VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF ENVIRONMENTAL ENGINEERING
DEPARTMENT OF ROADS

Vaida Vabuolytė

PUBLIC TRANSPORT DEMAND IDENTIFICATION IN KLAIPĖDA CITY BY CREATING GIS DATABASE

Master's degree Thesis

Civil engineering study programme, state code 621H20002
Urban Engineering Information Systems specialisation
Civil engineering study field

Vilnius, 2018

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OBJECTIVES FOR MASTER THESIS

.....No. .....
Vilnius

For student Vaida Vabuolytė

Master Thesis title: Public transport demand identification in Klaipėda city by creating GIS database

Approved on 18th of March., 2018. by Dean's decree No. 80 ap
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THE OBJECTIVES:

The aim of research. To create GIS database of PT routes network of Klaipėda city and to determine main indicators of PT demand and define its' minimal or maximal values to identify the need of new PT service introduction in transport districts.

Research tasks:

1. Analysis of public transport service indicators;
2. Analysis of possibilities of GIS methodologies;
3. Creation of GIS database of PT service network in Klaipėda city and its' peripheral areas;
4. Analysis of Klaipėda public transport service network for PT demand identification;
5. Creation of a methodology for identifying the demand for PT service in new developing areas;
6. Proposals on methodology applicability to other cities.

Consultants of the Master Thesis: .....

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Objectives accepted as a quidance for my Master Thesis

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Civil Engineering, ISmfu-16

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DECLARATION OF AUTHORSHIP IN THE FINAL DEGREE PAPER

May 21, 2018

I declare that my Final Degree Paper entitled „Public Transport Demand Identification in Klaipeda City by Creating GIS Database" is entirely my own work. The title was confirmed on March 19, 2018 by Faculty Dean's order No. 80ap. I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

The academic supervisor of my Final Degree Paper is Rasa Ušpalytė-Vitkūnienė.

No contribution of any other person was obtained, nor did I buy my Final Degree Paper.

(Signature)

Vaida Vabuolytė

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Vilnius Gediminas Technical University
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Master Degree Studies **Civil Engineering** study programme Master Graduation Thesis 4

Title	**Public Transport Demand Identification in Klaipeda City by Creating GIS Database**
Author	**Vaida Vabuolytė**
Academic supervisor	**Rasa Ušpalytė-Vitkūnienė**

Thesis language: English

Annotation

The final work of the master's degree includes the creation of the GIS database of Klaipėdą public transport as well as determination its demand in new developing areas in the peripheral zones of the city. To study public transport demand, scientific literature analyzed, the most important indicators set. Experts' survey was carried out in order to rank the significance of defined indicators. Having determined the weight of the indicators, a public transport analysis of the Klaipėda city and peripheral zone performed. The research uses GIS techniques and statistical analysis to evaluate the public transport demand in the new developing territories.

The research has developed a methodology that can be used to identify the demand for public transport in newly built territories in the city of Klaipėda and its peripheral areas. The methodology is also applicable to determine the demand for public transport in other cities.

Structure: introduction, 5 chapters, conclusions and suggestions, references.

Thesis consist of: 60 p. text without appendixes, 18 pictures, 9 tables, 44 bibliographical entries.

Appendixes included.

Keywords: Public transport, public transport demand, GIS database, experts' survey

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Antrosios pakopos studijų **Civilinės inžinerijos** programos magistro baigiamasis darbas 4

Pavadinimas **Viešojo transporto poreikio nustatymas Klaipėdos mieste sukuriant GIS duomenų bazę**

Autorius **Vaida Vabuolytė**

Vadovas **Rasa Ušpalytė-Vitkūnienė**

Kalba: anglų

Anotacija

Magistro baigiamajame darbe yra atliktas Klaipėdos miesto viešojo transporto GIS duomenų bazės sukūrimas, viešojo transporto poreikio besivystančiose periferinėse miesto teritorijose nustatymas. Viešojo transporto poreikiui nustatyti buvo išnagrinėta mokslinė literatūra, išskirti svarbiausi rodikliai. Atlikta ekspertų apklausa siekiant nustatyti apibrėžtų rodiklių reikšmingumą. Apskaičiavus rodiklių svorius, atlikta Klaipėdos miesto ir periferinės zonos viešojo transporto analizė. Siekiant įvertinti viešojo transporto poreikį naujose besivystančiose teritorijose, tyrime naudojami GIS metodai ir statistinė analizė.

Baigiamajame darbe buvo sukurta metodika, kurią taikant galima nustatyti viešojo transporto paklausą naujai užstatomose Klaipėdos miesto ir jo periferinių rajonų teritorijose. Ši metodika gali būti taikoma nustatant viešojo transporto paklausą kituose miestuose.

Darbą sudaro 5 dalys: įvadas, 5 skyriai, išvados ir siūlymai, literatūros sąrašas.

Darbo apimtis - 60 p. teksto be priedų, 20 iliustr., 9 lent., 44 bibliografiniai šaltiniai.

Pridedami priedai.

Prasminiai žodžiai: viešasis transportas, viešojo transporto poreikis, GIS duomenų bazė, ekspertinė apklausa

TABLE OF CONTENT

MARKINGS

Abbreviations

PT - public transport

EU- European Union

SQ – service quality

GIS – geographic information systems

VŠĮ - a public company

VGTU – Vilnius Gediminas technical university

UAB - a limited liability company

Definition of basic terms

Public transport – passenger, luggage and / or freight services on specified routes at a specified time, service provided to anyone applying.

Public transport infrastructure – transport infrastructure owned by the state or municipalities and intended for the carriage of passengers, luggage and / or cargo.

Operator – means the company engaged in transport activities (passenger, luggage and / or freight) which meets the conditions and requirements established by the laws of the Republic of Lithuania.

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INTRODUCTION

Half of humanity (about 3.5 billion people) already lives in cities and the number continues to grow. Such expansions cause certain problems to emerge, for example, high pollution level, increasing energy consumption, social inequality etc. Sustainable development is an ultimate solution for these and other problems of modern society and assistance to disordered urban growth. Sustainable development is based on ensuring the needs of a modern society without diminishing the prospects of human well-being as well as integrity and stability of the natural systems in the future. According to United Nations organization, there are 17 goals to reach sustainable development and 11th of them is sustainable cities and communities. This leads to the main topic of this thesis, as transport infrastructure and the provision of these services, as well as the operation, are one of the essential features in every city. So, public transport plays the significant role in sustainable transport ecosystem. Planning optimal public transport and at the same time providing access of the network infrastructure to as many urban and peripheral areas residents, could significantly contribute to solving certain problems in cities, though it is not an easy task.

There are many books, articles and other material that focus on public transport routes network indicators and their influence on routes planning as well as network optimization in cities. Such indicators include population, public transport routes density, frequency, run, accessibility, availability, operating speed etc. Unfortunately, in most cities of Lithuania, the number of inhabitants is decreasing, but at the same time, there is a tendency towards the increasing migration of population to peripheral areas. In the suburban areas, development of housing is often chaotic, therefore, public transport service operators are faced with the challenge of planning efficient and at the same time accessible PT service infrastructure to residents of newly developing territories. Unfortunately, in Lithuania, there is no methodology for identifying PT demand in the new developing territories. Methodology creation, identification of the main criterions for PT and definition of its values would be a significant help and guide for transport infrastructure planners and operators. It would help to identify the gaps in PT routes network, to determine if PT operates efficient enough to meet the needs of the residents or whether it needs some improvements, modifications.

The object of analysis. Klaipėda city and its' peripheral areas.

The aim of research. To create GIS database of PT routes network of Klaipėda city and to determine main indicators of PT demand as well as define its' minimal or maximal values to identify the need of new PT service introduction in transport districts.

Research tasks:

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1 REVIEW OF SCIENTIFIC AND LEGAL INFORMATION

1.1 Importance and definition of public transport

Transport has played a significant role in human evolution. In modern society, this is an engine of economic growth and it allows people to meet their daily needs by reaching destinations faster, to travel and to communicate. Finally, transport is a fundamental resource and an essential instrument for continuous European integration. So that, transport matters. Additionally, business and individuals in the EU are taking advantage of the benefits offered by the expansion and integration of the common market. This has led to an increase in the amount and complexity of transport. Though, the transport system in the EU is not yet sustainable. Growth in transport activities puts growing pressure on natural resources and societies. Emissions of greenhouse gases, air pollutants and noise from transport affect the environment, climate and also human health. To add more, rising energy consumption by the transport sector requires more resources.

Public transport is described as a modern way of transporting people when using vehicles that can transport large numbers of passengers in a short time. Public transport is a major solution for the world to help to achieve the objectives of economic growth, sustainable infrastructure and to limit climate change. It offers alternative modes of transportation to private motor cars. Public transport, including metro, trams, trolleybuses, buses etc., contributes to sustainability goals by relieving traffic congestion and at the same time reducing air pollution from streets transport. Public transportation systems can play a substantial role in creating a healthier society. Providing important environmental benefits — by reducing traffic-related air pollution, greenhouse gases etc. — public transportation contributes to meet EU goals and national air quality standards. Increased use of public transportation could have an even more significant impact on future generations. The use of public transport has to be encouraged if a sustainable transport policy is being developed.

Burinskienė *et al*. (2009) emphasize the importance of effectiveness and efficiency of public transport in cities. According to authors it must have secured funds and an efficient infrastructure to maintain the balance between the supply and demand of the services offered. The public transport system must be designed to ensure more convenient travel opportunities for the city's population and faster access to non-motorized facilities for daily activities (workplaces, educational institutions, medical services, etc.). The possibility of reaching the destination must be ensured for residents with mobility disorder and residents of the suburbs in order to avoid increasing social exclusion.

National Transport Development Programme 2014-2022 of Lithuania defined goals of which one is to promote the coherence of the local (urban and suburban) transport system. This goal is to be reached by preparing cities' sustainable urban mobility plans, planning multimodal transport and intermodality, developing bicycle transport infrastructure in cities, promoting use of public transport,

developing and modernizing towns and cities bypasses. This goal and tasks are directly related to the development of the system of Klaipėda city interconnection.

Strategic Plan 2013-2020 of development of Klaipėda city sets goals to implement the principles of sustainable mobility in the transport system (Table 1.1).

Table 1.1 Goals of the Klaipėda City Strategic Plan (2013-2020) for public transport

Measure	Indicator
To develop a system of public-private transport interconnection by installing vehicles parking lots	The number of installed car parking lots and places there, including the number of places at the access points of the old town and the center; The number of bicycle storage facilities and places there
To form a convenient public transport network for residents, by optimizing it taking into account regular surveys of passenger flows	Installed infrastructure objects, units; Length of the priority (A) lines of public transport, km; Distance from public transport stop to the most distant house in block of flats and individual residential buildings quarters, km
Integrate regular public transport (bus, route taxi etc.) route and scheduling networks and ticketing systems in the city and suburbs	Possibility to pay for car parking by e- ticket; Possibility to pay for public transport services by e-ticket
To create conditions for the emergence of new green public transport modes	Feasibility study prepared A special plan prepared Technical documentation prepared

1.2 Indicators of public transport

Public transport measure criterions should be the tool to evaluate system condition, level of service, and safety provided to customers based on economic, environmental and government policy goals. They should also evaluate the day-to-day performance for strategic management, analysis options, and trade-offs. Performance measures also provide information for a decision on how to allocate resources and help to prioritize improvements to the necessary areas. In general performance measure indicators should be policy driven, which can be used in analysis of options and trade-offs, decision making on resource allocation, and monitoring to provide clear accountability and feedback

(NCHRP, 2005). Observation of PT indicators can identify trends, or warn about the problems, and helps in decision making when it is needed an immediate action or long-term plans (Abreha, 2007).

Geerlings *et al*. (2006) report that the literature review undertaken as part of the EU project EQUIP identified over 400 indicators in PT. In most of the literature sources, PT indicators and parameters are usually divided into two categories: qualitative and quantitative. Qualitative indicators show the benefits to passengers, while quantitative – more for PT operators.

According to Burinskienė *et al*. (2009) and Jurkauskas (2004), main qualitative indicators are these:

- the regularity of vehicles;
- frequency;
- travel time;
- safety;
- travel transfer coefficient.

Jurkauskas (2004) suggests that main quantitative indicators are:

- number of passengers transported;
- run coefficient;
- passenger-shift coefficient;
- passenger travel time;
- number of passengers transported per hour;
- operating speed.

The choice of mode between private vehicles and public transport (PT) is a complex decision process, which is influenced by various factors. Trip characteristics, such as for purposes of the trip, time of trip and regularity of trip, and demographic characteristics, such as age, gender, and income level, were shown to be significant factors in mode choice (Ye *et al.*, 2007). Many studies were conducted to determine the most significant performance indicators of PT services. Usually, the choice was based on the goals and objectives of the authorities. However different studies used comparatively variant performance indicators, so it could not be used to reach a generalized conclusion (Benjamin and Obeng 1990; Karlaftis 2004). This has led some researchers to conclude that it may be necessary to use a more concise yet reliable set of indicators to describe the public transit system performance (Karlaftis 2004).

