengers, railway uses around 7 times less fuel than bus transportation and even 12 times less than car transportation (Butkevičius, 2011).

From the perspective of railway impact, the installation of technical interoperability in the railways has to be noted as well. In order to improve the technical interoperability of the whole 1520 mm railway network with the

railways of other EU states and to maintain current regional technical interoperability of the Baltic States railway systems, much attention is paid to the implementation of directives for technical interoperability.

Technical interoperability - the ability of a railway system to create conditions for safe and continuous movement of trains that meet the operation level required for these lines.

The design, modernization and construction of railway infrastructure and the construction and production of rolling stock complies with the technical interoperability specifications (TIS), required for all EU member states, that are applied to the systems of high-speed and conventional railway.

The technical interoperability of broad and European track gauge railway systems as well as other track gauge systems in the European Union states is regulated by the June 17, 2008 European Parliament and Council Directive 2008/57/EB regarding the railway system interoperability in the Community (new edition). The provisions of these directives are transferred to the national legislation of the Republic of Lithuania.

The main stakeholders interested in the technical interoperability of railway transport system may include:

- infrastructure manager responsible for the structural subsystems that take care of railway transport vehicle movement;
- railway carriers using the transport vehicles for passenger;
- customers-passengers;
- manufacturers of railway transport vehicles and equipment.

The decisions adopted by the stakeholders are interrelated and can have both positive and negative influence to one another. The following situation may stand as an example:

- the lack of railway lines that comply with the main health requirements does not justify the carrier's decision regarding the costs of depot modernization;
- the lack of manufacturers' offers or the "unaffordable" price of equipment or systems that comply with the main health requirements will limit the modernization possibilities;
- the lack of appropriate interest in the supply of international transportation will require such costs from the carriers and infrastructure manager that could not be covered by revenues.

Therefore, when changing the conditions of a system, the decisions of individual stakeholders should be taken into account, which are made after analyzing the costs and income of the business.

From the *infrastructure manager's* point of view, the decision regarding the maintenance and operation of the infrastructure and possible modernization is based on the expected income to be generated by allowing the use of railway infrastructure for the needs of movement. Furthermore, when making such a decision, it is necessary to take into account the possibilities of using external funds (EU funding, for instance) and intensifying the movement.

The analysis of the literature shows that the benefit which the infrastructure manager gets from the technical interoperability of railway transport is the possibility to get EU funding, fluidity of movement and control improvement, an increase in train speeds, a decrease in train arrival time, an increase in demand of a line, intensified movement, product unification and their market, higher accessibility of devices and a possibility to reduce their prices, as well as a higher safety level of train traffic.

From the *carrier's* point of view, the decision to buy a transport vehicle and the redemption of a route for the vehicle (in order for the train to move) is based on the expected income generated by transporting a certain amount of passengers or cargoes.

The benefits that the carrier gets from installing a technical interoperability in a railway transport system may include product unification and their market, higher accessibility and a possibility to reduce the price of an equipment and transport vehicle, an improvement of train movement fluidity, a possibility to increase the speed and reduce the traveling time, higher traffic safety, a reduction of accident risk level, an increase in the sphere of provided services, lower price of a train "with interoperability".

From the *customer's* point of view, the decision to use a railway transport vehicle is based on the notion that the cost of a transport service is at least equal to the benefit gained from using it.

The benefits that the customer gets from installing a technical interoperability in a railway transport system may include: greater possibilities to choose a carrier and a type of offer, an increase in speed and a decrease in traveling (transporting) time, a reduction of accident risk level, greater fluidity of movement, new and modernized trains that are more comfortable.

From *the manufacturer's* point of view, the decision to produce transport vehicles, equipment and their elements is based on the assumption regarding the possible added value that is achieved by selling the product. The benefits that the manufacturer gets from installing a technical interoperability in a railway transport system may include: increased sales market, higher competitiveness, better product quality, element unification and market, greater accessibility, a possibility to reduce the prices of materials and their supply.

