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Original Article

COMMUTING PREFERENCES IN EASTERN EUROPE: CASE STUDY IN TOWN OF ŠIAULIAI

Andrius JARŽEMSKIS[1]✉, Darius BAZARAS[2], Ilona JARŽEMSKIENĖ[3]

[1]*Dept of Business, Vilnius University, Lithuania*
[2,3]*Dept of Logistics and Transport Management, Vilnius Gediminas Technical University, Lithuania*

Highlights:

- a research conducted in the Town of Šiauliai showed that the network of public transport routes covers 99% residential areas and 95% of jobs;
- regardless of the coverage of the route network, part of the population chooses private cars;
- the research results show that the supply of public transport is not a criterion that leads to greater use of public transport;
- passenger travels' origin–destination pairs by car coincide with passenger arrival–departure pairs by public transport.

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Abstract. This article presents a study conducted in the Town of Šiauliai with a population of 100 thousand, located in the Republic of Lithuania, where the market economy has been operating for 32 years and which is a member of the European Union for 20 years. In the town, the share of commuting travels by car is significantly higher than by public transport. Since the availability of the public transport network is identified in scientific publications as one of the many criteria for choosing public transport, it was decided to conduct a study and check to what extent the availability of the public transport network determines the choice to travel by bus or car. The research hypothesizes that residents who live in neighbourhoods with worse access to bus routes and stops choose more cars than those who live in neighbourhoods with better access to public transport. The results of the study showed that residents choose to travel by bus or car regardless of the availability of the route network. It was found that the origin–destination pairs and relative proportions of those commuting to work match both those traveling by car and by bus. The results of this study may not necessarily be the same in Western European cities or towns. The main limitation of this article is that the trip matrices were compiled from population survey data, as statistical information on origin–destination pairs in Town of Šiauliai is not regularly collected.

Keywords: commuting, transport network, public transport, personal car, survey.

✉Corresponding author. E-mail: ***andrius.jarzemskis@evaf.vu.lt***

Introduction

The aim of the article is to investigate the dependence of commuting choice on the supply of the public transport route network. The scope of the article presents a methodology for testing whether public transport routes are a significant criteria for people's choice to travel. The methodology is tested by a representative survey of residents who use public transport and residents who do not use public transport in the Town of Šiauliai.

This article presents the methodology and research that was conducted in Lithuania, in the town of Šiauliai with a population of 100 thousand. In the Town of Šiauliai, public transport is organized only by buses. In the town, the share of commuting travels by car is significantly higher than by public transport (Šiaulių miesto savivaldybė 2022). The essence of this study was to verify factors that determine the choice of residents to travel by bus or by car. The article proposes a new method to evaluate public transport network as choice criteria actual for 2 sets of population: (1) those who are traveling by public transport, and (2) those who not traveling by public transport. The concept of origin and destination pairs and travel matrix was applied.

The limitation of the study is the fact that in Town of Šiauliai there are only origin points can be identified by ticket for each travel. Although the tickets are electronic, they are a check-in and journey-based ticketing system, not a time-zone-based ticketing system. Check-out is not in place. So, novelty on proposed methodology is related

to using of survey results to analyse origin–destination points against the actual routes network. On the other hand, this limitation led to the fact that in such cases, the methodology proposed by the authors is suitable for determining the departure and arrival stops using the same instrument both for those traveling by public transport and those traveling by car.

Šiauliai Town Municipality (Šiaulių miesto savivaldybė 2022) announces that 30.8% of trips are made by public transport, and 39.8% by car. The goal for 2030 is to increase the use of public transport to 33% and reduce the use of cars by down to 33%. Hereby, the research authors contribute to the administration of Šiauliai Town Municipality to find right measures to achieve goals.

The methodology (Section 2) used in the study and the population survey questionnaire was compiled taking into account the travel selection criteria, which are examined in the Literature review (Section 1). The research results are presented in Section 3. Last section represents the conclusion and further discussion.

1. Literature analysis

There are many scientific publications, which brings a number of criteria for selection of public transport. In general, accessibility, affordability, safety, and security of public transport are the main criteria for public transport selection as is found in a large number of scientific publications. Following subchapters present main finding of literature review.

1.1. General motives to encourage public transport

Public transport is considered less harmful to the environment than using private cars (Poudenx 2008; GOV.UK 2019). For instance, the unavailability of public transport in Barcelona (Spain) during the public transport strikes causes increased level of NO_x was between 4.4 and 7.1%. The same trend was recorded for increase of carbon particles in the air (Basagaña *et al.* 2018). In other words, access to public transport has consequences on air quality and health. Promoting public transport is on the political agenda of many countries around the world (Averchenkova *et al.* 2021). In particular, public transport is encouraged in cities, and this has already started several decades ago (Kawabata, Shen 2006). The economic and environmental performance of cities can be enhanced by connecting resources effectively and facilitating mass mobility (Bok, Kwon 2016). Many cities around the world subsidize public transport. Public transport creates fewer congestion than private cars. The increase in urban populations have caused the increase in traffic causing congestion on roads and environmental impacts. So, it is the reason why urban planners are more focused on encouraging towards public transport supply than private transport (Benenson *et al.* 2011).

Transport emissions represent around 25% of the European Union's (EU's) total greenhouse gas emissions, and these emissions have increased over last decade years (EC 2019). EU politicians' goal of being the 1st climate-neutral continent by 2050 requires ambitious changes in transport. A clear path is needed to achieve a 90% reduction in transport-related greenhouse gas emissions by 2050. The urban mobility framework sets out European guidance on how cities can cut emissions and improve mobility, including via Sustainable Urban Mobility Plans (SUMP). The main focus will be on public transport, walking, and cycling. Following guidelines Town of Šiauliai has designed SUMP in year 2017–2018 where main target are set.

Despite the universal and indisputable advantage of public transport over the car, the use of cars in the world is not decreasing. On the contrary, an increase in the number of passenger cars and their use is observed in various countries. Politicians and transport specialists are using various measures to limit the use of passenger cars in cities. However, not all measures provide the expected result.