White (2002) suggest measurement of the public transport within the scope and lists such criterions:

- The absolute number of trips, usually derived from ticket sales by operators of PT;
- The distance traveled, expressed in passenger-kilometers;
- User expenditure;

- Trip rates per head of population
- Market share.

Loader and Stanley (2009) stressed that a minimum level of PT service quality must be provided before ridership levels increase.

A large variety of approaches to service quality has been developed in recent years regarding the complexity of the concept and the broad range of attributes required to evaluate PT service quality. For a long time, the performance evaluation of Public Transport (PT) has been carried out from the service managers' perspective, based on the cost efficiency and cost-effectiveness of PT services and operations (e.g. Hensher and Daniels, 1995; Pullen, 1993). However, in the last few decades, Service Quality (SQ) has become a major area of attention for practitioners, managers, and researchers, who have focused on the passengers' perspective. Offering high-quality PT services will encourage a modal shift from private modes to PT services and, consequently, it will promote a more sustainable mobility (de Oña, 2014).

A large variety of approaches to service quality has been developed in recent years regarding the complexity of the concept and the broad range of attributes required to evaluate PT service quality. For a long time, the performance evaluation of PT has been carried out from the perspective of service managers, based on the cost efficiency and cost-effectiveness of PT services and operations (e.g., Hensher and Daniels, 1995; Pullen, 1993). However, in the last few decades, Service Quality (SQ) has become a major area of attention for practitioners, managers, and researchers, who have focused on the perspective of passengers. Offering high-quality PT services will encourage a modal shift from private modes to PT services and, consequently, it will promote more sustainable mobility (de Oña, 2014).

Beirao *et al.* (2007) findings indicated that the service should be designed in a way that accommodates the levels of service required by customers and by doing so attract potential users to increase public transport usage. Scientists added that if service is unreliable, has a low frequency or lack of comfort; people are likely to shift to using cars because they do not perceive public transport as a viable alternative to them. Attributes like frequency (Hensher *et al.*, 2003) and comfort (Friman and Gärling, 2001; Hensher *et al.*, 2003) are also highly valued by consumers, being key elements of consumer satisfaction. Other attributes found having a major negative impact on consumer satisfaction are travel time and fare level (Hensher *et al.*, 2003).

Beiraro *et al.* (2007) research have also defined most important indicators for different PT users according to their social status (worker, students). For instance, stated importance studies for bus services showed that in lines used predominantly by workers, some service attributes such as punctuality, frequency, bus driving security and information service are most important (Guirao *et al.*, 2016). Alternatively, ease of ticket purchase, onboard security and reliability are the most

important attributes in predominantly transporting students (Eboli and Mazzulla, 2009). In turn, derived importance studies show that comfort is the most relevant attribute for riders over 65 (Dell'Olio *et al.*, 2011), while sense of security (Yavuz and Welch, 2010) and cleanliness (Dell'Olio *et al.*, 2011) are important factors in determining travel satisfaction for women.

Paulley *et al.* (2006) concentrated on the PT demand identification findings regarding the influence of fares, quality of service and income and car ownership. In the original paper, there is little doubt that a wide range of factors influences the demand for public transport, and there is plenty of empirical evidence as to what the relevant factors are, and, which of them may be more important than others. In different circumstances, it must always be recognized that the results may be subject to a considerable degree of uncertainty.

Urban Transport Green Paper (2007) is European Commission document, which defines mobility issues in urban areas and the options to improve it. This document emphasizes that citizens expect public transport to cater for their needs regarding quality, efficiency, and availability. Public transport has to be not only accessible but also frequent, quick, reliable, and comfortable to be attractive. Experience shows that an obstacle to a modal shift from private to public transport is often the low quality of service, slowness, and unreliability of public transport.

1.3 Defined indicators of public transport service

Even though there are lots of measurement criterions of public transport, literature study revealed, that PT users mostly value the quality of service. A very large number of attributes have been used to evaluate service quality (e.g., Murray *et al*. (2010) consider 166 attributes).

Public transport quality depends on several factors (attributes) of the service; some are quantitative (e.g. average travel time and its reliability; transit waiting time; monetary costs) while others are qualitative, whose effects on user behaviour are more difficult to assess (e.g. riding comfort, information, personal security) (Cascetta and Carteni, 2014).

From the service providers' perspective, it is essential to identify the most important attributes of service quality that are perceived by current and potential users. However, the specification of a set of relevant attributes is complex (Prioni and Hensher, 2000). In addition, it is important to identify their relative importance to users' satisfaction. For instance, research has shown that reliability (being on time) is a decisive factor (Bates et al., 2001; Edvardsson, 1998; Hensher *et al*., 2003; König, 2002). The problem is not so much having to wait, but the uncertainty of when the transport will arrive (König, 2002). Likewise, attributes like frequency (Hensher *et al*., 2003) and comfort (Friman and Gärling, 2001; Hensher *et al*., 2003) are also highly valued by consumers, being key elements of consumer satisfaction. Other attributes found having a major negative impact on consumer satisfaction are travel time and fare level (Hensher *et al*., 2003).

Guirao et al. (2016) research on customer satisfaction surveys revealed that different social and age groups of people prioritize different indicators of PT service quality. For example, stated importance studies for bus services represents that in lines used mainly by workers, some service attributes such as punctuality, frequency, bus driving security and information service are most important (Guirao et al., 2016). Alternatively, ease of ticket purchase, on-board security and reliability are regarded are the most important attributes in predominantly transporting students (Eboli and Mazzulla, 2009). In turn, derived importance studies show that comfort is the most relevant attribute for riders over 65 (Dell'Olio et al., 2011) while sense of security (Yavuz and Welch, 2010) and cleanliness (Dell'Olio et al., 2011) are important factors in determining travel satisfaction for women.

Few studies have analyzed both subjective (traveler satisfaction) and objective (transit performance) measures (e.g. EN 13816, 2002; Nathanail, 2008; Tyrinopoulos and Aifadopoulou, 2008; Eboli and Mazulla, 2010).

One of the main documents, which specifies in the requirement to define target and measure quality of service in public transport, and provides guidance for the selection of related measurement methods is European standard *EN 13816:2002 Transportation - Logistics and services - Public passenger transport - Service quality definition, targeting and measurement*, which was approved by CEN on 30 December 2001. Since 2002 it was also adopted as Lithuanian standard. The main purpose of this document is to promote a quality approach to public transport operations and focus interest on customers' needs and expectations. This is done by specifying procedures most likely to:

- Draw the attention of the responsible parties to matters to be considered;
- Lead to relevant and well-founded decisions particularly with regard to the allocation of responsibilities;
- Enable customers, and others, to compare service quality claims from alternative suppliers, reliably;
- Contribute to the implementation of a process of continuous improvement.

This standard defines that it may be adopted by:

- Public transport services for which a single operator carries sole responsibility for all major quality criteria or two or more parties share responsibilities, in accordance with an agreement;
- Authorities in a tendering/contracting situation, requiring that the service is provided in accordance with this standard.

Although the overall quality of public transport contains a lot of criterions, EN 13816:2002 standard generalizes and divides it into 8 main categories:

1) Availability;
2) Accessibility;

3) Information;
4) Time;
5) Customer care;
6) Comfort;
7) Security;
8) Environmental impact.

According to the same EN 13816:2002 standard all these criterions could be divided into three levels and specified in more details. A full list of the quality criterions of public transport is provided in Annex 1.

Availability - extent of the service offered in terms of geography, time, frequency and transport mode. Network indicators measure the possibility to go anywhere without difficulty (e.g. share of existing and potential PT users with direct journeys, distance to boarding/alighting points, the area covered). Operation measures describe the quality of the services offered in terms of appropriate frequency, schedule, operating hours etc. Mode measures are access to services suitable to meet customers' needs or the share of customers living within a specific distance of boarding/alighting points of a given mode. (Cascetta *et al*., 2014)

Accessibility - access to PT system including interface with other transport modes. Access is the degree to which public transport is reasonably available to as many users as possible. A reasonable level of access to mobility services is unanimously considered an essential right in a democratic society.

This criterion includes internal/external interface and ticketing options. Ticketing indicators relates to the easiness of obtaining a service ticket and the overall fulfillment of ticketing selling services on and of-network. By EU legislation, availability of an integrated fare and its perceived quality was included as an important PT accessibility indicator.

However, most studies of public transport accessibility focus on proximity to stops and walking distances or time to reach them. In some studies accessibility is simply a transport measure captured by the number of public transport nodes within a respective radius (Ong and Houston (2002)) or the proximity to the nearest transport node (Holzer et al., 2003; Sanchez, 1999) or measures of route density (Rice, 2001).

Information is also a very important factor and the lack of it can contribute as a barrier to use public transport. It is a systematic provision of knowledge about PT system to assist the planning and execution of journeys. According to Beirao and Sarsfield Cabral (2007) research, some infrequent

users and non-users claim to lack information about the bus system and perceive public transport as difficult to use. Some car users say they might use the bus service if they have more information.

Providing greater access to service information and more interactive services (e.g., real-time timetable information) may be a way to increase individuals' perceptions of control with public transport (Gardner and Abraham, 2007).

Paulley *et al*. (2006) imply that even though it is relatively easy to discover who makes use of various different information systems, there is little direct evidence of their effect on demand.

Time - aspects of time relevant to the planning and executions of journeys with respect to trip length and adherence to schedule. Time indicator includes service regularity; average access, egress and interchange time; in-vehicle time; service punctuality; waiting times at boarding/alighting points; a number of connections not met etc.

Travel time is a key factor when choosing a mode of transport. For work or school journeys, time importance is much higher. Beirao and Sarsfield Cabral (2007) analysis of PT users and non-users survey proved that respondents want to feel in control when traveling and this means brief waiting times, a fast journey and reliability. Also, there is a preference for a direct frequent public transport service. Generally, people do not want to have to change vehicles during their journey, unless this is perceived as easy and fast. The problem is not so much having to wait, but the uncertainty of when the transport will arrive (Konig, 2002). If the pressure to be on time does not exist, like for leisure journeys, the value attached to time is lower.

Customer care - service elements introduced to effect the closest practicable match between the standard services and the requirements of any individual customer. It is the operators' attitude towards its customer, respect, and customer orientation, professional staff, assistance at service interruptions and for customers needing help. An important measure is ticketing options, tickets flexibility and concessionary tariffs for people with different social status. Thøgersen (2009) notes that it is imperative that attributes such as access and frequency of the PT service are not prohibitively limiting to the use of public transit. While fare price can support and encourage intentions to use PT, other quality attributes will determine whether such intentions are implemented and maintained.

Comfort - service elements introduced for the making of PT journeys relaxing and leisurable. Ušpalytė-Vitkūnienė Ph.D. dissertation (2006) suggests that this indicator is one of the priorities which has to be improved and is usually named among top criterions from the passenger perspective. It defines fast and comfortable vehicles, well-equipped bus stops.

Cascetta and Carteni (2014) elaborate that comfort includes seating and personal space, ride comfort, ambient conditions and aesthetic quality of terminals. For example, seating and personal space indicators are the level of crowding, a percentage of seats free, seat comfort (the last two indicators are innovative with respect to EU standards). Ride comfort indicators measure the quality of driving, while ambient condition indicators evaluate cleanliness, air conditioning, and noise (the last two go beyond EU standards). The architectural/aesthetic quality of terminals (not presented in EN 13816, 2002) is an important measure of comfort that could influence user travel choices.

İmre and Çelebi (2016) have found that even though comfort level of PT systems can be highly variable, depending on the number of factors, they particularly excluded crowd density in-vehicles during peak hour criterion. The scientist also implied that when the level of discomfort is higher than the passengers' acceptable level, the private car usage may become more attractive than public transport because of its convenience and comfort.

In Foote's (2004) study of customer-focused improvements in the Chicago Transit Authority's PT services, results showed a 5 % (or 15 million trips per annum) increase in ridership over 5 years after a sustained period of decline. Improvements focused on comfort-related issues such as vehicle cleanliness, safety and improved complaints handling (Redman *et al*., 2013).

Security – a sense of personal protection experienced by customers, derived from the actual measures implemented and from activity designed to ensure that customers are aware of those measures. Indicator concern subjective perception of security (e.g. freedom from crime) and some more objective statistics (e.g. rates of reported crime against passengers). It includes a low rate of PT involved accidents, security improvements in bus stops (special attention to ones, that exists in peripheral areas) etc.

According to Ušpalytė-Vitkūnienė PhD dissertation (2006) from the statistics of Lithuania point of view, comparatively low number (e.g. in 2003 traffic accidents where PT was involved reached 11,8 % of all accidents in Vilnius city) of traffic accidents of Lithuanian cities in PT service sector proves that the situation of security can't be the reason for not choosing PT as a way of transportation.