At the same time it is worth noting that the changes in a transport system, which allow a comfortable and timely traveling, influence the cohesion of a community, the unification of regional economy, the value of real estate. In the literature, the listed effects are often assessed individually but they are closely interrelated and should be analyzed in a complex manner.

3. Passenger transport by railway and evaluation of macroeconomic development relations

The mutual influence and relations of a transport and economic development are widely analyzed by scientists (Affuso, Masson, & Newbery, 2003; Afraz, Aquilina, Conti, & Lilico, 2006; Nordhaus, 2006; Canning & Bennathan, 2007; Dargay, Gately, & Sommer, 2007; Venables, 2007; Ribeiro, Antunes, & Paez, 2010; Sweet, 2011; Maskeliūnaitė, 2013). It is not very important which one is the reason and which is the consequence. Whether the economy, the structure of its branches, structural changes influence the transport development or vice versa - investments in transport infrastructure, vehicles, and technologies stimulate the economic development nonetheless.

In the European Union, the transport sector's activity creates on average 7 percent of GDP. The analysis of the transport sector and GDP has shown that transport is the second or third most important sector in the structure of GDP. In the European Union, on average 6–7 percent of all passengers per year travel by railway. Therefore the condition of passenger transport by railway is directly related to the macroeconomic situation of countries and regions, the indicators of public finance and quality of life.

It must be noted that the demand for passenger transport services depends on various social and economic phenomena characterized by certain macroeconomic indicators. And their effect on the process can be both positive and negative. The results of these factors are determined by the traveling possibilities and means chosen by passengers in order to satisfy their traveling needs.

In order to evaluate the relations of passenger transport by railway and the macroeconomic processes of a country or region, the following economic social indicators are chosen:

- GDP per capita;
- monthly net average wage;
- emigrated population;
- the final consumption expenditure of population;
- unemployment rate;
- retirement age population;
- overall average annual population;
- average annual rural population;
- road length;
- cars per 1000 inhabitants.

When performing an analysis, the passenger transport activity could be described by the main circulation indicators:

- passenger circulation of all transport types, passengers per km,
- length of the railways,
- railway passenger circulation, passengers per km,
- passenger circulation of internal transport by railway, passengers per km.

For measuring the correlation between the chosen economic social and transport indicators, a cluster analysis is used and a table of pair correlation coefficients is created thus eliminating collinear factors. This way key economic and social factors influencing the passenger transport by railway are identified. The strength of interrelation among the attributes is measured by the values of linear correlation coefficients. The regression models of resulting and

factor attributes are easily chosen from the list of selected factors, using the multiple regression method and statistical programs.

To summarize the ideas above, it has to be noted that the development of railway, as of any other type of transport, requires the coordinated solutions of various fields. It has to be balanced considering the economic efficiency, ecological rationality and social justification of the process (Fig. 1).

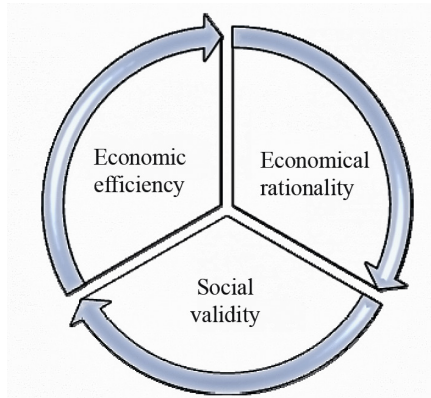


Fig. 1. Criteria of a balanced transport system development

According to the macroeconomic and passenger transport results of 2001–2012, the economic factors influencing passenger transport in the Republic of Lithuania are analyzed below.

Fig. 2 shows the dynamics of GDP and the number of passengers by all types of transport during the analyzed period.