1.2. Variety of factors to choose a travel mode

Many researchers conducting research to identify the reasons why people choose public transport and why they choose private cars. Recent researches represent causes of that as a complex concept including several dimensions, which includes temporal, spatial, social network, societal, economic, political, personal and mobility disadvantages among different segments of society (Bocarejo Suescún, Oviedo 2012). Studies in different countries show different results. For example, in economically developed countries, where public transport is efficient and fast, and owning a car is no longer a sign of prestige, a greater favourability of public transport is observed. Meanwhile, in developing countries, countries where the market economy was restored only after the collapse of the Soviet Union in Eastern Europe in 1990, different trends are observed (Yatskiv *et al.* 2017). In those countries, the car often remains a means of prestige and status in society. However, more than 30 years later, a change is taking place in Eastern Europe as well (Jarzemskis, Jarzemskiene 2017). In the countries that joined the EU, Gross Domestic Product (GDP) grew faster than the EU average in the last decade. The needs and attitudes of the population of these countries are changing. The health damage caused by pollution from private cars is increasingly emphasized (Mulley *et al.* 2016).

Various authors have used different methods to determine population preferences. Most often, a representative survey is used, in which the respondent is directly asked which factors determine the choice of travel method. The dominant answer is price, speed and availability (De Oña *et al.* 2013). However, many studies show opposing information. Although public transport is objectively cheaper than traveling by car, and accessibility is good, statistics show that despite this, people prefer private cars. The reason is the existence of different time perceptions. Fransen *et al.* (2015) examine accessibility using the concept of

time. Availability of public transport is considered one of the most important criteria by Cheng & Chen (2015). There is an often-considered hypothesis that public transport is available if a sufficient supply is created in terms of route network and frequency of services. Lack of frequency is perceived as poor supply, even if route network is dense enough. It is also stated that if the transport network is insufficient, residents choose a place to live where they can go to work by public transport (Hernandez 2018). Hernandez (2018) states that accessible mobility is a requirement for participation in "modern life".

Chatterjee *et al.* (2020) assessment shows that even persons mood is lower during the commuting than other daily activities and stress can be induced by congestion, crowding and unpredictability. Research get evidence that people who walk or cycle to work are generally more satisfied with their commuting than those who travel by car and especially those who use public transport.

De Vos (2019) found that the chosen travel mode is related on travel satisfaction. He argues that the effect of travel mode on travel satisfaction might be overestimated, and that it is not so much the travel mode itself that affects satisfaction with travel, but whether the chosen travel mode is consistent with attitudes towards that mode. Furthermore, travel satisfaction might affect travel mode choice and travel attitudes more than vice versa.

Handy & Thigpen (2019) found that commute quality differs by residential location, commute mode, student versus employee status, and gender. Overall, bicycle commuters and train commuters report the highest commuting quality, bus passengers report the lowest quality. The satisfaction for car users is on average quality. We also find that all 3 dimensions of perceived commuting quality are strongly associated with overall travel satisfaction. Associations between commuting and quality of life are described by Chatterjee *et al.* (2020).

Brutus *et al.* (2017) findings show, that those who cycled to work were less stressed than their counterparts who arrived by car. However, there was no difference in mood among the different mode users. A lower level of stress among cyclists offers further evidence for the promotion of active commute modes.

Marra & Corman (2020) identify that the route choices of passengers in public transport networks can depend on different factors, which make complex problem of their understanding. In order to understand the passengers' route choices and identify their main characteristics, it is necessary to identify the available alternatives. The literature identifies 2 problems: (1) the choice model, determining the actual chosen route out of a small set (choice set), and (2) the identification of a choice set from a large set of all possible alternatives called the universal set. However, the publications of these and many other authors compare the types of travel between tram, bus, train, and walking. This type of research is suitable for those countries and those cities that have a sophisticated transport system and severe restrictions on the use of passenger cars (Anderson *et al.* 2017). In many Western European residents do not consider using a car for daily commutes because of tax and fees applied by authorities. Paid parking, entry of cars into the central parts of cities takes place in parallel with the supply of train, metro or tram connections, as efficient complex of measures. However, this is not the case everywhere in the world. In many countries around the world, the car remains the main mode of transportation for the daily commute to work.

Beck *et al.* (2017) revealed in their research that one of the most important criteria for a passenger's choice is the saving of travel time. Savings in travel time are of different importance to passengers. On long journeys, saving a few minutes means little. For short journeys, the time savings of just a few minutes are already significant. This basically justifies why in large cities with a million or more inhabitants, public transport is chosen more often than the car for commuting. The travel time savings by public transport are really big to compare to car. Meanwhile, in a city with about 100000 inhabitants, even the longest journey to work by car can take up to 20 min.

Eltved *et al.* (2019) presented a joint model, which aims at representing the behaviour of passengers as realistically as possible including more hidden details. The results also show that providing timetable information to the passengers improve their utility function as compared to only providing information on frequencies. This article also compares cases of urban train, bus and walking, but does not compare with private car travel.

Danesi & Tengattini (2020) stated that public transport networks are supposed to enhance accessibility and pursue equity principles, overcoming socio-economical differences among people. According them in-vehicle time, schedule delay and users' arrival and departure preference are listed among main factors influencing commuting preference.

1.3. Network supply criteria for selection of public transport

Bocarejo Suescún & Oviedo (2012) presented the reasons that determine the use of public transport. They estimate the difference between public transport needs and public transport supply. The values of both indicators were normalized to make their units symmetric. Higher values of the index show the attention required in public transport demand for the area and vice versa. This article emphasizes that where there is a greater supply of public transport network, more it is used. It can be assumed that in areas with worse public transport supply, residents choose another mode of travel, for example by private car, or travel less altogether.

Authors examining the accessibility of public transport distinguish that it is not only the presence of the network that is important, but specifically the distance to the nearest stop on foot (Bok, Kwon 2016). This is especially important when it comes to trips to and from work. Residents are aware of the journey time not only by public transport, but also by walking to the stop.