Environmental impact - effect of the environment resulting from the provision of PT services. This means less pollution of the environment by means of vehicle exhaust gases and noise also reduced traffic in the city center. The optimal public transport routes network and frequency can contribute to improving this indicator.

However, literature study has proved that environmental concerns about car use did not seem so important in the travel mode choices for the PT customers. This adds to the studies which suggest that even though information about the negative environmental effects of the car use raises some

awareness, it is usually not sufficient enough to change behavior. (Anable, 2005; Hagman, 2003). Though, there is some evidence that the inclusion of environmental concern measures provides additional beliefs that can be targeted in order to change behavior (Anable, 2005).

1.3 Criterions of public transport service introduction in transport districts

Identification the need of new PT route or expanding the existing network in urbanized and peripheral territories of the city is a complicated process. Literature study revealed a number of indicators, which affect PT service demand and necessity to consider them in PT planning process, though the most frequently mentioned indicators are accessibility of public transport, population density and job density.

PT accessibility. PT accessibility is a broad term, which has been presented in chapter 1.3. To identify the need for public transport introduction, this criterion has been used as a proximity to the nearest transport node (access to the PT stop). Accessibility is an important characteristic of the urban areas and a crucial link between transportation and land use. As urban transportation planning is increasingly being considered an integral element of overall urban land-use planning, accessibility is becoming a key element in analyzing the efficiency of transportation systems, in predicting travel demand, in programming transportation investments, and in evaluating planning policies in the urban transportation planning process. Accessibility can be broadly defined as the ease with which activities at one place may be reached from another via a particular travel mode (Liu and Zhu, 2003). An accessible transport system is also essential to ensure equal opportunities for all people in society (Wu and Hine, 2003).

Public transport stops accessibility is a distance to the nearest stop. In terms of route density and vehicle speed, the best distance between stops is 500-600 m. The minimum distance between stops is 250-300 m. On express bus routes, the distance between stops can increase to 1,200-2,000 m. The public transport stop has an attraction zone for people reaching the radius of 500 m. (Burinskiene et al., 2009 m.)

A densely spaced public transport station obviously improves the geographic coverage and the accessibility but also increases in-vehicle time and supply costs. On the other side, eliminating service stops speeds up the system and reduces the operating costs.

There are several important reasons for the measurement of accessibility:

- To identify groups or areas with accessibility problems;
- To support decisions regarding transport schemes and policies;
- To identify relations between transport issues and wider policies, e.g. in planning, health, education.

The question to access to bus services can be most problematic in rural areas where demand density tends to be lowest. Where the rural population is clustered into compact villages fixed route services may be appropriate; where the population is more dispersed accessibility may be improved by demand responsive operation.

For example, in Brisbane, and other major Australian cities, a strategic policy goal of providing PT service to at least 90% of the population is stipulated in regional plans (Murray, 2003).

Ušpalytė-Vitkūnienė (2006) defines accessibility meanings of covered areas by public transport:

- 90 to 100% of the area is regarded as fully accessible;
- 70-90% of the area is well-accessible;
- 50-70% of the area is accessible;
- 30-50% of the area is little accessible;
- up to 30% of the area is not accessible.

Population density. Demography is the study of human population, of its composition, spatial distribution, and size. It is usually analyzed through the statistical and mathematical studies. Populations are never static, they increase or decrease through time and the interplay of demographic processes:

1. Fertility. The birthrate of a population.
2. Mortality. A Measure of the number of deaths in a population.
3. Migration. The movement of people from one area to another.

Population number consistently changes. The number of deaths or birth as well as migration rate makes the population number increase or decrease over time in the same area. In a small areas population size and composition can drastically change in a brief period of time regarding migration.

Demographic information and analysis assists specialists and planners with a lot of planning decisions as pointed below.

- Population information is used to determine the demand for different services among different segments of the population. Demand is determined by the composition of the population and how it is changing over time — age-sex distribution, occupation distribution, marital status, a spatial distribution of the population, household types, income levels and educational levels.
- It is also studied the present and the predicted composition of the population and its spatial distribution for choosing locations to provide services to meet local needs.
- Population characteristics are also examined to assess the relevance of new programs. For example, new kindergarten constructions in a village. Planners evaluate the distribution of age-sex at present and also the predictions of the future to define whether or not the new constructions are feasible.

- Impact of new plans on population change is also considered. Population growth could outcome of a new plan to promote rural industries as new families could move into the community for job potential. Beyond, housing and educational institutions plans might need to be reconsidered to meet the needs of new households that would possibly move into the area.
- The impact of population growth on the possibility to implement existing plans is also an important subject which concerns planners. They are interested in how changes in size, spatial distribution, and composition will influence efforts to implement different plans — social services, housing, and infrastructure such as water supply, roads etc.

Felcman and Silha (2015) research on limits of populations density for efficient public transport in mid-size cities provided the results that increasing residential density positively affects public transport use rather in neighborhoods with low density. Scientist defined the value for sustainable PT system of 40 inhabitants/ha for supporting bus service every 30 minutes, 170 inhabitants/ha for supporting bus service every 30 minutes. The same scientist made a conclusion that neighborhoods with density above 70 inhabitants/ha – primarily prefabricated housing estates – do not have significantly higher rate of public transport use.

Burinskienė et al. (2015) provides a limits of public transport service levels by population density:

- inefficient, with a population density of less than 25 inhabitants / ha;
- low intensity - 26-42 inhabitants / ha (public transport interval 30-60 min);
- medium intensity - 43-92 inhabitants / ha (public transport interval <30 min);
- intense - >92 inhabitants / ha (public transport interval <10 min).

Jobs density. Jobs density is the number of job places in the unit of area, usually jobs per ha or per km^2. It is an important indicator because job places have a high attraction rate as people make usually at least 2 trips a day between home and work generating large traffic flows in the morning and in the evening peak hours.

Most of the planners universally accept that urban density has a significant impact on citizen travel, both for their number and for travel (Dumbliauskas *et al.* 2015). In the Global report on human settlements presented by United Nations (2013) was defined the minimum limit of 3,500 inhabitants and jobs per square kilometer to generated enough passengers to cover the costs of PT. This value is defined for a car-dominant cities in Canada, USA, Australia and New Zealand.

Among other mentioned indicators is the distance of PT service from the city center, the distribution of educational institutions as well as distribution of service centers and other objects of attraction.

2 ANALYSIS OF GEOGRAPHIC INFORMATION SYSTEMS

2.1 Application of GIS

A geographic information system (GIS) is a framework for recording, keeping, inspecting, and representing data related to positions on Earth's surface. GIS is not just the software and hardware, but most importantly, the collection of information (the database) about where geographic features (roads, buildings, fire hydrants, pipes, crime incidents, ponds, streams, etc.) are located in terms of space.

GIS helps people and institutions to understand spatial patterns and relationships by relating at first sight incoherent data. For example, engineers might use GIS to develop public transport route networks, roads networks and transportation infrastructure. There is no limit to the type of information that could be analyzed using GIS technology (Fig. 2.1).

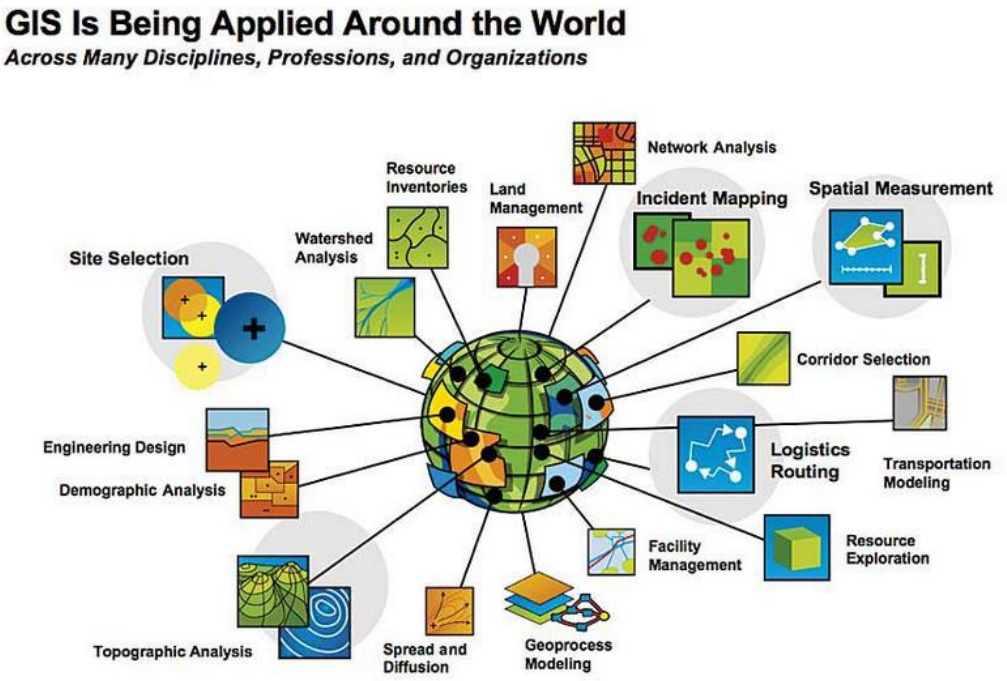

Fig. 2.1 Application of geographic information system

*GIS for Urban Planning and Community Development***.** GIS technology is widely applied in analyzing the urban growth and its direction of the development. It helps to identify proper sites for urban expansion. Urban planning and management is a complex task, one that cannot be completed without the use of a powerful analytical tool like GIS. GIS is applied in urban planning mainly as an analytical and modeling tool. It can be applied to a wide range of problems. This includes addressing problems related to database structures, simple and complex analytical models alike. GIS is also beneficial in the monitoring of an area or managing a feasibility study of a location for a particular

target. Feasibility study of even smaller structures like educational institutions or hospitals is essential and can be easily conducted with the help of GIS (GIS in Urban planning, 2014).

Traffic Density Studies: GIS is applied for the management of traffic problems. The exponential increase of population goes along with the road traffic. The tools of GIS make it an attractive option to be used to face the emerging traffic problems. Creation of the informative database that has all the traffic information such as traffic flow, road geometry, speed data, and other spatial data and processing this information provides the wider graphical image for the traffic management, problem range identification and decision making.

Energy Use Tracking and Planning. GIS is a valued tool that helps in the planning, organizing and subsequent growth in the energy and utility industries. It helps to make the management of energy systems more effective. GIS has a potential for planning, design, and maintenance of the facility.

GIS in Mapping: The main function of Geographic Information System is mapping, which provides a visual interpretation of data. With the help of different tools GIS process data in the database and then represent it visually in a mapped format. Google maps, maps.lt, Yahoo maps are the best example of internet-based GIS solution.

Accident Analysis and Hot Spot Analysis. GIS is applied as an important tool for minimization of accident risk on roads. Optimization and safety measures improvement of the existing road network can be achieved by proper management of the traffic. Identification of the accident locations simplify planning and implementation of the adjustment measures and minimize the amount of the accidents in the regions. Using GIS is also convenient for a redesign of routing.

Transportation Planning. Management of transportation and logistical problems is another field of GIS application. Adding environmental and topographical data into the GIS database helps planning for a new public transport route or a new branch of a street/road. GIS outputs the optimal route for the transportation based on the criterions like altitude, least impact to habitats and least disturbance from local residents. GIS technology is also valuable in controlling PT systems and streets/roads conditions.

Environmental Impact Analysis. EIA is an essential policy action to preserve natural resources and environment. Many human activities produce potential adverse environmental effects which include the construction and operation of highways, railroads, pipelines, airports, radioactive waste disposal and more. Environmental impact descriptions are usually required to include specific information on the size and features of environmental impact. The EIA can be carried out efficiently by the help of GIS, by combining different GIS layers, evaluation of natural characteristics can be performed.

Agricultural Applications. GIS can be used to create more effective and efficient farming techniques. Analysis of soil data provides information of the best crops to plant, maintenance of the

nutrition levels etc. Government agencies widely accept integrated management programs that support farmers and protect the environment.

Determine land use/land cover changes. GIS technology identifies land use/land cover changes in the different locations. It can find and assess the variation in the land use/ land cover pattern within a period of time. It enables to find out sudden changes in land use and land cover either by natural forces or by other activities like deforestation.

Navigation (routing and scheduling). Web-based navigation maps encourage safe navigation in the waterway. Ferry paths and shipping routes are identified for the better routing. ArcGIS supports safe navigation system and provides accurate topographic and hydrographic data. Lately, Coastal Resources Division began the job of finding, documenting, and recording these no historic wrecks with GIS. This division is giving public information that makes citizens informed of these vessel locations through web map. The web map will be constantly updated to keep the boating public notified of these coastal dangers to reduce the risk of accident and injury.