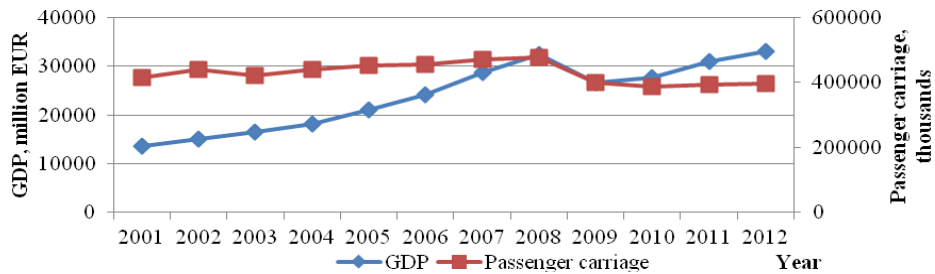


Fig. 2. Dynamics of GDP and passengers of all transport types

From figure 2 we can see that, even though there is a difference between the number of passengers by all transport types and GDP, the similar trend remains.

It is important that the passenger transport by railway is a part of state program ensuring the transport service for the country’s population, required to satisfy the needs for work, daily, leisure and tourism travels. The railway transport is not a novelty in Lithuania, it has deep traditions therefore the state supports this type of passenger transport.

The market decline of internal transport by railway during the economic crisis is related to the decrease in population’s mobility due to the territorial reallocation of jobs away from the railway lines, decrease in size and concentration of industrial and business objects, employment decline, the decline of leisure traveling market due to high occupation level among the employed and unfavorable railway routes and timetables, low flexibility of railway transport compared to the possibilities of road and its public transport. The railway transport has to compete with the road transport in local routes and with the air transport in international routes. The traveled distance by railway per

passenger gets longer, the average number of travels per inhabitant fluctuates. There is a noticeable tendency of passenger traffic growth, both for domestic and international routes.

Table 2. Indicators of passenger transport by railway in 2001–2011

Indicators	2001	2003	2005	2007	2009	2011
Total passengers, millions	7.72	7.0	6.72	5.19	4.37	4.65
of which: internal,	6.31	6.01	5.76	4.09	3.52	3.75
international	1.41	0.99	0.96	1.1	0.85	0.9
Passenger circulation, millions of passengers per km	532.80	432.07	427.92	408.71	356.94	389.12
of which: internal,	263.24	257.16	259.12	222.73	213.38	248.52
international	269.56	174.91	168.80	185.98	143.56	140.60
Average distance per passenger, km	69	69	64	79	82	83
Average number of travels per inhabitant	2.2	2.1	1.8	1.5	1	1.4

The correlation and statistical analysis of the indicators for the passenger transport by all transportation types and internal railways and of the above-mentioned macroeconomic indicators shows that the passenger circulation in the Republic of Lithuania largely depends on the economic situation.

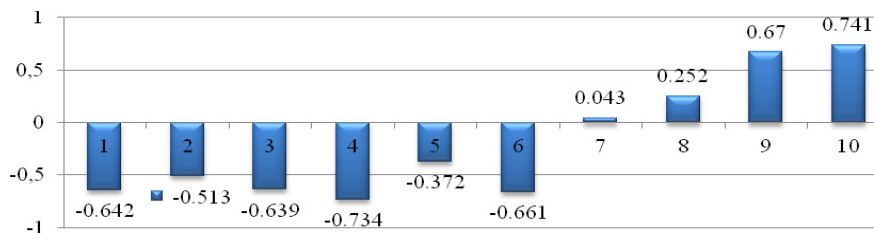


Fig.3. Pair correlation coefficients of passenger circulation by railway and macroeconomic indicators: 1 – cars per 1000 inhabitants, 2 – length of car roads, 3 – GDP per capita, 4 – average monthly net wage, 5 – number of emigrants, 6 – final consumption expenditure, 7 – unemployment rate, 8 – number of pension beneficiaries, 9 – average annual population. Urban and rural, 10 – average annual rural population.

