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INDICATORS AFFECTING THE OPERATION OF PUBLIC TRANSPORT IN REGIONS AND THEIR INTERFACES

ABSTRACT

The article reviews qualitative and quantitative indicators to measure transport demand. After the review of the indicators and taking into account the specificity of the analysed region and the availability of data, the selected indicators were divided into five indicators groups: demographic, public transport usage description, public transport service and infrastructure, automobilisation and economics. A database of relevant indicators has been developed to execute the evaluation. The study yielded three separate results: data of city municipalities, circular municipalities and regional municipalities. The purpose of this article is to identify the most important indicators that influence the passenger flows in regional public transport and to identify the interfaces between the indicators. The main raised hypothesis was that different groups of municipalities will have different key indicators influencing the use of public transport and that public transport planning cannot follow the same methods. Multiple Variable Analysis and Simple Regression Analysis were chosen to test the hypotheses and clarify the most important indicators. The analysis shows that unemployment has the greatest impact on the number of passengers on suburban routes, while bus mileage on suburban routes has the smallest impact. The number of buses also has an impact on suburban passenger flows.

KEYWORDS

regional public transport; indicators; simple regression analysis; multiple regression analysis; correlation coefficient.

1. INTRODUCTION

Public transport is an intelligent, efficient and sustainable mode of transport [1]. It is vital that sustainable public transport systems enable the society to travel with a minimum travel time, distance and cost [2]. Public transport is at the heart of mobility due to its capacity, economy, spatial rationality and environmental acceptability [3].

Service quality and innovation create a positive image of public transport, and only a positive image encourages people to use public transport rather than private transport [4]. High quality public transport is often seen as means of rural development that allows people to stay in rural areas, because public transport becomes a viable means of travel to work or school [5].

In most literature sources, public transport indicators and parameters are generally divided into two categories: qualitative and quantitative. According to Burinskienė, Paliulis & Ušpalytė-Vitkūnienė [6] & Jurkauskas [7], the main qualitative indicators are regularity, frequency, travel time and safety of public transport. Jurkauskas [7] proposes the following main quantitative indicators: number of transported passengers, travel time of a passenger, number of passengers transported per hour and exploitation speed. According to Cascetta & Cartenì [8], quantitative indicators are average travel time, waiting time, costs and qualitative indicators, whose impact on user behaviour is more difficult to assess. Qualitative indicators would include travel comfort, information and personal safety. Frequency, convenience, reliability and travel time are the most common characteristics of regional public transport quality discussed in the literature [9].

In EN 13 816: 2002, public transport indicators are classified into eight main categories: accessibility, availability, information, time, customer service, comfort, safety, impact on the environment [10].

The level of public transport services in both urban and rural areas is limited by many other additional factors: attitude of service staff (drivers), ticket prices, punctuality, stability of service provision, convenience of accessing the public transport stations / stops [11].

Carter & Lomax [12] classified public transport indicators into six groups: economy (cost per kilometre, cost per hour), cost effectiveness (passenger travel cost), service use / efficiency (frequency per kilometre, frequency per hour), vehicle utilisation / efficiency (kilometres travelled per vehicle), quality of service (average speed, vehicle mileage in the event of an accident), labour productivity (number of passenger trips per employee, vehicle kilometres per employee).

A slightly different classification was proposed by Meyer [13], who classified the indicators of public transport into three categories. The first category consists of general service indicators, such as the population of the served area, the number of passenger trips, vehicle kilometres and hours. The second category includes efficiency measures: provision of services (number of passenger trips per inhabitant, number of passenger trips per hour), service quality (average speed, number of accidents), availability (frequency, route kilometres). The third category includes efficiency measures: cost-effectiveness (operating costs per passenger trip, cost per revenue hour), use of the vehicle (vehicle kilometres and hours during peak hours), productivity (number of trips per passenger), energy consumption (vehicle kilometres per kWh), ticket price.

In conclusion, it was decided to analyse indicators in five groups – demography, quantity, service quality, automobilisation and economy. The main focus was pointed to the service quality describing public transport service and infrastructure indicators and to the economic indicators which have an influence on the mobility of citizens in total.

The purpose of this article is to identify the most important indicators influencing the passenger flows in regional public transport and to identify the interfaces between the indicators. Theoretical analytical method of statistical analysis is applied to achieve this purpose – a simple and multiple regression analysis is performed, with the help of which an empirical model of multiple regression of Lithuanian public transport is created.