Very important are the studies that show that the supply of public transport is strongly related to the unemployment rate. Johnson *et al.* (2017) research proposed to consider the accessibility of public transport system as a vital parameter to address employment. Research by these authors shows that in the absence of public transport, people do not consider the car as an alternative for commuting. However, it is very important to understand in which countries the research is conducted. In Western European countries where private car ownership is taxed and various restrictions are applied, such studies provide a good basis for the link between the unemployment rate and public transport. However, in countries where the average age of a car is 15 years, where there are no parking charges, no car pollution taxes, no city center entry fees – these patterns does not work. It is in this article that this hypothesis is tested by choosing the Town of Šiauliai with a population of 100 thousand, located in the Eastern EU country – Lithuania, where the average age of cars is 15 years, and the country lacks the political will to limit the use of private cars by fees, restrictions, and other measures.

1.4. Personal and public transport competition causes

However, the competition between the car and the bus does not only take place in Eastern Europe. This was influenced not only by the economic history of the country's development, but also by the habits and purchasing power of the population. The arrangement of the urban structure is very important. Kawabata & Shen (2006) showed differences between US cities and Japan in their study. Cities that are more car-friendly have a higher number of cars. There more commuting by car is more common than by public transport. Despite the fact, that other authors (Lättman *et al.* 2016; Mackett, Thoreau 2015; Pons Rotger, Sick Nielsen 2015) assume accessibility of public transport as a potential indicator of social inclusion that is not applied for all countries. Social inclusion is also perfectly ensured by the use of private cars, if they are not restricted by authorities and politicians. To use public transport for commuting is more typical of Scandinavian countries, France, Germany, the United Kingdom, but less typical of the US or Eastern Europe, South America, and Asian countries.

Researchers present the availability of public transport as an indicator of quality of life (Bieri, Dawkins 2016). Chai *et al.* (2016) present trends and demand growth in China for cars. Badami & Haider (2007) focuses on public transport use in urbanised India. It can be said that in some cities of the world, especially in Asia, South America, public transport is well organized there for those residents who belong to the middle or working class for commuting purposes, but this only happens in very large cities with a million and more inhabitants. Population density in cities is also important when choosing public transport (Saghapour *et al.* 2016). In smaller cities in those countries, residents commute to work by old cars. Meanwhile, in Western and Northern European countries with high GDP, public transport is used by high-income individuals even in cities with less than 1 million inhabitants. In this way, it can be defined that Eastern European cities have more similarities with Asian and South American cities or even US when it comes to the choice between a bus and a private car for commuting purposes. Design of urban infrastructure also play huge role there.

The use of public transport is undoubtedly influenced by the level of service, but it is also perceived differently in different countries. Guglielmetti Mugion *et al.* (2018) note that the transport network and the existence of routes are one of the most important criteria for describing the availability of transport services. However, frequency of services, cost, cleanliness, appropriateness of schedules, reliability of schedule compliance are also important criteria (Diana, Daraio 2014).

The restriction of the use of private vehicles is promoted by the European Commission (EC). EC proposal also prioritises zero-emission solutions for urban fleets, including taxis services, the last mile of urban deliveries, and the construction and modernisation of multimodal hubs, as well as new digital solutions and services. Today's proposal maps out the funding options for local and regional authorities to implement these priorities (EC 2019). Scholars also acknowledge that without government regulation and restrictions on private cars, there is little increase in public transport use (Veeneman, Mulley 2018).

There are also many publications in the literature that examine real-world passenger flows in a city and determine origin and destination points using public transport electronic ticketing system data (Marra, Corman 2020). However, not all cities have this opportunity. In cities that do not have a temporary or zonal ticketing system, they usually use single-trip tickets, where the check-in system is applied. In this case, the electronic ticketing system allows you to collect statistics about boarding passengers, but there are no statistics on where those passengers disembark. This is quite complicated, because then the city does not have the real data on the exact travel needs. In such cases, it is necessary to use alternative methods of obtaining data, such as physical observation, representative surveys. This kind of data is very important because having it makes it possible to compare the flows of passengers using public transport and those using private cars. Widiyani (2019), Brutus *et al.* (2017), Jain *et al.* (2014) in their studies just assess the choice of passengers to use public transport and private cars. Studies show quite different results (König, Grippenkoven 2020), which depend on the country.

The competition between public transport and private cars in cities has a different character if public transport has more transport modes or multimodal trips are organized. Cities where passengers can transfer from metro to tram or bus, from train to metro are usually cities with at least half a million inhabitants. Smaller cities often have only one or 2 modes of public transportation. In cities that are smaller and have fewer modes of transportation, daily

commuters are more likely to choose private cars. If there are several types of public transport in a city, it is very important to coordinate them with each other (Anderson *et al.* 2017; Garcia-Martinez *et al.* 2018; Jiang *et al.* 2020).

1.5. Affordability, frequency and speed criteria

Paulley *et al.* (2006) in their study reveal in more detail the demand for public transport and its dependence on household income and car ownership. Population choice criteria related to switching from cars to public transport have been studied by Beirão & Cabral (2007); Jain *et al.* (2014); Gundlach *et al.* (2018) and Saleh & Sammer (2009). Studies show that commuters in India and EU countries have different selection criteria for transport mode. Environmental benefit was examined as a separate criteria, but it is perceived differently in different countries of the world (Dirgahayani 2013). The main selection criteria are the availability, frequency, speed and price of public transport. The availability of public transport is understood as the presence of a network of routes and the distance to the nearest stop (Saif *et al.* 2019). Often, these public transport selection criteria are collectively called service quality, which is tested as a complex assessment by Eboli & Mazzulla (2008); Echaniz *et al.* (2018); Dell'Olio *et al.* (2011); De Oña *et al.* (2013) and De Vos (2019). The speed or time of communication is evaluated differently in different countries because the value of time is different. In cities with higher incomes and higher wages, time is more valuable (Abrantes, Wardman 2011).