Telecom and Network services. GIS can be an excellent planning and decision making tool for telecom businesses. It allows wireless telecommunication organizations to include geographic data into the complicated network design, planning, optimization, maintenance, and activities. This technology allows telecom to enhance a variety of application like engineering application, customer relationship administration, and location-based services.

There are lots of other fields of geographic information systems application. GIS is a relatively comprehensive term, which can refer to a number of technologies and processes, so it is attached to many operations..

2.2 Planning and implementation process of infrastructure project in GIS

Information system like GIS plays a substantial role and serves as a full platform in all the stages of infrastructure life cycle from planning, capital projects and operations to visualize and analyze spatial data. GIS software can make various maps to present visualization and analysis in a more understandable way. Advancement and availability of technology has set new marks for the professionals in the infrastructure development areas. Now more and more professionals are seeking help of these technologically smart and improved information systems like GIS for infrastructure development. Geographic information system (GIS) technology gives the tools for planning, controlling, examining, and visualizing the data connected with growing and maintaining infrastructure. GIS lets civil engineers maintain and distribute data and convert it into clearly recognized reports and visualizations that can be examined and communicated to others (Maisuria 2016)

GIS software provides civil engineers with the IT framework for managing and extending important data and uses across every phase of the infrastructure project life cycle (Fig. 2.2) including preparation and design, data gathering and administration, spatial analysis, construction, and operations administration and support. This structure gives the instruments to gather intelligent GIS applications and develop a project process by giving engineers, construction contractors, surveyors, and analysts a single data source from which to work. Central hosting applications and data make it easy to maintain, coordinate, and combine geographic data, including CAD data, from existing databases to visualize, investigate, and make choices. The system supports combat data transmission errors, dropping the need for multiple, flat files in different systems (Maisuria 2016).

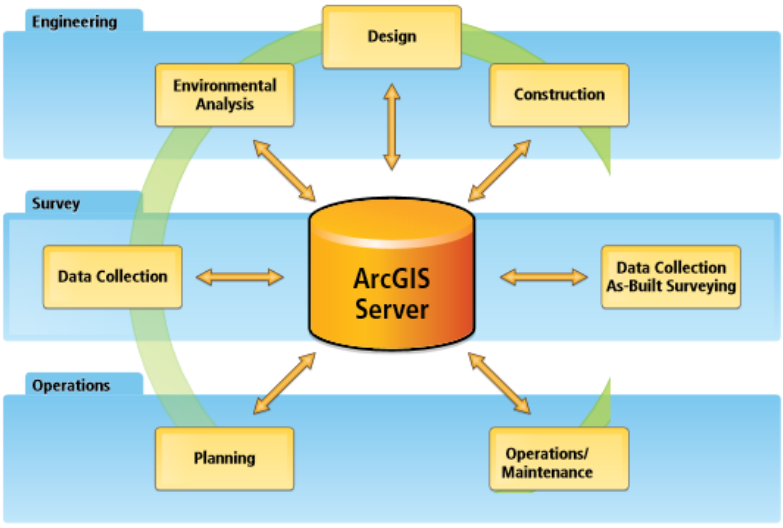

Fig. 2.2 Infrastructure life cycle

Planning: GIS gives an ordered set of data in the planning stage, which helps specialists to succeed in complicated tasks related to the choice of area, environmental impact, the study of the ecosystem, controlling risk regarding the use of natural sources, sustainability concerns, managing traffic jam, routing of streets/roads and pipelines etc.

Data Collection: Correct and reliable data is a necessary factor of the thriving project. GIS user has access to the needed data at a right time as the software is implemented with all kind of instruments and functions that, which helps during the process.

Analysis: One of the main and most important phases of infrastructure lifecycle is analysis. The analysis controls us about the validity or exactness of design, the analysis is a process which assists our design. Some examples of the analyses that are operated by GIS are:

- Traffic volume;
- Pipelines distribution analysis;
- Streets network analysis;
- Volume calculations;

- Environmental impact etc.

Analysis of the environment with a GIS enables you to view models, trends, and connections that were not obvious without the visualization of data.

Design: GIS lets the making of new infrastructure data for current civil works including design calculations, specification,s contouring, mitigation plans etc. This involves integration with traditional design tools such as CAD and databases for new design abilities.

Construction: It is the step when all plan come into presence. The GIS supports the specialists to know the site situations that touch the plan baseline and expense baseline. To hold the construction of resources and schedule GIS guides us about how to use our sources on site productivity by:

- Appropriate usage of construction equipment.
- Working Hours
- Consequences of annual fluctuations.
- Optimizing routes for utility vehicles;
- Earth filling and cutting
- Estimation of amounts and sections of constructed phase thereby helping in Evaluation and valuation.

Data Collection As-Built Surveying: GIS gives the tools to assemble exact situation data and document existing states. With such surveying infrastructure data, operators use set, operational, industry-standard data models. As-built surveying with GIS technology allows the engineer to produce data into operational GIS, reducing expensive data change and decreasing mistakes.

Operations/Maintenance: Operations are managed by modeling of situation data and related by the baselines settled in the planning stage. Modeling of the situation might be in the shape of raster images or CAD sketches (NIT Silchar, 2012). Spatial determination and presentation tools let you visualize planned work, continuing actions, recurring support problems, and past information. The topological features of a GIS database can help network duplicate and can be used to investigate particular properties or services that might be affected by such stoppages, breaks, and other defects.

3 ANALYSIS AND METHODOLOGY OF PUBLIC TRANSPORT DEMAND IDENTIFICATION

Results of the literature analysis provided a number of indicators used to analyze PT service network in districts and six of them were selected:

1. Accessibility;
2. Jobs density;
3. Population density;
4. The density of educational institutions in the area;
5. The density of I level of services in the area;
6. Distance of the district from the city center.

3.1 Determination of the significance of criterions for public transport

To determine the factors that have the greatest influence on the introduction of public transport services in transport districts, experts survey has been performed. The opinions of individual experts are often incompatible and may be controversial, so it is important to use expert ranking methods to determine the significance of the criterions. By this method, criterions are evaluated by methodologically-prepared questionnaires completed by experts (Annex 2). Identification of significance of the criterions is a 9 steps process presented in figure 3.1 below.

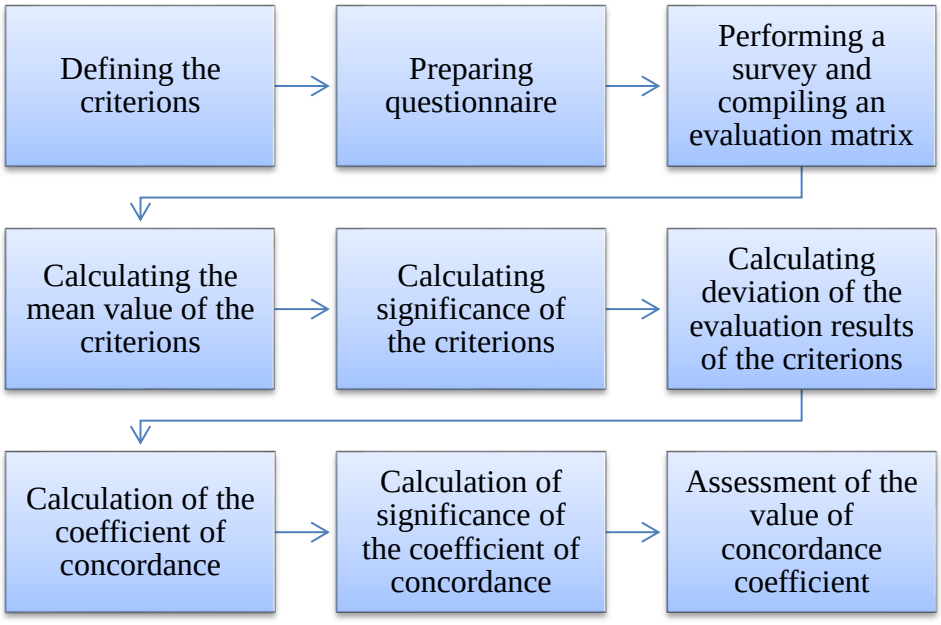

Fig. 3.1 Determination method of the significance of criterions

Experts finding is a difficult task because the experts and their skills and knowledge are rare, expensive, constantly changing and varying in depth. When addressing difficult multidisciplinary

problems, a combination of knowledge from several experts is often required (Ivlev et al. 2015). All the experts that have been chosen for a survey are specializing or are related to the field of transport and territorial planning. 11 respondents in total have participated and the division between the workplaces are: 1 expert from SĮ Vilniaus planas, 4 experts from Department of the roads of VGTU, 1 expert from Ministry of Transport and Communications, 1 expert from UAB "Urban Line", and 4 international experts from Italy, Sweden, and Portugal.

A list of 6 criterions has been made in order to identify what factors determine the need for the introduction of public transport in the districts (Table 3.1). According to the selected criterions, a questionnaire was prepared and transmitted to experts for evaluation. Some experts suggested several other criterions that could be also considered, for example, checking if any PT exists within the district area, accessibility of the destination points, motorization rate, density of PT stops, PT frequency, the length of the bus priority line between the district and city center, price of the trip, vehicles condition (new, ecological, innovative etc.).

Table 3.1 Factors influencing demand of the introduction of public transport service

No.	Criterion	Unit
1 criterion.	Population density in the transport area	Inhabitants/ha
2 criterion.	Jobs density in the transport area	Workplaces/ha
3 criterion.	Accessibility of public transport	%
4 criterion.	District distance from the city center	km
5 criterion.	Density of educational institutions	units./km^2
6 criterion.	Density of objects of I level services	units./km^2

Kendall's concordance coefficient is used for determining the compatibility of the received experts' evaluations (Sivilevičius, 2011). In other words Kendall's coefficient of concordance (W) is a measure of the agreement among several (p) experts who are assessing a given set of m objects. It is calculated according to the formula 3.1:

$$W = \frac{12S}{p^2(m^3-m)}, \qquad (3.1)$$

here: p – number of experts; m – number of criterions; S - the deviation of the sum-of-squares of the mean of estimates.

Table 3.2 Matrix of the criterions ranking

No.	Criterions	Number of expert and ranks											Sums of ranks	Position
		1	2	3	4	5	6	7	8	9	10	11		
1	Population density in the transport area	1	1	1	1	1	1	2	4	1	1	1	15	1
2	Workplaces density in the transport area	2	2	2	3	2	2	1	3	2	3	3	25	2

No.	Criterions	Number of expert and ranks											Sums of ranks	Position
		1	2	3	4	5	6	7	8	9	10	11		
3	Accessibility of public transport	3	3	6	2	3	5	3	1	5	4	2	37	3
4	District distance from the city center	6	6	4	5	6	4	4	2	6	5	6	54	5
5	Density of educational institutions	4	5	3	4	4	3	5	5	3	2	4	42	4
6	Density of objects of I level of services	5	4	5	6	5	6	6	6	4	6	5	58	6

The deviation of the sum-of-squares of the mean of estimates is calculated according to the (3.2) formula (Sivilevičius 2011):

$$S = \sum_{j=1}^{m}(R_j - \overline{R})^2 , \quad (3.2)$$

here: R_j – sums of ranks of the criterion; $\bar{R}$ - the mean of the R_j values.

Since the concordance coefficient is a random variable, the significance of the coefficient must be calculated. The significance is determined according to the (3.3) formula (Sivilevičius 2011):

$$\chi^2 = p(m-1)W, \quad (3.3)$$

We establish the compatibility of all expert estimates by calculating the minimum value of the concordance coefficient according to the (3.4) formula (Sivilevičius 2011):

$$W_{min} = \frac{\chi^2 \nu\alpha}{p(m-1)}, \quad (3.4)$$

here: : $\chi^2 \nu\alpha$ – critical statistics of Pirson, the value is found in Montgomery's table by choosing a degree of freedom v = m – 1 and the significance level α close to zero.

Weights of criterions ranking (Table 3.3) are calculated according to the (3.5) formula (Sivilevičius 2011):

$$Q_m = \frac{(m+1)-Rj}{\sum_{j=1}^{m} Rj}, \quad (3.5)$$

here: Rj – mean of the normative criterion rank.

Calculations are performed using the criterions ranking matrix (see Table 3.2). Calculating the Kendall concordance coefficient:

$$W = \frac{12 \cdot 1369.5}{11^2 \cdot (6^3 - 6)} = 0.64675$$

Kendall's W statistic is an estimate of the variance of the row sums of ranks R_j divided by the maximum possible value the variance can take; this occurs when all judges are in total agreement; hence $0 \leq W \leq 1$ (Legendre 2005). If the coefficient of concordance is equal to or very close to the 1, it means that the experts have equally or very similarly evaluated all the criteria, when the coefficient value is zero or close to zero, then the experts do not have a unanimous opinion. W = 0.64675> 0, therefore it can be stated that the reliability of the significance of the criteria obtained is sufficient.