It is hypothesised that different groups of municipalities will have different key criteria influencing the use of public transport and that public transport planning cannot follow the same methods. Exclusive criteria can have a radically different impact depending on the type of municipality. Another hypothesis was that the use of public transport does not depend solely on the level of public transport service. Knowing the most important criteria, it is possible to plan the public transport service more efficiently according to the type of municipality.

The overview of indicators is presented in the next section. The third section is dedicated to the methodology, the fourth section presents the results, and the fifth section presents the conclusions, discussions and suggestions for upcoming studies.

2. INDICATORS FOR PUBLIC TRANSPORT IN THE REGIONS

Regional public transport also consists of two types of service – suburban public transport and intercity public transport. Suburban public transport serves more densely populated areas near major cities, while intercity public transport serves the entire territory of the regions. The service of the regions by public transport consists of both of these components, which complement each other. Therefore, it is important to analyse both of these components.

Based on the literature analysis and the collected data, the indicators affecting the demand for public transport in the regions are classified into five groups: demographic indicators, public transport usage indicators, public transport service and infrastructure indicators, automobilisation indicators and economic indicators (*Table 1*).

Demographic indicators

The group of demographic indicators consists of the average population, population density and average age of the population.

The Canterbury Public Transport Plan 2018–2028 emphasises that public transport operators avoid serving sparsely populated areas and low density regions due to inefficiencies [14]. Providing remote areas with public transport services has always been problematic: a dispersed network of settlements and a low population density have never promoted high demand [15, 16]. According to Yigitcanlar, Rashid & Dur [17] population density determines traveller behaviour for four reasons:

Table 1 – Description of the indicators

Group of indicators	Indicator name	Unit of measure
Demographic indicators	Average population (x_1)	inhab.
	Population density (x_2)	inhab./km^2
	Average age of the population (x_3)	years
Public transport usage indicators	Passenger turnover on suburban routes (y_1)	total passengers km
	Passenger turnover on intercity routes (y_2)	total passengers km
	Number of passengers on suburban routes (y_3)	passengers/year
	Number of passengers on intercity routes (y_4)	passengers/year
Public transport service and infrastructure indicators	Bus mileage on suburban routes (x_4)	km
	Bus mileage on intercity routes (x_5)	km
	Number of buses (x_6)	unit
	Number of bus routes (x_7)	unit
	Frequency of bus routes (x_8)	buses/day
	Accessibility of bus stops (x_9)	%
	Number of bus trips per inhabitant (x_{10})	unit/1 inhab.
Automobilisation indicators	Length of car roads (x_{11})	km
	Level of automobilisation (x_{12})	vehicles/1,000 inhab.
	Number of cars (x_{13})	unit
Economic indicators	Unemployment level (x_{14})	%
	Average salary (x_{15})	Eur
	Revenue from ticket sales (x_{16})	Eur
	Compensations (x_{17})	%
	Dotations/subsidies (x_{18})	%
	Financing indicator (x_{19})	Eur/ha

- higher population density expands local personal contacts and activities that can be carried out without the use of motor vehicles;
- higher population density widens the range of local services, thus reducing the need for travel;
- higher population density reduces the travelled distance between homes, services, workplaces;
- higher population density – more passengers using public transport.

It can be argued that in suburban areas with a low population density, residents travel longer distances than in suburbs with a high population density. A study by Borg & Ihlström [17] in low-density rural areas in Sweden (Östergötland, Dalarna and Jämtland) determined that residents prefer to drive cars than to use regular public transport because of the biggest advantage of cars – flexibility. Daniels & Mulley [18] argue that flexible public transport services in sparsely populated areas are a valuable perspective that should be taken into account compared to limited schedule public transport services.

Public transport often becomes the only available means of transport for young and older people [19]. The age of the population in the region affects the demand for public transport. Ricciardi et al. [20], a study in Perth (Australia) found that even if the older population reaches 70%, the usage of public transport increased just to 25 %.

Public transport usage indicators

The group of public transport usage indicators consists of the passenger turnover on suburban and intercity routes and number of passengers on suburban and intercity routes.

Passenger turnover is expressed in passenger kilometres obtained by summing the passengers distances travelled by buses [21]. According to a study by the Baltic Institute for Research and Development

[22], the public transport passenger turnover in the world has not increased for many years compared to the total passenger turnover in all modes of transport. People experiencing economic hardship are quicker to refuse to travel by bus than travel by train, metro or car. According to the International Transport Forum, the demand for public transport for suburban passengers as well increase of passengers kilometres will be more efficient than in urban areas [23].