Regarding the accessibility of public transport, the choice of routes is very important (Jánošíková *et al.* 2014). In cities where there are several modes in public transport supply, it is common to organize trips with a transfer. In smaller cities, residents aim to have non-stop journeys as much as possible. The route network and schedule compatibility, as well as the reliability of schedule adherence, are crucial for transfer trip when commuting (Leng, Corman 2020; Nassir *et al.* 2015; Prato, 2009; Tan *et al.* 2015; Soza-Parra *et al.* 2019). Eltved *et al.* (2019) note that at a certain frequency of service on a route, the reliability value of schedule compliance disappears. Frequency of public transport services influences route choice (Zimmermann, Frejinger 2020; Fosgerau *et al.* 2013). Czerliński & Bańka (2021) highlight the importance of public transport pricing policy. The general idea of their research is to fucus on 2 main factors: (1) ticket prices, and (2) the structure of the tariff.

1.6. Safety and security criteria

Public transport has experienced a reduction due to the Covid-19 pandemic. Residents considered private cars safer. Scientists Vickerman (2021); Gkiotsalitis & Cats (2021); Gutiérrez *et al.* (2021); Beck & Hensher (2020) studied the needs of passengers for public transport in different countries and cultures of the world – Australia, United Kingdom, EU countries. Rudyk *et al.* (2019) highlight increased interest in road safety, environmental issues and most importantly total costs of ownership of the vehicle. Hu *et al.* (2022) suggested evaluation index system related to the comprehensive experience of passengers including safety security, as well as affordability, frequency and accessibility.

1.7. Summarisation of literature analysis

Summing up the analysis of the literature, we can say that the factors affecting the passenger's choice are very diverse and depend on specific circumstances. These factors dominate differently depending on the country, city, historical experience of the population. There is no single correct ranking of these factors. Different authors emphasize the importance of different factors, but this is due to the focus of the authors themselves on some area. Economists look more for answers in pricing and demand and supply management, engineers look for answers in safety and security.

The literature analysis showed the complexity of the problem according to the latest scientific research state of the art. Next, in Section 2, the methodological approach of the authors of this article is presented to investigate the factor of the availability of the route network for the commuting preferences of the residents.

2. Methodology

The research methodology is designed to test 2 hypotheses. The 1st hypothesis is that the presence of a public transport network close to the place of residence and close to the place of work are significant factors that lead to the choice of public transport over the car when commuting. This hypothesis assumes that there is a part of those who live and work in such places where there is no public transport and therefore, they have to choose a car. The 2nd hypothesis is that if there is a convenient opportunity to commute by public transport from residents use this opportunity. Be the 2nd hypothesis essentially authors verify whether the population is traveling on similar routes by bus and car, if there are both equal opportunities. Many scientific studies show that when public transport network match the origin–destination pairs, commuters should choose public transport.

In order to verify the 1st hypothesis, statistical information about the places of residence of city residents can be used. Such information is anonymized and is available in national registries in many countries. Jobs are also available publicly, in many countries, especially in Northern Europe, the number of employees of companies and the addresses of companies are publicly announced. Thus, the 1st hypothesis can be tested by a purely statistical – graphical method. After displaying the residential areas on the map and dividing them into grids of 250×250 m and showing the number of residents living or working in them, the layout can be seen on the map (as in Figure 2

and Figure 3). By displaying the public transport stops and the route network on the same map, it is possible to see the correspondence of the network to places of residence and work. It is estimated that a distance of less than 500 m to a stop is considered a factor indicating the availability of public transport. A resident can cover this distance in 6...7 min. Statistical matrices allow you to calculate the coverage percentage of the transport network quite accurately (as in Figure 2 and Figure 3).

Testing the 2nd hypothesis is more complicated. If all the data about each resident's place of residence and workplace were available, then it would be possible to compile detailed travel matrixes of origin–destination pairs, but it would still remain unclear which way the resident travels – by public transport or by car. In addition, such data are actually inaccessible due to personal data protection legislation. Depersonalized data was sufficient to test the 1st hypothesis, but depersonalized data no longer allows linking the resident's place of residence and workplace.

However, commuting routes and concrete origin–destination stops are very important for testing the 2nd hypothesis. In this study, the authors chose a representative survey, during which residents are asked to indicate from which district to which district they go to work. In order for residents to easily assign themselves to a district, it is very useful to use the actual division of the city into districts. In the case of Town of Šiauliai, a representative survey was conducted with 2368 respondents (error 2.65%, probability 99%). Separate travel matrixes are created for those who commute to work by car and separately for those who commute to work by public transport. Since a population survey is used instead of actual population numbers, further calculations are made in relative sizes. The proportion of respondents traveling between districts is calculated. All trips are considered 100%. Each district is marked as D_n. N is total number of districts. In Town of Šiauliai case there were 8 districts, but the method could be used with larger number of districts (Figure 1). D_1D_{n+1} represents the number of trips from D_1 to D_{n+1}. $D_{n+1}D_n$ represents the number of trips from D_{n+1} to D_n. If the journey starts and ends in the same district, it is counted as an intra-district trip, and it is marked as D_nD_n. For each pair D_1D_{n+1}, $D_{n+1}D_n$ as well as D_nD_n share of the total number of trips is taken from survey results. The total number of all trips is defined as D – Equation (1). For total number of bus trips is used D_b, and for car trips – D_c. Share of bus trips for each pair is marked as P_{bm}. Share of car trips for each pair is marked as P_{cm}. Total number of possible pairs is marked as M. Total number of possible pairs is related to number of district as in Equation (1):

$$\sum_{n=1}^{N} D_{n+1}D_n \cup D_nD_{n+1} \cup D_ND_N = D; \quad (1)$$

$$M = N^2. \quad (2)$$

Separately, the proportion of origin–destination pairs from all trips is calculated for bus trips (Equation (3)) and car trips (Equation (4)). The difference between car and bus travel shows the different needs of car and bus travellers (Equation (5)).

$$\sum_{m=1}^{M} P_{bm} = 1; \quad (3)$$

$$\sum_{m=1}^{M} P_{cm} = 1; \quad (4)$$

$$\Delta_m = P_{bm} - P_{cm}. \quad (5)$$

Since in the case of the Town of Šiauliai there are 8 districts, all trips are divided into 64 origin–destination pairs. It is difficult to apply a unified formula in order to determine how big the difference between origin–destination pairs is, if one wants to see the importance of the transport network for the choice of travel. In this case, a difference threshold of 1.5 percentage points was chosen. After calculating the results, qualitative evaluation is important in the evaluation of the results. If 80% of the origin–destination pairs between those traveling by bus and car coincide, it can be said that there are other reasons for choosing a car than the inaccessibility of the public transport network.