Calculating the significance of the concordance coefficient:

$$\chi^2 = 11 * (6 - 1) * 0.64675 = 35.57$$

From Montgomery's table with a degree of freedom ν = 5 and a significance level α = 0.005, I choose $\chi^2 \nu\alpha = 16.75$ and calculating $W\alpha$:

$$W\alpha = \frac{16.75}{55} = 0.304545$$

The results W > Wα, confirms that the expert opinions are compatible.

Table 3.3 Results of the calculations

No.	Sum of ranks	Mean of ranks	S	Weights of ranks	Position
1	15	1.36364	552.25	0.268	1
2	25	2.27273	182.25	0.225	2
3	37	3.36364	2.25	0.173	3
4	54	4.90909	240.25	0.100	5
5	42	3.81818	12.25	0.152	4
6	58	5.27273	380.25	0.082	6
Mean:	38.5				
Sum:			1,369.5		

The significance of the criterions (meanings of weights) are presented in the graph below (Fig. 3.2).

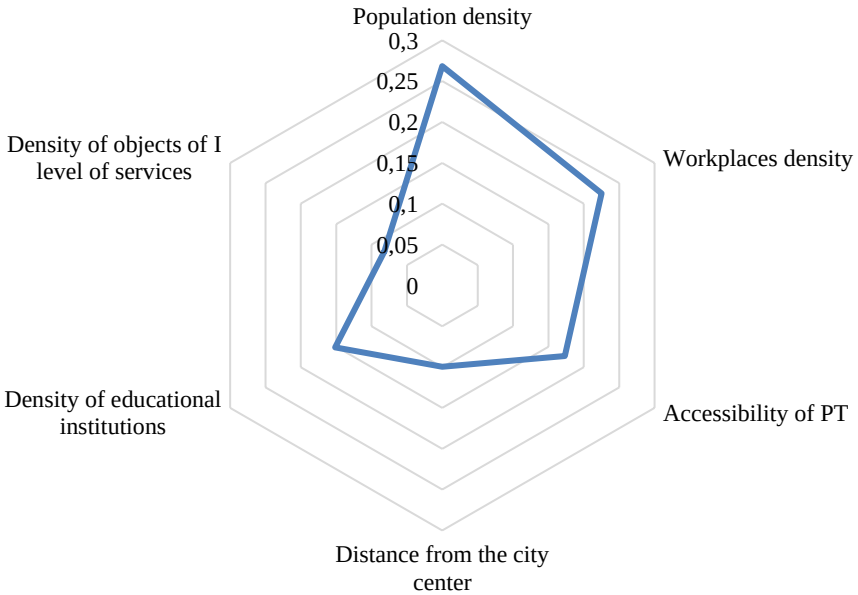

Fig. 3.2 Meanings of weights of criterions ranking

The estimated values of the criterion weights indicate that the introduction of public transport in the districts is mostly influenced by the population density in the district, jobs density, accessibility

of public transport, and other criterions, that are less relevant according to expert assessment. Experts defined that the least influential for PT introduction is the density of objects of I level of services.

3.2 Creation and analysis of GIS database for the further research of public transport

Geographic information systems (GIS) is an essential element in the methods and techniques for analyzing, monitoring and a better understanding of transport processes. GIS is considered as a significant tool for transport management and modeling due to its spatial operation possibilities and query sets operations. Public transport researchers use GIS software to create PT routes network, measure the accessibility of PT, identify optimal routes, optimize bus stops infrastructure, evaluate the level of service etc. Usually, GIS is used as the main software together with statistical techniques.

GIS database creation.

The initial data (streets and roads, city limits, buildings, water land etc.) had been taken from GDR10LT - georeferenced spatial dataset of Lithuania. Public transport database of Klaipėda city was created by the comprehensive collection of data available from the VŠĮ "Klaipėdos keleivinis transportas" website, "Department of the statistics of Lithuania", and other public authorities.

A primary image and GIS layers created as thematic maps in a topological data structure. Spatial analysis and query allowed due to topologically coded geo-data while complicated sets of many data types efficiently maintained. In this way, matters such as PT services and infrastructure insufficiency and deficiency of accessibility of PT services can be addressed more easily than by traditional methods. All the objects such as transport districts, PT routes network, PT stops educational institutions, land use areas stored as separate shapefiles, which can be easily represented graphically. Relevant information about objects was input in attribute tables (Fig. 3.3). Geometrical data like length or area obtained by GIS tools calculations.

Table

Routes of public transport

FID	Shape *	Id	Type	Direction	Route_No	Length
6	Polyline	0	Bus	Autobusų stotis - VLG	1	10,953441
7	Polyline	0	Bus	VLG - Autobusų stotis	1	10,786842
74	Polyline	0	Bus	Autobusų parkas - Statybini	10	19,023113
94	Polyline	0	Bus	Klaipėda (AS) - Palanga (A	100	16,081727
95	Polyline	0	Bus	Palangos oro uostas - Plang	100	15,848646
38	Polyline	0	Bus	Turgus - Lėbartai	11	12,723087
39	Polyline	0	Bus	Lėbartai - Turgus	11	12,13979
40	Polyline	0	Bus	BIG - Šernų sodai	11A	15,789436
41	Polyline	0	Bus	Šernų sodai - BIG	11A	15,550888
42	Polyline	0	Bus	BIG - Dovilai	11B	20,104319
43	Polyline	0	Bus	Dovilai - BIG	11B	19,952108
44	Polyline	0	Bus	Turgus - VLG	12	9,729662
45	Polyline	0	Bus	VLG - Turgus	12	9,773592

Fig. 3.3 Attribute table of routes of PT in GIS environment

Data created with the student version of ArcGIS 10.5 software package. Tables, graphs, and maps were extracted from the numerical data.

Analysis.

The research analysis is based on relevant literature, legislations, statistical data from the Department of the Statistics of Lithuania, master plans, sustainable urban mobility plans, maps, data of public authorities and from the reports written by these institutions, data results of experts' survey. The parameters used during analysis included:

- demographic data in the districts;
- number of workplaces in the districts;
- walking distances to PT services;
- covered area of PT services;
- land use.

From the descriptive information such as infrastructure, population data and area of the districts, the following parameters were derived:

- PT accessibility;
- population density;
- jobs density;
- density of educational institutions;
- density of objects of I level of services.

Criterion-analytical method of analysis followed the further research of PT demand indicators in Klaipėda city and its peripheral areas.

4 ANALYSIS OF PUBLIC TRANSPORT OF KLAIPĖDA CITY

4.1 Klaipėda city

The main object of this master thesis work is the case of Klaipėda city and its peripheral areas. Klaipėda - the third largest city of Lithuania – is situated in the Western part of the country. The city was founded in 1252 by the Livonian Order. It is the oldest city in Lithuania and one of the oldest in the Eastern coast of the Baltic Sea.

It is an ice-free port with a favorable geographical position (55o 43' North latitude, 21o 07' East longitude) on the coast of the Baltic Sea and Curonian Lagoon, within close distance to other Baltic sea-ports: Kaliningrad (Russia) and Riga (Latvia). The city covers 98.35 km2.

Klaipeda has excellent road, rail and sea links to Latvia, Kaliningrad region (Russian Federation), Scandinavia and Central Europe.

The closest airport – Palanga International Airport is located on the Northern limits of Klaipeda, within a 30 min. drive. The airport and Klaipeda are connected by the internationally significant road that extends from Liepaja (Latvia) to Klaipeda. The International Ferry Port in the city connects Klaipeda with the ports of Kiel in Germany and Karlshamn in Sweden.

The linear structure of the streets network, formed along the seaport, forms a clear urban structure of the Klaipėda city. This allows successful organization of the public transport service network and prevents traffic flows in the inner streets of the blocks (Juškevičius et al. 2006).

Master plan of Klaipėda divides the city into 4 urban centers comprising the struncture:

- Historic city center;
- Commercial - public center near Klaipeda University;
- Commercial - entertainment center between Agluonos str. and Kauno str. to the Baltic Avenue;
- Commercial - service center in axis of Smiltelės street

Residential areas of the city is possible to differentiate into a multifunctional historical core of the city and residential districts located to the southern part, mostly occupied by the Soviet-era large-scale construction of residential buildings with a monofunctional land use characteristic which is typical of that period. Another important segment of residential areas is residential neighborhoods in the northern part of the city. The indicators of these quarters are sufficient to ensure the efficient functioning of the developed infrastructure. Peripheral zone quarters in the territory of Klaipėda District Municipality, on the contrary, have no clear urban structure. Although the growth of periphery does not slow down, but due to the dynamics of chaotic development, their indicators are still too small to pay off investments in the construction of engineering infrastructure.

When analyzing the typology of dwelling-houses, there is a clear tendency of market and builders orientation towards single and duplex-dwelling buildings. The volume of construction of dwelling houses and duplex houses in the peripheral territory of Klaipėda has drastically increased in the last years. In the urban area, the volume of construction of single-family and duplex houses also exceeded the volume of construction of apartment buildings. This tendency indicates that residents value the benefits of a safe and clean environment provided by an individual dwelling house rather than the proximity of the infrastructure proposed by the city's territory. Not the last place here is played and almost the same price for an analogous comfort apartment in the city and the house in the suburbs.

Further analysis of the public transport will be performed according to territorial partitions – 33 internal and 4 peripheral transport districts of the city (Fig. 4.1).

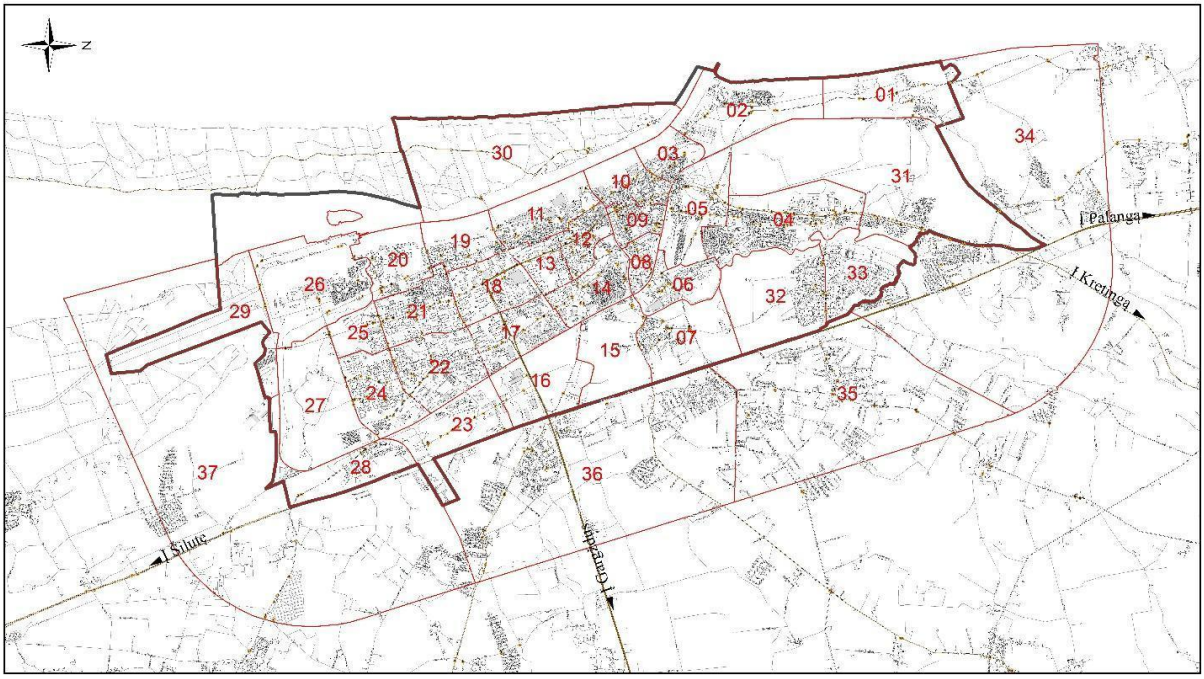

Fig. 4.1 Transport districts of Klaipėda city

4.2 Current state of public transport of Klaipėda city

Klaipeda bus station provides public transport on regular routes within the city area, suburban area and between the cities. The main public transport type in Klaipėda city is buses. Klaipėda is serviced by 32 city routes (including regular and express) and 16 suburban routes which merges into the city's PT network providing access to the services for the residents of peripheral areas. Public transport routes network scheme is presented in the fig. 4.2. Public transport service in Klaipėda is provided from 4:00 to 23:38 by daily routes (for example, route 8), and on the weekends service hours extends from 00:05 to 4:28 by night route N1.