The number of passengers is a key indicator of the productivity of public transport, taking into account the number of passengers carried by public transport vehicles on a daily basis [24]. According to the Lithuanian Department of Statistics, 372,883,600 passengers were transported by road in the country in 2019. In Lithuania, the problems of smaller towns and villages are often associated with half-empty public transport. The number of people wishing to use public transport services is low, so buses often carry only five passengers in rural and suburban areas, or sometimes less than two [25].

In order to assess the impact of COVID-19 on Lithuanian passenger transport by bus and to see predictions for Lithuanian passenger transport development after 2020, an expert survey was conducted. Experts believe that the average volume of intercity passenger transport in Lithuania will decrease by 30–90%, while local (urban and suburban) passenger transport will decrease from 20 to 40%. According to experts, the Lithuanian passenger bus sector will recover in 1–2 years. Local (urban and suburban) passenger bus transport is expected to recover faster [22]. Due to the COVID-19 pandemic, as a result of the temporary reduction in the number of passengers carried on intercity routes, operators are planning to reduce the route network in order to minimise losses.

Public transport service and infrastructure indicators

According to Eboli & Mazzulla [26], the public transport service category includes the bus route network characteristics by route and coverage, number of bus stops, distance between stops, location of stops and service characteristics such as frequency of service, duration of services, travel time, need for transfers.

The group of public transport service and infrastructure indicators consists of the bus mileage on suburban and intercity routes, number of buses, number of bus routes, frequency of bus routes, accessibility of bus routes, number of bus trips per inhabitant.

The mileage indicator is the number of kilometres travelled by all buses during the reporting period. The indicator includes kilometres travelled by public vehicles with or without passengers [21].

Frequency is also an important indicator for public transport passengers [27]. Very often in remote areas buses run every hour, but there are exceptions when routes are not available (mid-morning and early afternoon). For example in the city suburbs of the Netherlands, the frequency of public transport is 15–30 minutes, while in the rural areas it is 30–60 minutes [28]. Passengers in areas where the bus stops network is not well developed face the so-called “last mile problem” [29].

Hansson et al. [5] indicated that a distance of 1,000 m is the limit for walking to the bus stop on foot. People living away from the nearest bus stop use public transport even more. This statement is supported by a study by Bos [30]. The study shows that 46% of respondents living more than 3,000 m from the nearest bus stop use public transport every day, and only 32% of those living less than 500 m from the nearest bus stop use public transport every day.

Ušpalytė-Vitkūnienė & Burinskienė [31] define the following values of accessibility of territories: when 80–100% of the area is reached by public transport, the area is considered to be fully accessible; when 60–80% of the area is reached by public transport, the area is considered to be well accessible; when 40–60% of the area is reached by public transport, the area is accessible; when 20–40% of the area is reached by public transport, the area is little accessible; when up to 20 % of the area is reached by public transport, the area is inaccessible.

Another indicator is the number of bus trips per inhabitant per day, called population mobility which is important by defining the need of public transport service in the area.

Automobilisation indicators

The group of automobilisation indicators consists of the length of car roads, level of automobilisation and number of cars.

Increase of living standards threaten the priority of public transport as more and more people choose private, faster, more convenient transport [4]. However, according to official calculations, the use of a car is cheaper only for short distances, assuming that more than one person is transported [32].

Due to the growing number of cars, the number of passengers in public transport services is constantly decreasing [33]. 90% of trips are made by private car in Lithuania, therefore it is very important to promote the sustainability of the local suburban public transport system. Suburban public transport systems no longer meet the needs of the current population and do not ensure the desired quality of transport, therefore the use of private cars is increasing in Lithuania, as in other countries in the world. High vehicle traffic leads to congestion, which has a negative impact on the economy, social welfare, health and the environment [34]. Road congestion is one of the biggest problems in all countries of the world. According to various estimates, the congestion is growing and costing the European Union around 1% of GDP [35].

It is not surprising that the European Commission has focused on solving the problem of automobilisation, because the growing number of vehicles is a major cause of environmental pollution, accounting for around 40% of CO_2 emissions and 70% of other air pollutants [36]. It is predicted that form 2015 to 2050 CO_2 emissions from non-urban passenger transport will double [37].

Economic indicators

The group of economic indicators consists of the unemployment level in the region, average salary, revenue from ticket sales, compensations and dotations/subsidies percents, financing indicator.

The average salary of the population has some effect on the people mobility and to the choice of transport modes. Whether a public transport service is affordable for people depends on salaries and ticket prices. Clearly, ticket price is not a major factor in the shift to public transport, with the exception of low-income consumers, for whom travel costs are a vital factor [26]. The results of a Christchurch City Council (CCC) [38] survey showed that 29% of respondents living in Christchurch (New Zealand) asked for a reduction in ticket prices. This move would encourage them to travel with public transport.