The results of 2001–2012 show that the total passenger transport activity (circulation) was significantly influenced by GDP growth (correlation coefficient – 0,87) and especially by the resulting increase in average wage (correlation coefficient – 0.73) and final consumption expenditure (correlation coefficient – 0.84). The population welfare indicators led to an important phenomenon – the growth of the population’s car mobility. During the analyzed period, the number of cars grew by 1.6 times, the length of car roads – by 7 percent. The correlation coefficient of passenger circulation and cars per 1000 inhabitants – 0.75. Therefore, during the analyzed period, the railway passenger circulation was relatively decreasing, and its correlation coefficients with the above-mentioned macroeconomic indicators are negative: with GDP per capita – 0.64, with the average wage – 0.73, with the population’s final consumption expenditure - 0.66. It has also become clear that the passenger transport by railway positively correlates with the population dynamics (correlation coefficient – 0.67) and especially with the rural population change (correlation coefficient – 0.74).

These tendencies are also illustrated by the dynamics of the analyzed passenger transport and macroeconomic indicators (Figs 4 and 5).

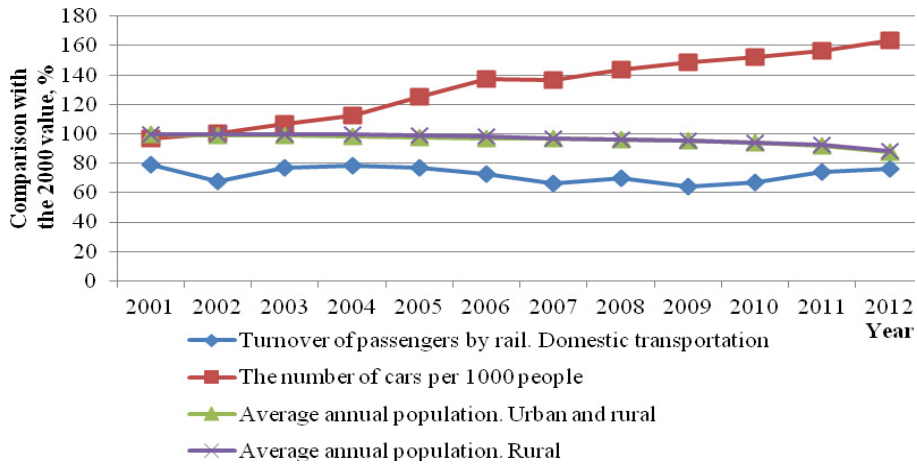


Fig. 4. Dynamics of macroeconomic indicators

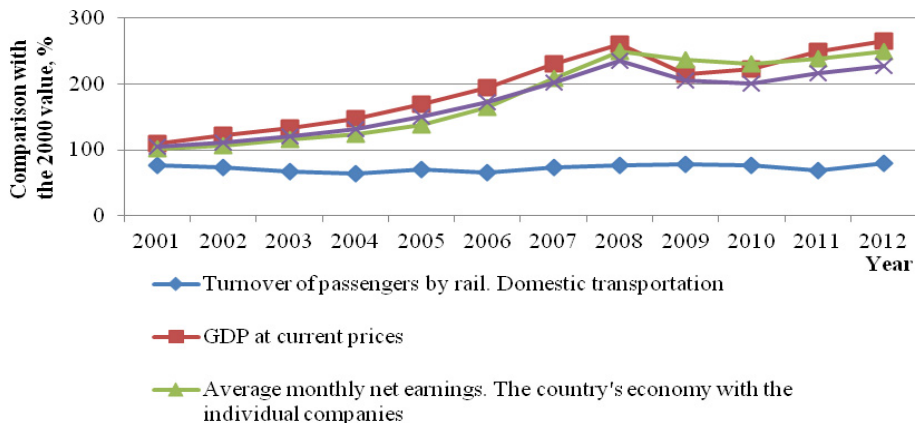


Fig. 5. Dynamics of passenger circulation by railway and macroeconomic indicators

The passenger circulation by railway was least influenced by the unemployment rate (correlation coefficient – 0.04) and the number of retirement age population (correlation coefficient – 0.25).