Fig. 4.2 Public transport scheme of Klaipėda city

Source: *klaipedatransport.lt*

Current situation of the fleet of the vehicles in Klaipėda city shows that buses are old. The average age of the newest buses is 10.9 years and approximately same amount of vehicles are ~16.2 years old (Fig. 4.3). The higher the average age means higher investments in the upkeep of the fleet, lower quality of the vehicles, higher impact for the environment, less comfort for passengers. In the long-term perspective, it means decreasing satisfaction of level of services and descending passenger flows.

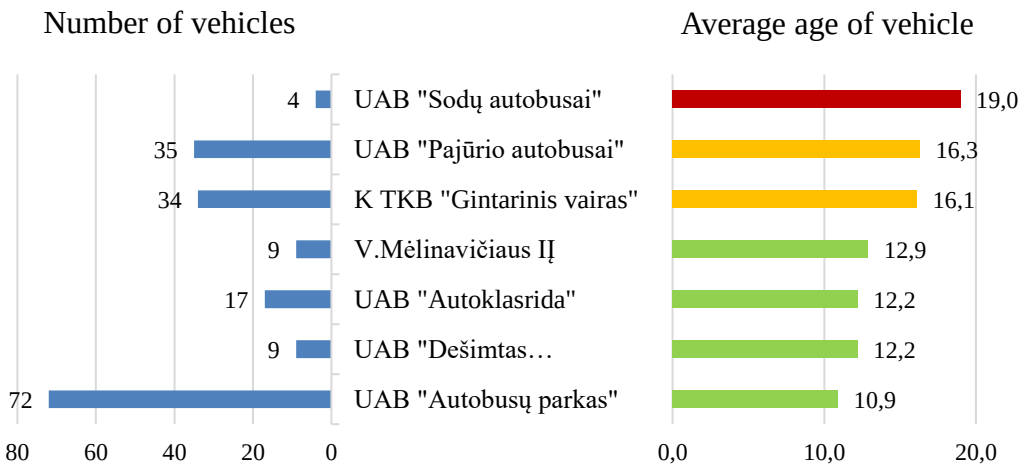

Fig. 4.3 Fleet of the vehicles of Klaipėda city

Providing a positive customer experience is an important factor when talking about public transport service. Public transport users have needs and preferences, including reliability, convenience, safety, comfort, accessibility, and affordability, which affect their satisfaction with the services provided. In order to determine the quality of a public transport system, user surveys are used to collect ratings on specific operational aspects, such as network coverage, waiting time, availability

of service, among others. The results and findings of such research highlight to transport planners and decision makers the attributes that are important for public transport users, by mode, to focus on. (Inam, 2014) In the chart below it is shown that in general satisfaction level of public transport services in Klaipėda city has an overall slight tendency of decreasing (Fig. 4.4). Overall satisfaction of PT service in Klaipėda has always been quite high, above average. The public transport rating is falling at the same time by giving its share in modal-split for personal transport. Recovering neglected positions and the recent loss of public transport users should not be difficult and late, but it is important to take urgent action to change this trends. This could be done by improving PT image, its availability, accessibility to PT, improving comfort and reliability of the service.

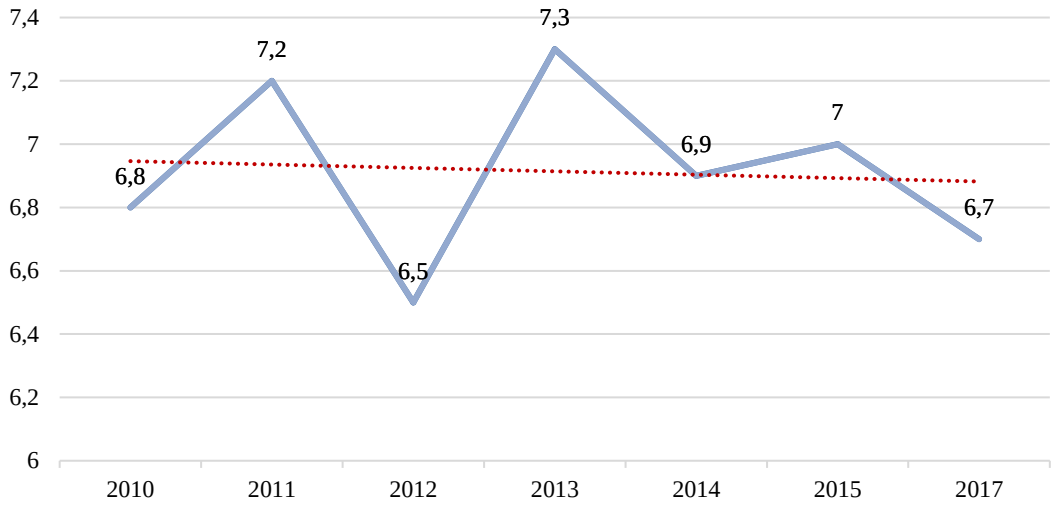

Fig. 4.4 Assessment of public transport services of Klaipėda city

Speed is an important indicator since travel time has a large influence on mode choice. Furthermore, speed also affects operational efficiency since fewer vehicles are needed when speeds are higher. (Orth, H, 2012)

Actual speed achieved is influenced by vehicle and alignment speed, as well as by stopping at passenger stops and general traffic conditions. Operating speed is the average speed of bus travel along bus route with 'N' spacing. It is the speed of travel offered to the public. (Abreha, DA, 2007)

The average urban and suburban public transport bus speeds in Klaipėda city is (Fig. 4.5):

- City routes (M3 short) - 21.2 km/h;
- City routes (M3 long) - 18.1 km/h;
- City Express - 23.6 km/h;
- Suburban (M2) - 36.3 km/h;
- Suburban (M2) - 32.8 km/h

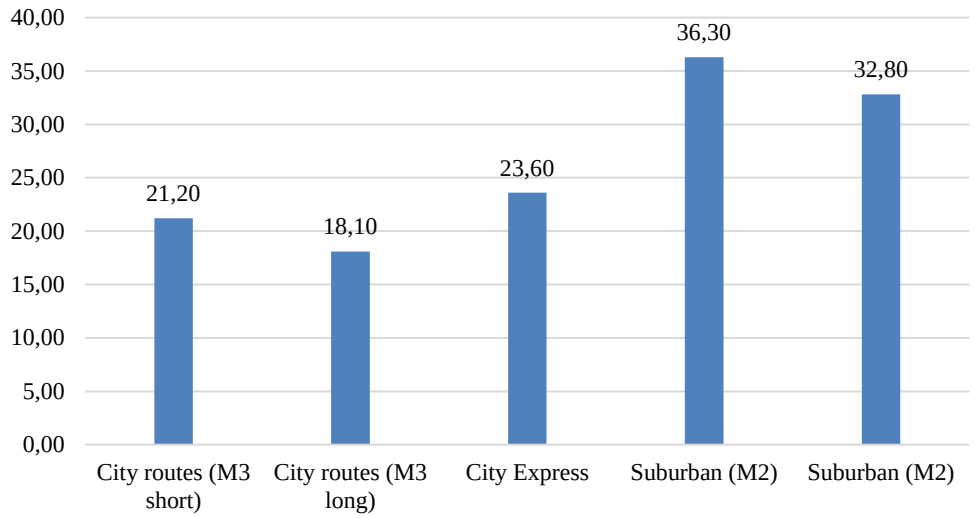

Fig. 4.5 Average urban and suburban public transport bus speeds in Klaipėda city

Passenger flows - the number of passengers carried in a given time span, usually per day, month or year. In most of the major cities of Lithuania, passenger flows has decreased in the last decade. It was influenced by easily affordable private vehicles, low fees for using them and a significant decrease in the image of public transport. Comparison of passenger flows presented in the figure 4.6 below, shows that since 2004 to 2016, Klaipėda passenger flows in public transport increased from 27.7 million trips per year up to 34 million trips per year.

The biggest increase in passenger flows was in 2005-2007, when it had risen from 5.3 to 11.2 % per year, then they slightly fell. This could have been caused by the economic crisis in 2008, when people lost their jobs or their income declined significantly. In the following period, passenger flows were consistent: increasing and decreasing by 1-2%. Only the year 2013, when passenger traffic increased by 4.6%, could be distinguished (SUMP of Klaipėda city, 2017). Recent years passenger flows are slightly decreasing (in 2015 - 0.8 %, and in 2016 - 1.48 %), but the overall tendency in the travelling tendencies shows the consistent slight rise since 2004 through years (passenger flows have increased by 6.27 million per year over the past 12 years). Though, considering the last 2 years tendencies it is slightly decreasing.

Run of public transport is distance traveled by PT vehicles during servicing routes. Run of the vehicle shuttling in the city has a tendency of increasing. Since 2004 till 2015 it increased 1.45 times. The relative comparison of carried passengers and annual run shows that passenger transportation is growing by the increase of the run: travel and transport from peripheral districts are increasing.

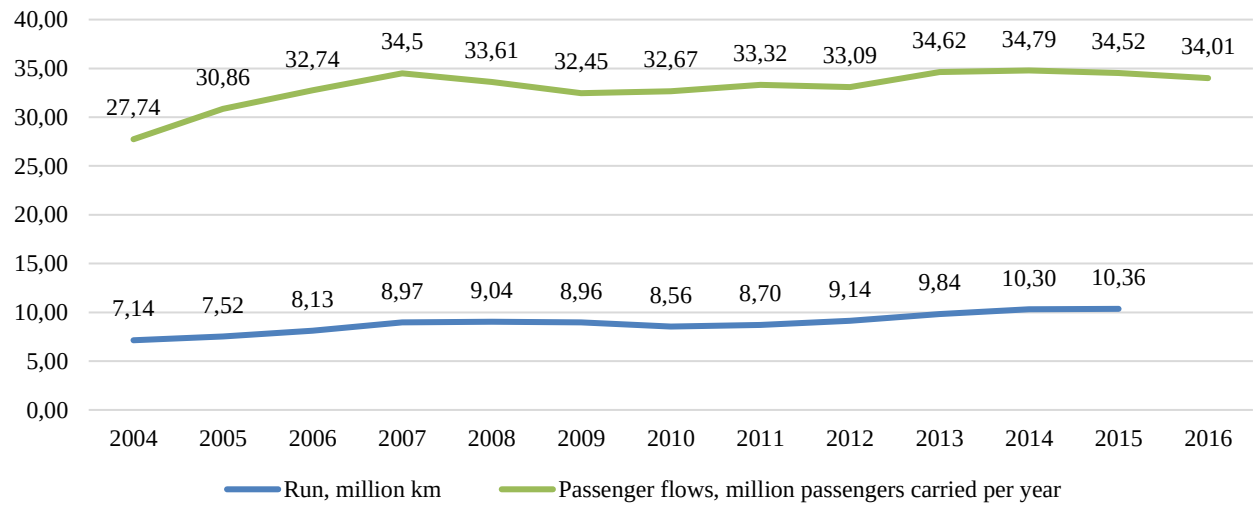

Fig. 4.6 Passenger flows and run of Klaipėda city PT

Analysis of 2017 years 3rd quarter distribution of boarding passenger flows in PT stops, revealed the most strained points (Fig. 4.7). It is clear that the main passenger flows are located on the Taikos Avenue and Herkaus Manto street axis. Here align most strained stops which are these: I. Simonaitytė, Smiltelės, Žardės, Naujojo Turgaus, Sveikatos priežiūros centro, Kauno, Turgaus, Atgimimo, Biblioteko, Universiteto and Ligoninės. These stops serve the most flows of public transport passengers.