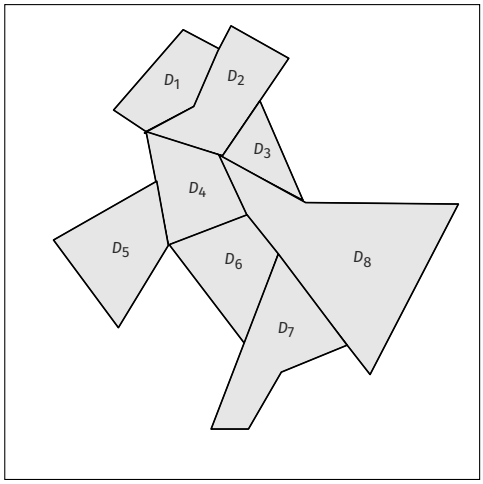

Figure 1. Divisions of a town to the transport districts

3. Results – case in Town of Šiauliai

At the beginning, the results of coverage of residents' residences and workplaces by the network of public transport routes are presented. Town of Šiauliai is a relatively compact with a railway line running through the middle. The railway line bisects the town and the route network only crosses the railway in 3 places. Figure 2 shows the layout of the network of public route stops in the Town of Šiauliai.

The map in Figure 3 shows the results of the survey. Squares on the map represent territories with a size of 250 × 250 m. The squares marked with different colours show the number of people leaving home to work by car – from 7 to 8. These data reflect the results of the population survey. For those traveling by car, the main commuting locations are South and Central. This corresponds to the main

departure points of the population commuting by public transport. It should be noted that the majority of non-travelling by public transport residents start their journeys outside the town limits – Northwest of Medelynas Dictrict, North of Gubernija District. These passengers do not have the opportunity to use public transport, but their share is small – less than 9%. It should be noted that, with the exception of respondents living on the outskirts of the town, the majority of respondents start their journeys near public transport stops. The map grid size is 250×250 m.

The map in Figure 4 shows the results of the survey. Squares on the map represent territories with a size of 250×250 m. The squares marked with different colours show the number of people who commute to work by car – from 1 to 14. These data reflect the results of the population survey. The main destinations of residents traveling by car are located in the Center. Other important travel destination are Gubernija District, Lieporiai District, Pabaliai District. Relatively fewer residents travel to the Rėkyva District and Zokniai District. Less than 9% non-travelling residents travel to outside the town limits – Ginkūnai District and to the West of the Medelynas District. It should be noted that, except for those who travel outside the town, the majority of respondents travel to places that are not far from public transport stops. The map grid size is 250×250 m.

The map in Figure 5 shows the connections between residential areas and routes of public transport. The boundary of the municipality is outlined in *green*; the routes are marked in *blue*. Places that are no more than 500 m away from the nearest stop are marked in *pink*. Residential areas are marked with squares measuring 250×250 m.

Areas that are up to 500 m away from the nearest stop were analysed. The area of such territory in Town of Šiauliai is counted as 48.46 km^2. It represents 60% of the area of Šiauliai Town Municipality. An average resident can walk 500 m in less than 10...15 min. This is considered to be the maximum acceptable distance to the stop. According to the official statistics of Šiauliai, 98414 inhabitants live in this territory. This is 97.8% of the total population of Šiauliai Town Municipality.

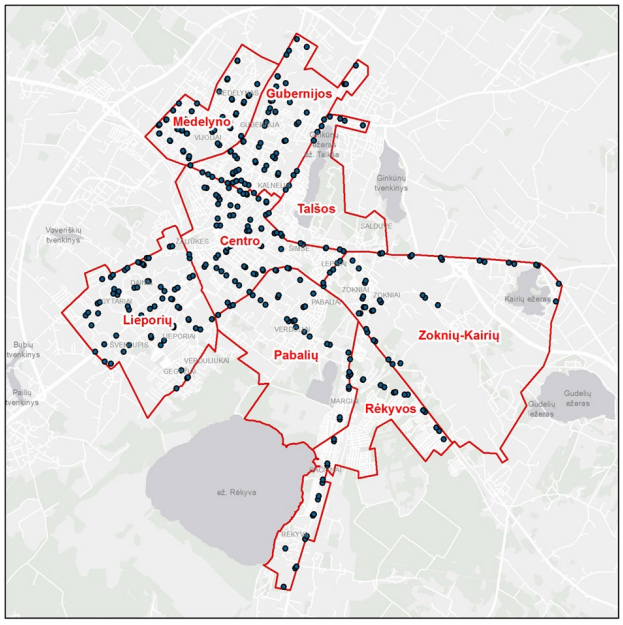

Figure 2. Location of the network of public route stops in the Town of Šiauliai

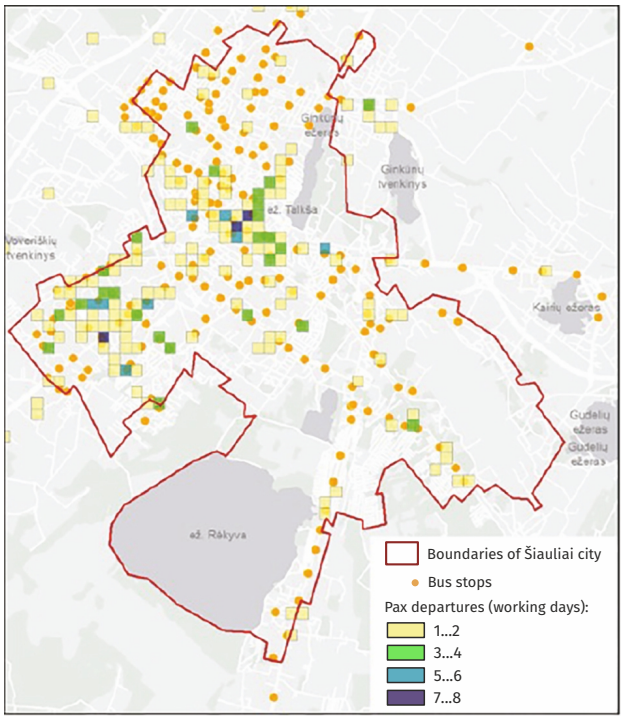

Figure 3. The number of people leaving home on weekdays by car according to survey data