Unemployment level is an indicator expressed as the proportion of the unemployed to the labour force, it has influence on the mobility in total and to the dependence on the public transport service.

The public transport service must be available to all social groups in society in terms of price, compliance with quality requirements, but at the same time providing economic benefits to operators. Revenue from ticket sales is an indicator of economic efficiency is important in the planning of tariff and pricing systems [39]. Ticket prices are one of the main sources of revenue for public transport operators. The Lithuanian municipalities usually set the price for the trip. It also provides for an additional 30 cents per passenger or an additional 5 cents per kilometre if the route is inefficient but service should be provided for the social needs [40, 41]. The prices of intercity routes tickets depends on the distance of the trip. The Ministry of Transport of the Republic of Lithuania sets the maximum tariff limits.

In any case, public transport operators are obliged to provide the service incurring costs. Losses incurred by public passenger transport operators are covered by two types of compensation: compensations where the carriers are reimbursed for the benefit itself, and subsidies where the revenue with compensation does not cover the costs of the operators. The loss of revenue for operators based on monthly reports on discounted tickets is compensated from the budgets of municipalities [42].

The special feature of the bus transport system is that routes connecting local centres are profitable, and routes connecting small settlements often require dotations/subsidies [43]. The dotations/subsidies are needed because the current transport tariffs are lower than those that would allow the company to operate profitably [44]. The amount of dotations/subsidies varies from country to country and region to region. In the case of Sweden, the dotations/subsidies for local and regional public transport is on average 52% [45]. For example, in Hanover, dotations/subsidies cover only 15% of losses, in Stockholm 50% and in the Hague 68%. Most Baltic cities, including Copenhagen and Malmö, have subsidies between 30% and 60% [46].

Another economic indicator under consideration is the public transport funding indicator (the sum of revenue from tickets, dotations/subsidies and compensation divided by the area of the municipality). These indicators show the financial capacity of the region to provide the service and increase the level of comfort.

3. METHODOLOGY

3.1 Database of the analysed indicators

The database of the analysed indicators (*Table 1*) is based on the data collected by the Department of Statistics of the Republic of Lithuania and by the authors. The databases, and at the same time the data sample, reflect the fragmentation of Lithuania into 60 municipalities. Demographic, public transport usage or motorisation level and part of the economic (unemployment level, average salary) data are collected by the Department of Statistics. Other data was collected by the authors after carrying out the survey of municipalities and operators of the Republic of Lithuania by e-mail. As far as possible, the calculations used data from 2019, as the use of public transport has decreased significantly due to the global COVID-19 pandemic.

Before conducting the analysis of the research, the collected database was checked: indicators with too little data were rejected and data that deviated from the context of the sample were deleted.

3.2 The progress of the research

The progress of the research is shown in *Figure 1*.

At first, a Multiple Variable Analysis was performed between all variables to calculate correlations between pairs of variables. In this research, a Pearson correlation coefficient was calculated (denoted by the letter r) (*Equation 1*), which shows the strength of the correlation between two variables on a scale from -1 to +1. The perfect positive correlation is +1. The perfect negative correlation is -1. If there is no correlation, r will be close to 0 [47].

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{1}$$

where r is the correlation coefficient, y is the dependent variable, x is the independent variable and n is the sample size [48].

The correlation strength of the correlation coefficient is interpreted on the basis of the following ranges [49]:

$|r| < 0.3$ very weak correlation;

$0.3 \leq |r| < 0.5$ weak correlation;

$0.5 \leq |r| < 0.7$ mean correlation;

$0.7 \leq |r| < 0.9$ strong correlation;

$0.9 \leq |r| < 1$ very strong correlation.

In the Multiple Variable Analysis, the P-value was also determined, which shows the statistical significance of the calculated correlations. P-values lower than 0.05 indicate statistically significant non-zero correlations at 95.0% confidence level.

The analysis shows which pairs are statistically significant and which indicators correlate with the key indicators: number of passengers on suburban routes (y_3), number of passengers on intercity routes (y_4), passenger turnover on suburban routes (y_1), passenger turnover on intercity routes (y_2).