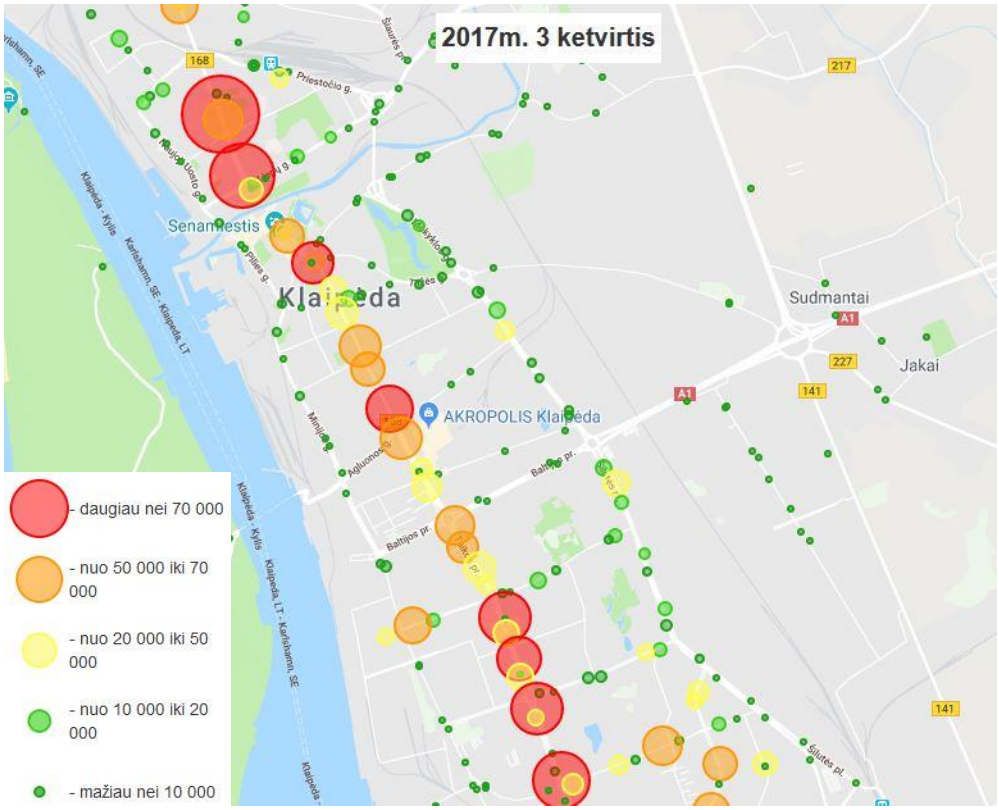

Fig. 4.7 Number of boarding passengers in bus stops (e-ticket information)

Source: www.klaipedatransport.lt

Route density. One parameter which is used to represent the coverage/distribution of bus service is route density. It represents the number of bus lines between origin and destination and whether it is a direct or indirect route when considering travelling by bus. Route density reflects the possibility of different travel directions and different destinations from a given origin along different transit routes, where they diverge. Route density is the quantity of bus route lengths divided by their whole service area. The denser the bus line is distributed, the more people are expected to choose travelling by bus because of greater opportunity for direct trips without transfers. It also means the denser the route density the shorter the walking distance.

Šeštokas and Juškevičius (1973) proposed such values of optimal PT routes density in transport districts:

- For buses 2-3 km/km2;
- For trolleybuses ≤1.5 km/km2;
- For trams 0.8-1.0 km/km2;
- For metro 0.4 km/km2 .

Table 4.1 Public transport density in transport districts

District	Density of buses, km/km^2	District	Density of buses, km/km^2	District	Density of buses, km/km^2
1	1.8	15	3.12	29	0.56
2	2.36	16	3.39	30	0
3	1.81	17	18.76	31	1.84
4	7.56	18	24.26	32	1.15
5	11.88	19	3.92	33	1.68
6	4.64	20	4.43	34	0.79
7	5.39	21	25.48	35	1.16
8	16.44	22	16.32	36	0.85
9	20.98	23	0.57	37	0.59
10	11.28	24	22.38		
11	1.99	25	13.63		
12	30.49	26	2.15		
13	18.88	27	3.42		
14	19.24	28	6.81		

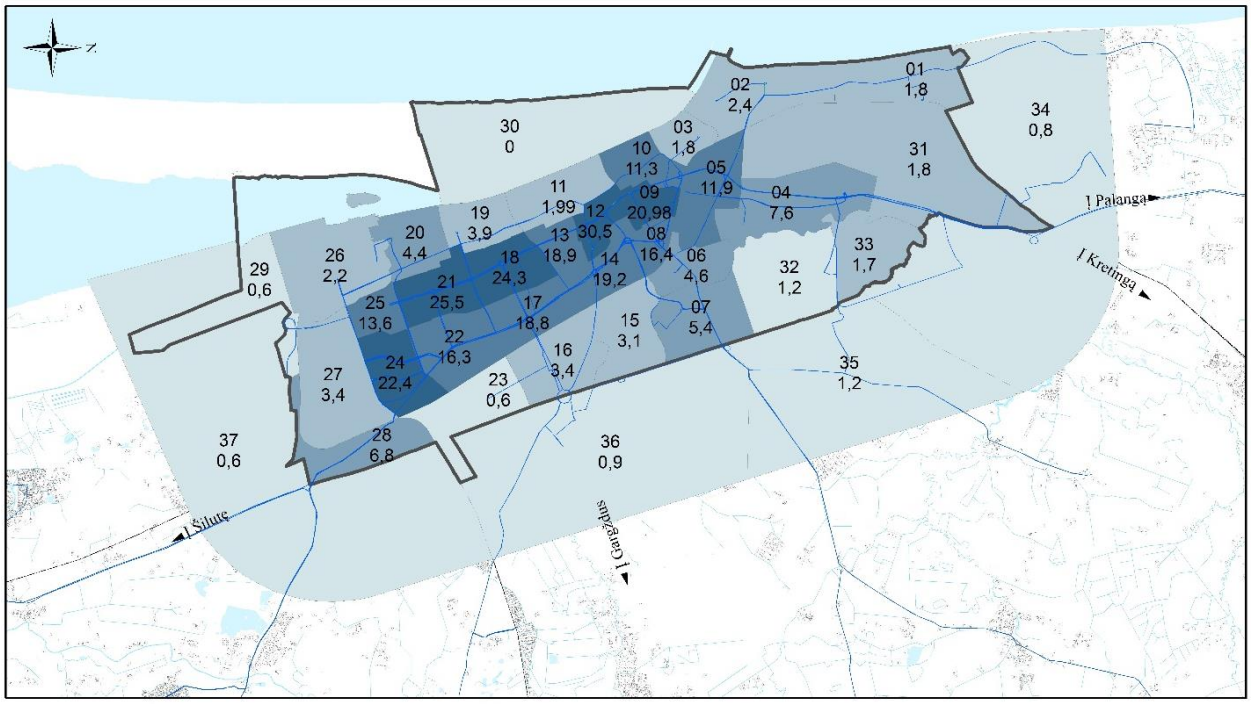

Fig. 4.8 Public transport density in transport districts

3.3 Assessment of public transport demand indicators in Klaipėda city

Public transport accessibility

The accessibility to PT has been assessed with ArcGIS program by creating buffer zones around the existing PT stops. The reach limit was taken within a radius of 500 m from stops (Fig. 4.9). Level of accessibility was estimated by subtracting the green and water areas of a total area of the districts.

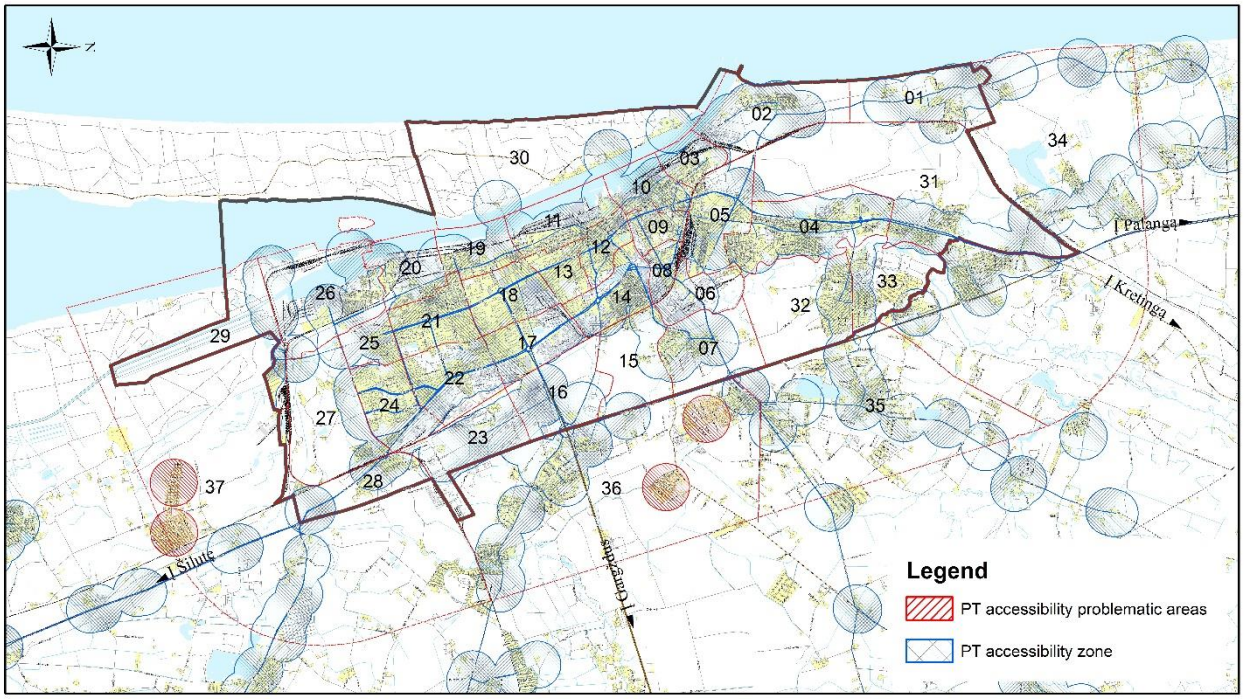

Fig. 4.9 Public transport stops accessibility of Klaipėda city (buffer zone 500 m) and problematic areas of accessibility

Most of the territories in Klaipėda city are fully or well-accessible by public transport. Accessibility level meets appointed requirements of Lithuanian regulations - 500 m radius must be provided for not less than 80 % of built-up area of the city. Only one out of thirty seven transport districts is little accessible (district 34 – 46.7 %) and two districts are not accessible (district 29 – 28.1 % and district 37 – 17.1 %) (Table 3.2). Most of the built-up areas which are not fully or well-accessible are the districts in the peripheral area of the city. Not surprisingly, since single and duplex dwelling-houses is spread here, the territories do not have a clear shape and structure due to the dynamics of chaotic development.

Table 4.2 Public transport stops accessibility (radius of 500 m) in transport districts by covered area in %.

District	Covered area, %	District	Covered area, %	District	Covered area, %
1	100.0	15	95.5	29	28.1*
2	98.8	16	88.0	30	96.5
3	100.0	17	100.0	31	82.0
4	100.0	18	100.0	32	91.3
5	100.0	19	100.0	33	57.5
6	66.9	20	100.0	34	46.7
7	90.7	21	100.0	35	63.8
8	100.0	22	100.0	36	59.5
9	100.0	23	89.4	37	17.1
10	100.0	24	100.0		
11	100.0	25	100.0		
12	100.0	26	92.1		
13	100.0	27	72.4		
14	100.0	28	84.2		

** No inhabitants in this territory*

Population density

Klaipėda county is the third largest country in terms of population. More than 320 thousand of people live in Klaipėda city, Klaipėda district, Kretinga, Skuodas, and Šilutė district, Palanga city and Neringa municipalities (which makes up to 11.2% of Lithuania's population). Two trends of Lithuania are prevailing in Klaipėda city and county:

- The decrease in population;
- Aging of population.

Analyzing the 10-year period, in 2008, 357,201 residents lived in Klaipėda County and it is 10.24% (36,575) more than at the beginning of 2017. In Klaipėda city municipality in 2008, there were 172,686 permanent residents, which is 12.43% more than in the same period in 2017 (151,227 permanent residents). The number of inhabitants in Klaipėda County in 2008-2017 decreased by 1%

per year on average annually. The largest decrease (-2.93%) was recorded in 2011 - during the economic crisis (Fig. 4.10).

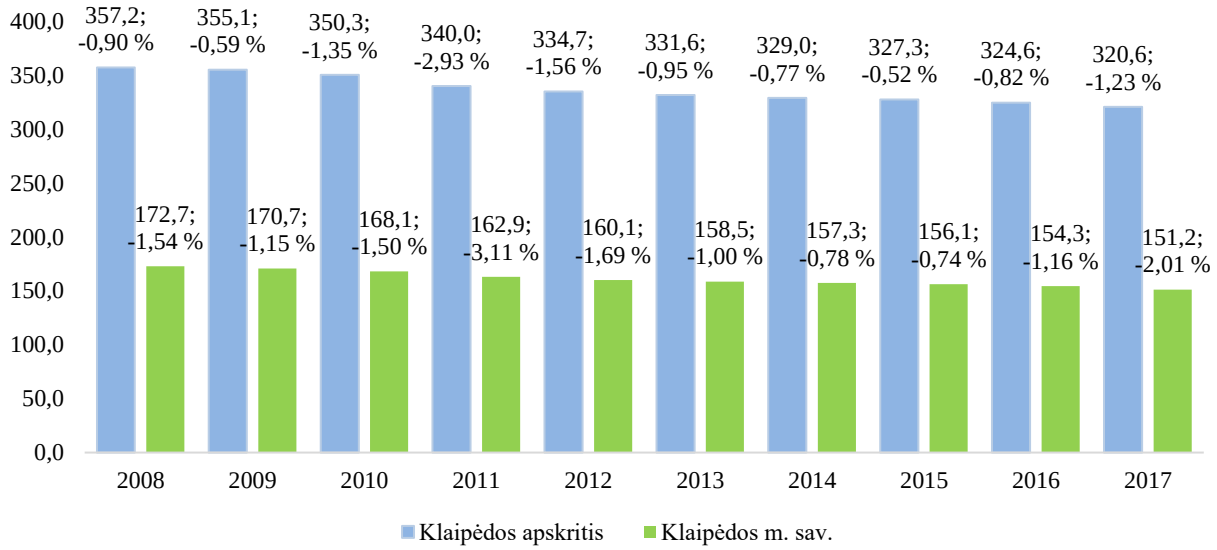

Fig. 4.10 Range of Klaipėda city and region population, thousands inhabitants

Source: Department of statistics of Lithuania data

Klaipėda county has a negative migration rate for more than 20 years. During the year 2016, 3,280 more people left Klaipėda County than arrived here. It can be assumed that the negative population growth rate was determined by migration. Looking at the percentage change in the population of Klaipėda city municipality, it can be seen that it is slightly higher than that prevailing in Klaipėda County. This leads to the conclusion that some of the Klaipėda city residents moved to the suburban areas.