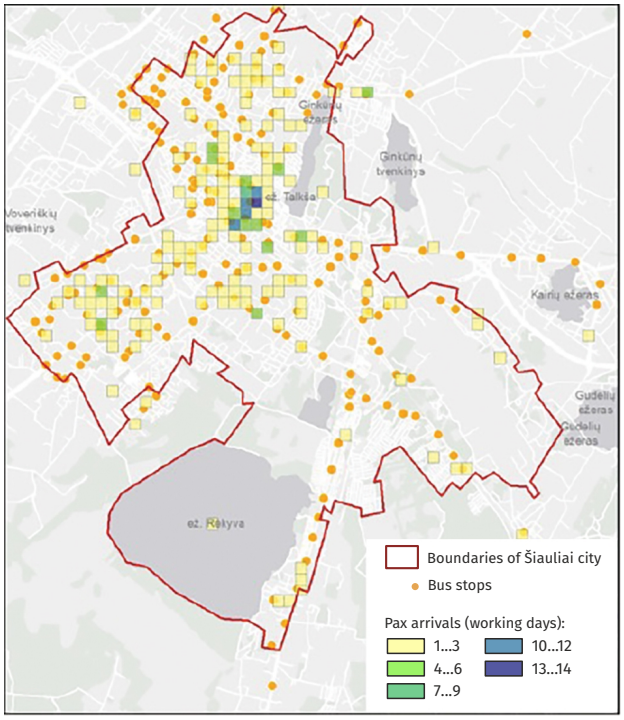

Figure 4. The number of people coming to work on weekdays by car according to survey data

Additionally, an analysis of workplaces that are no more than 500 m away from the stops was carried out. The map in Figure 6 represents the connections between workplaces and routes of public transport. The boundary of the municipality is outlined in *green*, the routes are marked in *blue*. Places that are no more than 500 m away from the nearest stop are marked in *pink*. Workplaces are marked with squares measuring 250×250 m. According to the data of the official statistics, 54091 jobs fall into this territory. In total, according to statistical data, there are 54418 workplaces in the territory of Šiauliai Town Municipality. Accordingly, 99% workplaces are less than 500 m from the nearest bus stop. The analysis of the network of stops allowed us to determine its coverage – 97.8% of the population lives closer than 500 m from the nearest bus stop, 99% of jobs fall within this area. This clearly shows that the availability of public transport in the network is sufficient to serve all workplaces.

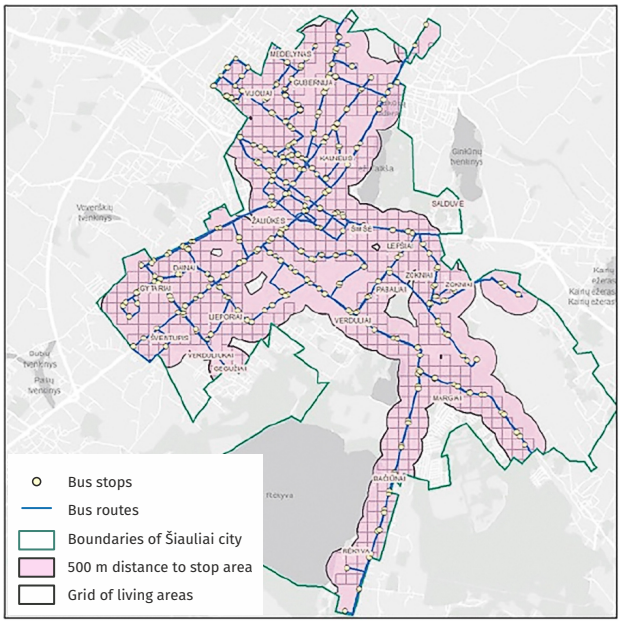

Figure 5. The territory of the Town of Šiauliai, where the distance to the nearest bus stop and living areas is up to 500 m

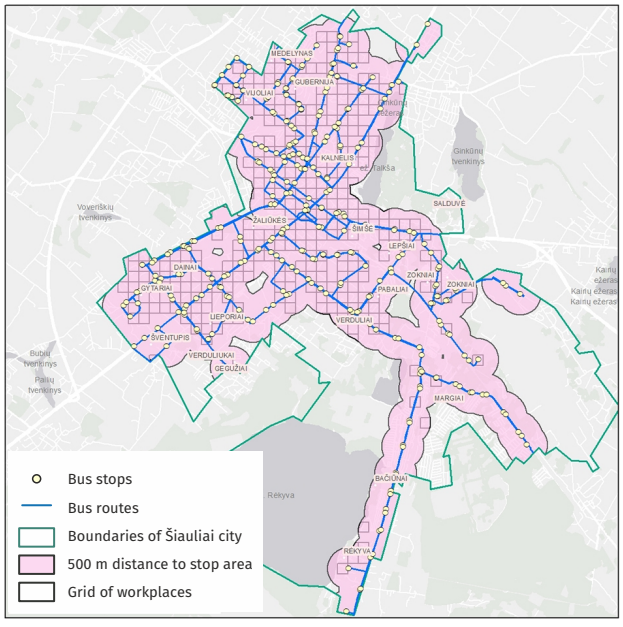

Figure 6. The territory of the Town of Šiauliai, where the distance to the nearest bus stop and workplaces is up to 500 m

A network survey of bus stops and routes layouts, while showing accessibility in a network, does not show convenience in a network. The main focus of this study was on the convenience of the network, in order to understand whether the network influences people's decision to use a car or bus for commuting to work. The essence of the network convenience methodology is to check whether the travel routes of those who go to work by bus or car coincide. According to the methodology described by the authors in Section 2, the survey data collected are shown in Tables 1–3. Table 1 shows a matrix of bus trips in which bus trips are linked by origin and destination districts. So, origin and destination pairs are assumed as districts pairs. Table 1 shows the percentage of surveyed residents who leave home and go to work between specific districts every day by bus.