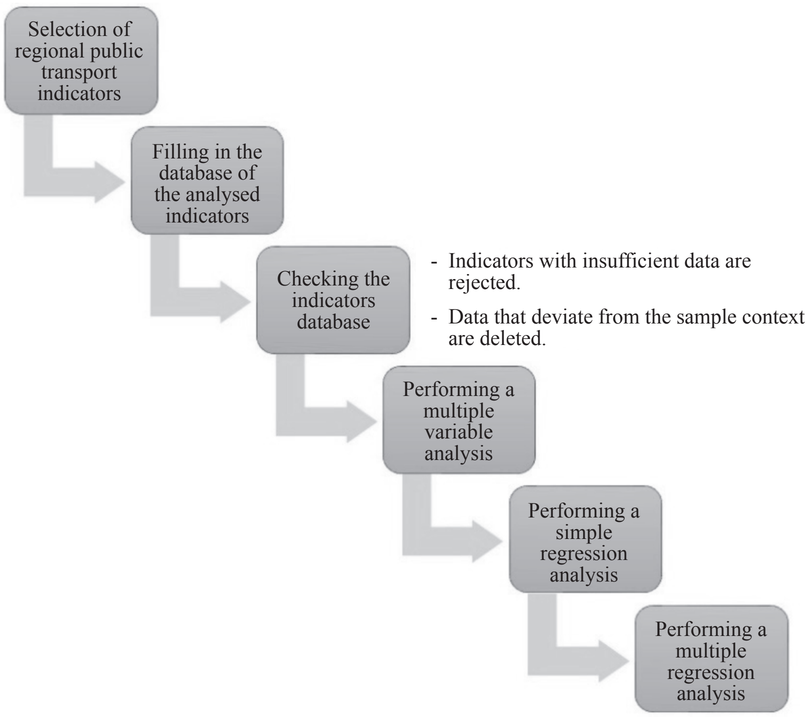

Figure 1 – The progress of the research

Simple Regression Analysis was performed with statistically significant indicators (P-value<0.05). The linear relationship was determined between the dependent variable (y_1, y_2, y_3, y_4) and the statistically significant indicator. Expression of a Simple Regression Analysis model (*Equation 2*):

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{2}$$

where β_0 is constant, β_1 is the coefficient to independent variable and ε is the random error component [50].

A Multiple Regression Analysis method is used to identify the most characteristic indicators influencing the demand for public transport and their interfaces. Multiple Regression Analysis shows the relations between the dependent variable (y_1, y_2, y_3, y_4) and all significant independent variables. Expression of a Multiple Regression Analysis model (*Equation 3*):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon \tag{3}$$

where β_1, β_2, β_p are coefficients to independent variables and x_1, x_2, x_p are independent variables [49].

When P-value is greater than or equal to 0.05 in a Multiple Regression Analysis, this indicator is not statistically significant at the 95.0% confidence level. Such an indicator is removed from the model, and the Multiple Regression Analysis is repeated with the remaining indicators until all model indicators are statistically significant.

4. RESULTS

During the research, the data of the database was divided into three groups: data of city municipalities, circular municipalities (which are surrounding the biggest cities) and regional municipalities. City municipalities consist of seven municipalities, six circular municipalities and 47 regional municipalities. As Lithuanian municipalities were divided into three groups, this study yielded three separate results.

Statistical analysis of the indicators on which public transport passengers flows may depend was performed by using a statistical software *Statgraphics*.

4.1 Results of the circular municipalities

In the analysis of circular municipalities, it was initially decided to remove the x_{19}, x_5, x_{17}, x_{18} indicators from the study due to the lack of data for most municipalities. Also, due to the lack of data, the relation between the number of passengers on intercity routes (y_5), the passenger turnover on intercity routes (y_2) and all other indicators are not examined in this case. This was followed by multiple variable analysis, which identified one correlated pair – the number of passengers on suburban routes (y_3) and the bus mileage on suburban routes (x_4). Therefore, only simple regression analysis is performed in this study. The results are as follows:

Table 2 – Results of simple regression analysis of circular municipalities

Model	Coefficients for variables	t-statistics	P-value
Constant	-176120	-0.948606	0.4128
Bus mileage on suburban routes (x_4)	0.462285	4.62405	0.0190

From *Table 2* we can see that the indicator is statistically significant, because P-value<0.05. In this case, the correlation coefficient is r=0.937, which means there is a very strong correlation. The model of simple regression analysis was obtained as follows:

$$y_3 = 176120 + 0.462285 \cdot x_4 \tag{4}$$

where y_3 is the number of passengers on suburban routes and x_4 is the bus mileage on suburban routes.

According to *Equation 4*, the number of passengers on suburban routes strongly depends on the mileage of the buses on suburban routes. That means that if the public transport service stays in the high service level, it would attract more passengers.

Due to the lack of data on the variables of circular municipalities and too small statistical sample (six circular municipalities), a reliable multiple regression model could not be created.