Thus the changing regional economic situation, emigration, motorization significantly contributes to the outrivaling of public transport, including railway. Therefore the main goal of the public railway transport - to increase its competitiveness, to expand the range of provided services and improve their quality, adjusting to the services provided by other transport systems and maintaining as much travel integrity as possible. The main criteria for the quality of passenger transport services are presented in Figure 6.

We can see that the improvement of passenger transport service quality is a process which requires good technical, technological, organizational and investment solutions. When the economic conditions do not allow installing technical innovations for a certain period of time, it is recommended to settle for an organizational restructuring and for the development of specialized passenger services (Dailydka, 2011). Furthermore, this process is related to the installation of a corporate management system for passenger service quality. Its purpose – to create and implement an efficient, customer-oriented passenger service technology.

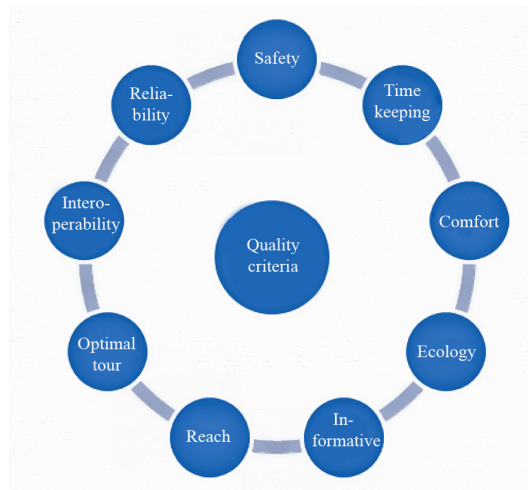


Fig. 6. The main quality criteria for the passenger transport by railway

4. Conclusions

The passenger transport activities are closely related to the economic and social development of a country. The passenger transport by railway is not only a business but also a social function of the state, satisfying the population's needs of work and personal life. The result of modernizing such activities is measured by the following positive effects gained by the passengers, carriers and countries (regions): reduction in traveling time, reduction in traveling costs, achieved traffic and ecological security, improvement on travel comfort, changes of regional cohesion and economic development.

One of the most important indicators of passenger transport's economic and social efficiency is the Value of Travel Time and Cost Savings. In order to evaluate and optimize it, the mathematical model of the costs incurred by a passenger and a carrier per trip is presented, which measures the length, traction and other components of a train, depending on the change of the number of passenger on a route. The research has shown that this way the passenger losses could be reduced four times on individual Lithuanian railway routes, and the trips filled with passengers could achieve a positive result. Therefore the improvement of the passenger transport process is related to the change in transport technologies – formation of modular and shuttle trains, installation of harmonized timetables for the traffic of trains and other transport vehicles, dissemination of the information, acceleration of train traffic.

Lithuania is obliged under its membership in the European Union to adjust to the technical interoperability conditions of the Trans-European Rail network (TEN-T). A transitional period is set in order to adapt the country's remaining railway infrastructure to the main requirements. The main issue, when setting the scope and moment for the implementation of interoperability in the railway network, is the evaluation of the cost and benefit of such changes considering the decisions of all the stakeholders in the railway transport system.

It is recommended to create such a simulation model that, according to various costs and benefit conditions and limitations on the decisions of individual stakeholders in railway transport system, would allow evaluating the possibilities of installing the technical interoperability in the transport system from various perspectives.

For identifying the relations between the passenger transport by railway and macroeconomic processes of a country (region), the correlation and regression statistical analysis of people's income, consumption, motorization, change in population, unemployment and passenger circulation is used. The 2001–2012 statistical research indicators for Lithuania have shown that, due to the increased motorization as a result of the growing standard of living, the amount of railway passengers is decreasing, negative – reverse correlation coefficients between the passenger transport and the indicators of GDP, average wage, final consumption expenditures were found. Also close correlation of the passenger transport and the change in population were recorded.

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