A survey of bus passengers showed that 54% residents regularly travel between the Lieporiai District, Central District and Gubernija District. The largest flow is from Lieporiai District to the Central District (23.95%), from the Central District to Lieporiai District (14.62%), from Lieporiai District to the Gubernija District (5.33%) and from the Gubernija District to the Central District (3.6%). The majority of respondents start their journey in Lieporiai District and Central District (72%). The smallest flow is formed in the Zokniai–Kairiai District (2.89%), Rėkyva District (3.18%) and Medelynas District (3.66%). 13.15% trips took place within the boundaries of the districts – most of them took place in the territory of the Central District (6.87%) and in the territory of Lieporiai District (4.68%)

The Table 2 shows the percentage of surveyed residents who leave home and go to work between specific districts every day by car.

The study of people traveling by private cars showed that 28.2% of residents regularly travel from the Lieporiai District to the Central District (9.2%), from the Central District to the Lieporiai District (8.3%), and within the boundaries of the Central District (7.5%) and Lieporiai District (3.1%), 9% the beginning of the journey is outside the considered districts; 8.6% ends its journey outside the considered districts. Table 3 represents differents in percentage point between bus and car commuters as in Equation (5).

The research revealed that the differences between the departure and arrival points of trips to work between those traveling by bus and private car are very small. Only from Lieporiai District to the Center is there a greater use of bus transport. Cars are used more from the Centeral District to the Talkša District, but slightly. Of the 64 transport pairs, only 6 had a difference of more than 1.5 percentage points between the percentage of bus and car trips. There were only 3 cases out of 5 when there were more cars than buses – in the Central District – when the start and end of the journey is in the Central District, from the Central District to Talkša District and from Lieporiai District to Talkša District.

Table 1. Matrix of commuter travel by bus

Percentage of all trips P_{bm}	To Lieporiai District	To Pabaliai District	To Rėkyva District	To Central District	To Zokniai–Kairiai District	To Talkša District	To Gubernija District	To Medelynas District	Total
From Lieporiai District	4.68%	2.31%	1.02%	23.95%	0.89%	2.37%	5.33%	0.58%	41.14%
From Pabaliai District	0.93%	0.03%	0.07%	1.62%	0.03%	0.07%	0.29%	0.14%	3.18%
From Rėkyva District	1.26%	0.31%	0.41%	1.82%	0.03%	0.12%	0.53%	0.02%	4.51%
From Central District	14.62%	1.51%	1.08%	6.87%	1.36%	1.14%	3.42%	1.00%	31.00%
From Zokniai–Kairiai District	0.40%	0.00%	0.03%	1.86%	0.17%	0.09%	0.33%	0.02%	2.89%
From Talkša District	2.13%	0.14%	0.09%	1.86%	0.07%	0.24%	0.07%	0.00%	4.59%
From Gubernija District	3.49%	0.22%	0.40%	3.60%	0.24%	0.14%	0.74%	0.19%	9.02%
From Medelynas District	0.74%	0.21%	0.09%	2.46%	0.02%	0.00%	0.15%	0.00%	3.66%
Total	28.25%	4.73%	3.18%	44.03%	2.82%	4.16%	10.87%	1.94%	100.0%

Table 2. Matrix of commuter travel by car

Percentage of all trips P_{cm}	To Lieporiai District	To Pabaliai District	To Rėkyva District	To Central District	To Zokniai – Kairiai District	To Talkša District	To Gubernija District	To Medelynas District	Total
From Lieporiai District	3.1%	1.6%	1.3%	9.2%	1.3%	3.2%	2.7%	0.7%	1.8%
From Pabaliai District	1.5%	0.3%	0.1%	1.6%	0.0%	0.4%	0.4%	0.4%	0.1%
From Rėkyva District	0.9%	0.1%	0.3%	1.7%	0.0%	0.6%	0.2%	0.0%	0.2%
From Central District	8.3%	1.0%	1.4%	7.5%	1.3%	3.4%	3.8%	0.8%	3.1%
From Zokniai–Kairiai District	0.8%	0.1%	0.1%	0.9%	0.3%	0.2%	0.0%	0.1%	0.3%
From Talkša District	2.2%	0.7%	0.3%	2.3%	0.5%	1.0%	0.8%	0.9%	1.7%
From Gubernija District	2.4%	0.8%	0.4%	2.5%	0.1%	0.6%	1.3%	0.5%	0.5%
From Medelynas District	1.0%	0.2%	0.1%	1.4%	0.0%	0.4%	0.3%	0.4%	0.0%
Total	1.3%	0.2%	0.1%	4.0%	0.3%	1.0%	1.2%	0.1%	0.8%

Table 3. Differences in matrix of commuter travel by car and by public bus

Difference Δm	To Lieporiai District	To Pabaliai District	To Rėkyva District	To Central District	To Zokniai–Kairiai District	To Talkša District	To Gubernija District	To Medelynas District	Total
From Lieporiai District	–0.9%	–0.4%	0.5%	–12.9%	0.6%	1.5%	–2.1%	0.3%	–13.3%
From Pabaliai District	0.8%	0.3%	0.1%	0.3%	0.0%	0.4%	0.2%	0.4%	2.5%
From Rėkyva District	–0.1%	–0.2%	0.0%	0.2%	0.0%	0.6%	–0.3%	0.0%	0.1%
From Central District	–4.7%	–0.3%	0.6%	2.2%	0.2%	2.9%	1.1%	0.0%	2.0%
From Zokniai–Kairiai District	0.6%	0.1%	0.1%	–0.7%	0.2%	0.2%	–0.3%	0.1%	0.3%
From Talkša District	0.5%	0.7%	0.3%	0.9%	0.6%	1.0%	0.9%	1.1%	6.1%
From Gubernija District	–0.6%	0.8%	0.1%	–0.6%	–0.1%	0.6%	0.8%	0.4%	1.4%
From Medelynas District	0.5%	0.0%	0.0%	–0.8%	0.0%	0.5%	0.2%	0.5%	1.0%
Total	–3.8%	1.2%	1.6%	–11.5%	1.3%	7.8%	0.6%	2.8%	0.0%

Summarizing the results of the study, it is possible to reach the conclusions that in a town with 100 thousand inhabitants, in a country where the market economy has been operating for just over 30 years, the preference of residents to choose a car over a bus is not determined by the inadequacy of the bus network or the inconvenience of access.