4.2 Results of the city municipalities

In the analysis of city municipalities, it was decided to remove the x_{19}, x_{16}, x_{17}, x_{18} indicators from the study due to the lack of data for most municipalities. Data that falls out of the sample context were also deleted.

This is followed by a Multiple Variable Analysis that identifies statistically significant pairs for which simple regression analyses are performed: between the dependent variable – number of passengers on suburban routes (y_3) and independent variables – x_{14}, x_6, x_4; between the dependent variable – number of passengers on intercity routes (y_4) and independent variables – x_7, x_5, x_6, x_{11}, x_{13}, x_1, x_{10}, x_{15};

between the dependent variable – passenger turnover on intercity routes (y_2) and independent variables – x_7, x_5, x_{11}, x_{13}, x_{12}, x_3, x_1, x_{15}, x_{10}. In this case, the indicator passenger turnover on suburban routes (y_1) has no correlation with any of the indicators under consideration.

The strongest correlation was observed in simple regression analyses between the dependent variable – number of passengers on intercity routes (y_4) and independent variable – number of bus routes (x_7). In this case, the correlation coefficient is r=0.998, which means a very strong correlation. The following results of this simple regression analysis were obtained:

Table 3 – Results of the most characteristic simple regression analysis of city municipalities

Model	Coefficients for variables	t-statistics	P-value
Constant	41875.5	2.18865	0.0938
Number of bus routes (x_7)	3294.96	31.009	0.0000

From the *Table 3* we can see that the independent variable is statistically significant because P-value<0.05. The model of simple regression analysis was obtained as follows:

$$y_4 = 41875.5 + 3294.96 \cdot x_7 \tag{5}$$

where y_4 is the number of passengers on intercity routes and x_7 is the number of bus routes.

Equation 5 shows that the number of passengers on intercity routes depends on the number of bus routes. It could be explained that public transport has higher attraction where the PT route network is more expanded and people could choose more directions to do their trips.

Then multiple regression analyses are performed with statistically significant indicators. The equation of multiple regression analysis was obtained as follows:

$$y_3 = 462598. + 53197.1 \cdot x_{14} + 770.041 \cdot x_6 + 0.26191 \cdot x_4 \tag{6}$$

where y_3 is the number of passengers on suburban routes, x_4 is the bus mileage on suburban routes, x_6 is the number of buses and x_{14} is the unemployment level.

In this case, the correlation coefficient r=1, which means that there is a 100% correlation (r^2=100%) and a very strong relation.

A multiple regression analysis of city municipalities has shown that the unemployment rate has the strongest impact on the number of passengers on suburban routes and bus mileage on suburban routes has a lower impact. It is becoming clear that the higher the unemployment level in cities, the more population is dependent on cheaper public transport. It can also be seen that the number of buses also affects passenger flows in the suburbs. This confirms the assumption that the higher the public transport supply, the higher the demand for public transport.

4.3 Results of the regional municipalities

This is followed by a multiple variable analysis that identifies statistically significant pairs for which simple regression analyses are performed: between the dependent variable – number of passengers on suburban routes (y_3) and independent variables – x_4, x_{13}, x_1, x_3, x_2, x_{10}, x_{14}, x_{16}; between the dependent variable – number of passengers on intercity routes (y_4) and independent variables – x_5, x_{19}, x_2, x_{16}; between the dependent variable – passenger turnover on suburban routes (y_1) and independent variables – x_4, x_6, x_{13}, x_1, x_3, x_{10}, x_{14}, x_{16}; between the dependent variable – passenger turnover on intercity routes (y_2) and independent variables – x_5, x_{16}.

The strongest correlation was observed in simple regression analyses between the dependent variable – number of passengers on intercity routes (y_4) and independent variable – bus mileage on intercity routes (x_5). In this case, the correlation coefficient is r=0.937, which means a very strong correlation. The following results of this simple regression analysis were obtained:

Table 4 – Results of the most characteristic simple regression analysis of regional municipalities

Model	Coefficients for variables	t-statistics	P-value
Constant	15273.1	2.09727	0.0448
Bus mileage on intercity routes (x_5)	0.139637	14.4455	0.0000

From *Table 4* we can see that the independent variable is statistically significant because P-value<0.05. The following model of simple regression analysis was obtained:

$$y_4 = 15273.1 + 0.139637 \cdot x_5 \tag{7}$$

where y_4 is the number of passengers on intercity routes and x_5 is the bus mileage on intercity routes.

Equation 7 shows how strongly the number of passengers on intercity routes depends on the bus mileage on intercity routes.

Furthermore, multiple regression analyses are performed with statistically significant indicators, removing statistically insignificant indicators from the model until all model indicators are statistically significant (P-value<0.05).

When the dependent variable is the number of passengers on suburban routes (y_3),s the results of the multiple regression analysis are as follows:

Table 5 – Results of multiple regression analysis of regional municipalities when the dependent variable is y_3

Model	Coefficients for variables	t-statistics	P-value
Constant	-20591.9	-0.397715	0.6930
Bus mileage on suburban routes (x_4)	0.454482	8.59065	0.0000

From *Table 5* we can see that the independent variable is statistically significant because P-value<0.05. In this case, the following equation of the multiple regression analysis model is obtained:

$$y_3 = -20591.9 + 0.454482 \cdot x_4 \tag{8}$$

where y_3 is the number of passengers on suburban routes and x_4 is the bus mileage on suburban routes.

Since the correlation coefficient of the model is r=0.805 (r^2=64.85 %), this means that there is a strong correlation. *Equation 8* shows that only bus mileage on suburban routes has an impact on the number of passengers on suburban routes.

When the dependent variable is the number of passengers on intercity routes (y_4), the results of the multiple regression analysis are as follows:

Table 6 – Results of multiple regression analysis of regional municipalities when the dependent variable is y_4

Model	Coefficients for variables	t-statistics	P-value
Constant	15273.1	2.09727	0.0448
Bus mileage on intercity routes (x_5)	0.139637	14.4455	0.0000

From *Table 6* we can see that the independent variable is statistically significant because P-value<0.05. In this case, the following equation of the multiple regression analysis model is obtained:

$$y_4 = 15273.1 + 0.139637 \cdot x_5 \tag{9}$$

where y_4 is the number of passengers on intercity routes and x_5 is the bus mileage on intercity routes.

Since the correlation coefficient of the model is r=0.937 (r^2=87.80%), this means that there is a very strong correlation. *Equation 9* shows that only bus mileage on intercity routes has an impact on the number of passengers on intercity routes.

When the dependent variable is the passenger turnover on suburban routes (y_1), the results of the multiple regression analysis are as follows:

Table 7 – Results of multiple regression analysis of regional municipalities when the dependent variable is y_1

Model	Coefficients for variables	t-statistics	P-value
Constant	4.36507E6	3.15324	0.0033
Bus mileage on suburban routes (x_4)	2.74491	5.48204	0.0000
Unemployment level (x_{14})	-393167	-2.51907	0.0165

From *Table 7* we can see that the independent variables are statistically significant because P-value<0.05. In this case, the following equation of the multiple regression analysis model is obtained:

$$y_1 = 4.36507E6 + 2.74491 \cdot x_4 - 393167 \cdot x_{14} \tag{10}$$

where: y_1 is the passenger turnover on suburban routes, x_4 is the bus mileage on suburban routes, and x_{14} is the unemployment level.

Since the correlation coefficient of the model is r=0.783 (r^2=61.38 %), this means that there is a strong correlation. According to *Equation 10*, the unemployment level has the highest impact on passenger turnover on suburban routes and the bus mileage on suburban routes has the least impact.

When the dependent variable is the passenger turnover on intercity routes (y_2), the results of the multiple regression analysis are as follows:

Table 8 – Results of multiple regression analysis of regional municipalities when the dependent variable is y_2

Model	Coefficients for variables	t-statistics	P-value
Constant	630048	1.00577	0.3228
Bus mileage on intercity routes (x_5)	6.72233	8.08441	0.0000

From *Table 8* we can see that the independent variable is statistically significant because P-value<0.05. In this case, the following equation of the multiple regression analysis model is obtained:

$$y_2 = 630048 + 6.72233 \cdot x_5 \tag{11}$$

where y_2 is the passenger turnover on intercity routes and x_5 is the bus mileage on intercity routes.

Since the correlation coefficient of the model is r=0.832 (r^2=69.27 %), this means that there is a strong correlation. *Equation 11* shows that only the bus mileage on intercity routes has an impact on passenger turnover on intercity routes.

After analysing the results of multiple regression analyses of regional municipalities, it is concluded that both intercity and suburban passenger flows depend on bus mileage. Passenger turnover on suburban routes has an additional strong correlation with the unemployment level. This relation is logical, as working people of the regions are forced to commute to work and those who are unemployed almost do not use the public transport service at all.