Conclusions and further discussion

The research carried out in the case of the Town of Šiauliai revealed that the network of public transport routes is 95%, covers the residences and 99% covers work locations with the distance to the nearest stop up to 500 m. From this point of view, the coverage of the public transport network is not the reason why residents choose private cars, as far as almost all has access to public transport in walking distance. Of course, this coverage criteria alone cannot judge the suitability of routes because of 2 reasons. In particular, network coverage does not reflect the convenience of routes and schedules to reach the required places for residents. Another aspect is the safety and convenience of access to the stop. This study did not include physical infrastructure coverage. Aspects such as the presence of pedestrian pathways from the house to the stop, lighting of pedestrian pathways, adequacy of the infrastructure of the stops such as protection from wind and sun were not fully investigated and evaluated.

However, the coverage of the route network is a criteria, the compliance of which allows for a deeper investigation. Ideally, if data on each resident's place of work and residence were available, then it would be possible to create pairs of origin and destination, but such data is not available for data protection reasons.

In the research, it was expected to be able to identify certain transport districts, between which traffic flows by public transport and cars are very different. It was assumed that there are transport districts between which people use cars because there are no convenient public transport routes. The data collected during the research and displayed in the matrixes showed that there are very small differences between the travel routes of residents who use buses and those who use cars.

Based on the results of the survey, matrices of regular trips were compiled for both those traveling by bus and private cars. A survey of bus passengers showed that 54% residents regularly travel between the districts of Lieporiai District, Central District and Gubernija District. The largest flow is from Lieporiai District to the Central District (23.95%), from the Central District to Lieporiai District (14.62%), from Lieporiai District to the Gubernija District (5.33%) and from the Gubernija District to the Central District (3.6%). The majority of respondents start their journey in Lieporiai District and Central District (72%). The smallest flow is formed in the districts of Zokniai–Kairiai District (2.89%), Rėkyva District (3.18%) and Medelynas District (3.66%). 13.15%. trips took place within the boundaries of the districts – most of them took place in the territory of the Central District (6.87%) and in the territory of Lieporiai District (4.68%)

The survey of people commuting by private cars revealed that 28.2% of residents regularly travel from the Lieporiai District to the Central District (9.2%), from the Central District to the Lieporiai District (8.3%), and within the boundaries of the Central District (7.5%) and Lieporiai District (3.1%), 9% the beginning of the journey is outside the considered districts; 8.6% ends its journey outside the considered districts.

Compared to residents who travel by bus, the trips of those who use car more often take place outside the districts of Lieporiai District and Central District. 6.1 percentage points more people travel from Talkša District, 2.5 percentage points more people travel from Pabaliai District. 7.8 percentage points more people travel to Talkša District, 2.8 percentage points more people go to Medelynas District.

This result was a little unexpected, because a certain hypothesis had been formed that residents drive cars when there is no suitable and convenient public transport network. This hypothesis was formed for the authors by the results of the literature analysis. However, the study revealed very valuable results that justified the need to look for other reasons why people choose a car and a bus.

Moreover, the differences that were determined by comparing the trip matrices between bus and car trips showed that the biggest difference appeared in favour of buses. That is, 23.95% of all passengers travel by bus from Lieporiai District to the Central District, while 9.2% travel there by car. However, the study did not show such a significant difference in the opposite case, where there would be a higher proportion of people traveling by a car than by a bus. Of the 64 transport pairs, only 6 had a difference of more than 1.5 percentage points between the percentage of bus and car trips. There were only 3 cases out of 5 when there were more cars than buses – in the Central District – when the start and end of the journey is placed in the Central District, from the Central District to Talkša District and from Lieporiai District to Talkša District. From the Central District to Lieporiai District, from Lieporiai District to Gubernija District, there are more buses than cars.

Thus, summarizing the case study of Town of Šiauliai, it can be concluded that in this case, the choice of residents to travel by car instead of public transport is related to reasons other than the existence of public transport routes. Taking into account the results of the obtained research, the authors conducted another study in the Town of Šiauliai, where more data were collected from the same respondents, about their education, income, car ownership, marital status, and age. The results of this study are planned to be processed and published in another scientific article as a follow-up study of the Town of Šiauliai cases on the preferences of residents choosing to travel by bus or car.

The results of this study may not necessarily be the same if a western European city were analysed, where the market economy and the imbalance of residents' wealth, the price of housing in the districts, or the distribution of the population in the districts according to income are higher. As the analysis of the literature showed, in countries where the market economy has a much longer history than the city under consideration, there is a dependence of the residents' residences on income and on available assets. In Town of Šiauliai, as in many new market economies, especially in post-Soviet countries, there are no such

wealth divides. The relative wealth and cultural equality among residents may be the reason why the study in Town of Šiauliai did not show the dependence between the travel matrices of residential areas and workplaces with the choice of travel method. The relative wealth and cultural equality among residents may be the reason why the study in Town of Šiauliai did not show the dependence between the travel matrices of residential areas and workplaces with the choice of travel mode.

Statistical verification of the conducted research would be very useful and could increase the value of this scientific article. However, no statistics are collected on regular bases in Town of Šiauliai on the number of passengers boarding and disembarking at each stop. The electronic ticket system is configured in such a way that it allows only the boarding point to be determined, but there is no possibility to determine the passenger's destination point. For this reason, there are no statistics on origin–destination pairs. The conducted survey filled this gap and made it possible to see the connections of origin–destination pairs and their correlations with places of residence and work. It makes sense to test this methodology in another city where complete statistics are available. Once the methodology has been validated, it can be widely applied in cities around the world where statistics are not collected.

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