5. CONCLUSIONS AND DISCUSSIONS

By summarising the outcomes from the regression analysis some tendencies could be seen. In all types of municipalities, the number of passengers depends on the level of public transport service. In cities, the number of passengers depends mainly on the coverage of the public transport network and the number of routes, which leads to a greater choice of travel destinations for the population. There is a dependence on mileage in circular and regional municipalities, which indicates a higher frequency of public transport. In places where the frequency of public transport is low, the public transport service cannot be adapted to the needs of the citizens and they are forced to choose other modes of transport, which reduces the number of passengers in public transport.

Another important indicator in the operation of regional public transport is the level of unemployment in the region. Unemployed people in the regions are losing the need to travel every day; as a result, the importance of frequent public transport is reducing too. Regions with low levels of unemployment are highly dependent on regular public transport services, as residents of the region use it on a daily basis for business travel. Applying the presented models for planning a public transport service will be a more integrated and thus more sustainable solution to the problems of regional public transport can be found, which would help to attract more citizens to use public transport while contributing to lower CO_2 emissions.

The main conclusions of the paper as follows:

1) In most literature sources, public transport indicators and parameters are generally divided into two categories: qualitative and quantitative. The main qualitative indicators are the regularity, frequency, travel time and safety of public transport. Therefore, the main quantitative indicators would be the following: the number of transported passengers, travel time of a passengers, number of passengers transported per hour and exploitation speed. Frequency, convenience, reliability and travel time are the most common characteristics of regional public transport quality discussed in the literature.
2) The indicators for the analysis of public transport were clustered in five groups – demography, quantity, service quality, automobilisation and economy. The main focus was pointed to the service quality describing public transport service and infrastructure indicators and to the economic indicators which influence the mobility of citizens in total.
3) Due to the lack of data on the variables of the circular municipalities and too small statistical sample, it was not possible to create a reliable model of multiple regression analysis.
4) A multiple regression analysis of city municipalities has shown that the unemployment rate has the strongest impact on the number of passengers on suburban routes and bus mileage on suburban routes has the least impact. There is a direct dependency in a city or suburb, which shows that the more unemployed the population, the more they are dependent on cheaper mode of travel. It can also be seen that passenger flows in the suburbs are also affected by the number of buses. This confirms the assumption that the higher the public transport supply, the higher the demand for public transport.
5) After analysing the results of multiple regression analyses of regional municipalities, it is concluded that both intercity and suburban passenger flows depend on bus mileage. Passenger turnover on suburban routes has an additional strong correlation with the unemployment level. This is the reverse dependence: the higher the unemployment level in the regions, the lower the need to use the public transport service because the population is not forced to go to work.

6) The research shows a causal dependence that the more passengers use the public transport, the higher the mileage of the buses or number of bus routes. Dependence indicates the satisfaction of the need.

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RODIKLIŲ, ĮTAKOJANČIŲ REGIONINIO VIEŠOJO TRANSPORTO DARBĄ IR JŲ TARPUSAVIO SĄSAJŲ ANALIZĖ

SANTRAUKA

Straipsnyje apžvelgiami kokybiniai ir kiekybiniai rodikliai, įtakojantys viešojo transporto poreikį. Atsižvelgus į analizuojamo regiono specifiką bei duomenų prieinamumą, atrinkti rodikliai suskirstyti į 5 rodiklių grupes: demografinius, viešojo transporto keleivių pervežimo, viešojo transporto aptarnavimo ir infrastruktūros, automobilizacijos ir ekonominius. Analizei atlikti buvo sukurta nagrinėjamų rodiklių duomenų bazė. Tyrimo metu gauti 3 atskiri rezultatai: miestų savivaldybių, žiedinių savivaldybių ir regioninių savivaldybių. Tyrimo tikslas – nustatyti svarbiausius rodiklius, įtakojančius regioninio viešojo transporto keleivių srautus ir nagrinėjamų rodiklių tarpusavio sąsajas. Pagrindinė iškelta hipotezė yra ta, kad skirtingos savivaldybių grupės turės skirtingus pagrindinius rodiklius, įtakojančius viešojo transport poreikį, todėl viešasis transportas turi būti planuojamas skirtingai. Hipotezėms patikrinti ir pagrindiniams rodikliams identifikuoti buvo atlikta kelių kintamųjų analizė ir porinė regresinė analizė. Atlikta analizė parodo, kad stipriausią įtaką keleivių skaičiui priemiestinio susisiekimo maršrutais turi nedarbo lygis, o mažiausią – priemiestinių maršrutų autobusų rida. Priemiesčių keleivių srautams įtakos turi ir autobusų skaičius.

RAKTINIAI ŽODŽIAI

Regioninis viešasis transportas; rodikliai; porinė regresinė analizė; daugianarė regresinė analizė; koreliacijos koeficientas.

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