This fact also can be verified by the intensive expansion of residential areas in the suburban districts. After the real estate crisis, the migration of the population to the suburbs has already become a dangerous trend - housing in the peripheral territories of Klaipėda is significantly larger than in the city. Suburban areas attract mostly younger, higher-income people, families with children.

Until 2030, the most likely change in the city of Klaipėda is the demographic change. According to the data of population census, migration, fertility, and social trends, as well as data from the Department of Statistics, we can assume that the population of Klaipėda will decrease by about 10% by 2030. In order to determine the trends of population changes in segregated parts of the city, the number of electors in electoral districts from 2004 to 2016 was used. The data revision was based on the assessment of the change of electoral districts, the social structure of the district population and the total number of voters. This analysis has revealed that different parts of the city also have different demographic trends.

The southern part of the city is shrinking and aging the fastest. By 2030 this part of the city will lose about 20% of the population, some areas even up to 30% of the population. Meanwhile, the northern part of the city is expanding and growing rapidly. The number of inhabitants may double in Tauralaukis, Giruliai, Šilojai districts and in suburban areas. Unlike the southern districts, here move in and settle young adults and families.

This demographic trend raises significant challenges for the optimal and sustainable planning of urban mobility, as the southern districts are densely populated and supported by PT. Meanwhile, northern parts of the city and suburban areas, although rapidly expanding but the density of population is low, public transport is not efficient and these territories lack of social infrastructure so residents are forced to move to other areas of the city.

Table 4.3 Population by transport districts (2011 years data of Department of Statistics and derivative data of GIS database)

District	Population	Population density, inhabitants /ha	District	Population	Population density, inhabitants /ha	District	Population	Population density, inhabitants /ha
1	396	9,21	15	296	11,25	29	0	0,00
2	867	21,81	16	53	8,98	30	82	2,64
3	3867	115,37	17	7967	95,76	31	1340	17,38
4	6950	34,58	18	12676	87,20	32	1890	21,22
5	7657	73,18	19	8690	153,70	33	881	10,91
6	122	10,28	20	3033	69,44	34	1820	6,57
7	1039	18,41	21	33666	194,01	35	553	2,43
8	140	11,74	22	18294	170,10	36	2183	7,39
9	4964	82,80	23	38	3,05	37	178	1,19
10	5465	84,11	24	25529	199,08			
11	1960	45,70	25	6343	169,68			
12	8390	116,05	26	499	9,42			
13	10130	145,87	27	1248	33,63			
14	5780	62,54	28	472	11,05			

The density of Klaipėda population in the built-up area was counted with the help of GIS analysis tools by using Department of Statistics population data and spatial GIS database information. The average density of population in the internal transport district of Klaipėda city is 63 inhabitants/ha. The most densely populated, which means the most compact are 24th, 21st, 22nd and 25th transport districts near Smiltelės and Statybininkų streets axis, here lives 45 % of total inhabitants of Klaipėda city. The average density of Klaipėda city populations is in line with the similar mentalities cities like Riga (64 inhabitants/ha in 2014), Prague (71 inhabitants/ha 2014) indicators. A sustained decline in the urban population reduces the compactness of the city, threatening the maintenance of efficient infrastructure systems.

However, in the peripheral areas of Klaipėda city, the number of population density is more than 10 times lower than within the city limits and moderately reaches only 4,4 inhabitants/ha. The main reason for such difference is the typology of prevailing residential buildings which was analyzed before. Though the density of population is currently lowest in the peripheral areas, the changes of the population observed through recent years and augment of inhabitants in these areas are one of the highest in all Klaipėda district and reaches up to +66 % (Fig. 4.11). The main development in the city of Klaipėda is the development of residential buildings in the northern part of the city and suburbs of the city. Tauralaukis district, the nursery garden area, the northern part of Liepų Street near the Bachmano Estate are the fastest growing areas where the construction of low-rise buildings is mainly developed. All these districts are located far from the main city arteries, where public transport operates. According to the questionnaire survey, conducted during the preparation of the Sustainable Urban Mobility Plan, it is evident that these areas have the largest share of trips with private cars and very few pedestrian trips.

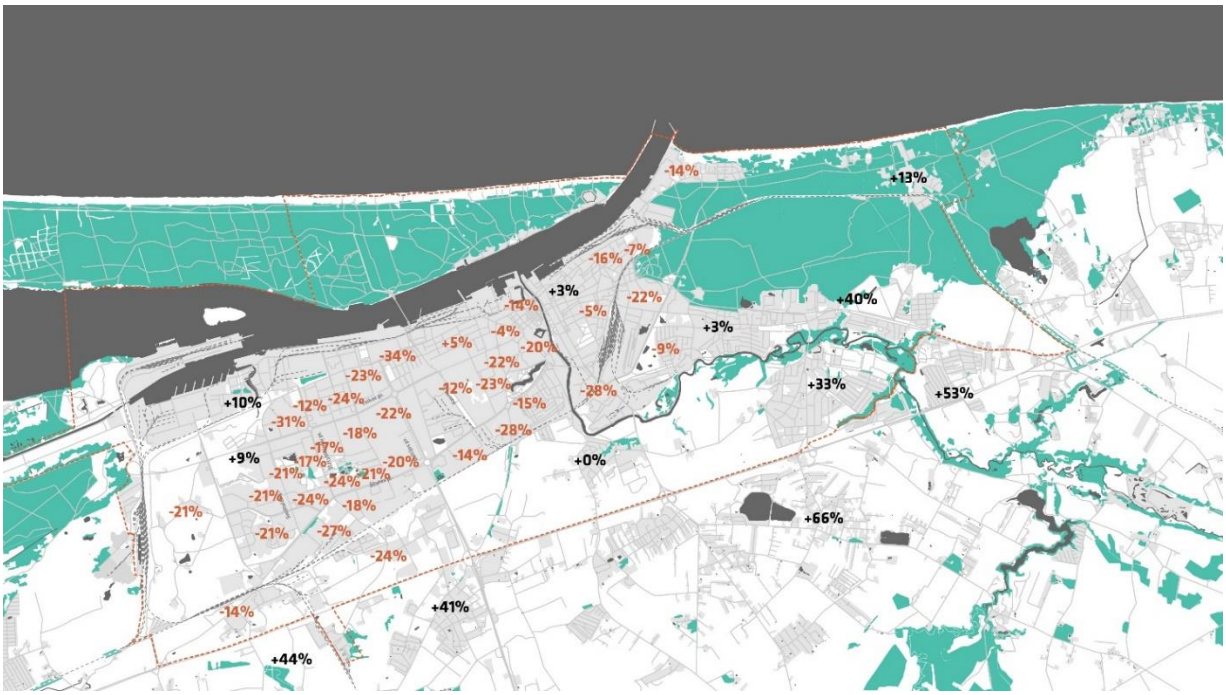

Fig. 4.11 Demographic change of Klaipėda district

Source: SUMP of Klaipėda city 2017

There is enormous variation between different types of area in the pattern, type and level of public transport services, and the demand for them. According to Paulley et al. (2006), people in areas with low population densities tend to rely more on cars and less on public transport than their more urban equivalents, and are therefore more likely to have the option of turning to car travel in case of decreasing or insufficient level of PT services in the area.

Jobs density.

Collection of workplaces data is not an easy task. Unlike residential areas, workplaces are not always static and may change. For analysis of jobs distribution in Klaipėda, GIS derivative data was used.

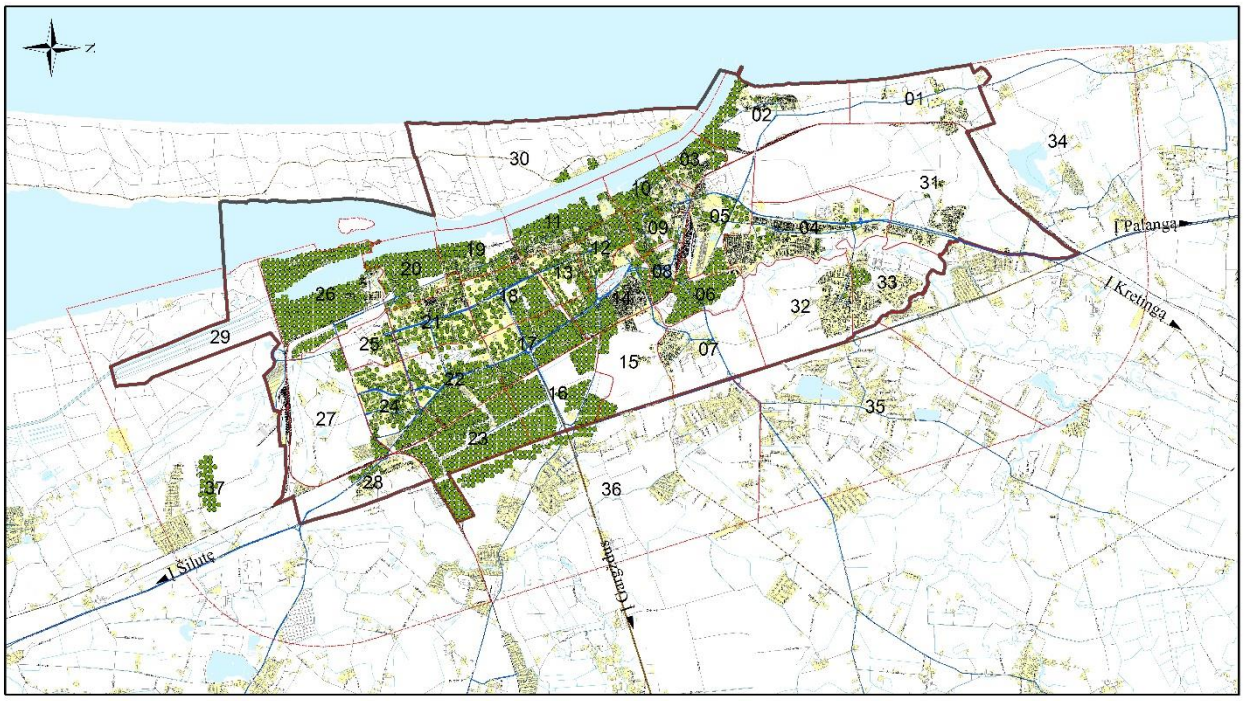

Fig. 4.12 Jobs places distribution in Klaipėda city

Highest density of jobs is in 6th, 9th, 12th, 16th, 23rd and 26th transport districts (in central part of Klaipėda, in the southern part of Klaipėda city near "Klaipėdos konteinerių terminalas" and in Lypkių district), here concentrates almost half (48.8 %) of all workplaces of Klaipėda city (Table 4.4). Workplaces have a high attraction rate for everyday trips, so it is important that access to these places would be convenient not only by car but also comfortable and fast by public transport.

Table 4.4 Jobs density by transport districts, jobs/ha

No.	Jobs	Jobs density, jobs/ha	No.	Jobs	Jobs density, jobs/ha	No.	Jobs	Jobs density, jobs/ha
1	67	2	15	660	25	29	3	0
2	1578	40	16	4214	714	30	356	11
3	1433	43	17	3945	47	31	32	0
4	3614	18	18	3328	23	32	52	1
5	2057	20	19	1656	29	33	379	5
6	2275	192	20	3027	69	34	94	0
7	437	8	21	2838	16	35	43	0
8	890	32	22	4453	41	36	2753	9

No.	Jobs	Jobs density, jobs/ha	No.	Jobs	Jobs density, jobs/ha	No.	Jobs	Jobs density, jobs/ha
9	11488	192	23	6044	485	37	1264	8
10	6903	106	24	2921	23			
11	3090	47	25	598	16			
12	15162	179	26	7127	135			
13	1469	18	27	542	15			
14	2021	19	28	227	5			

The most development of workplaces is anticipated around the Šilutė highway, the territory of the LEZ and the A13 road. Large companies of logistics and manufacturing build up here. These urban areas are very well accessible by car, but rarely or not at all by public transport. There is also no coherent network of bicycle paths and there are no or exist very fragmentary public spaces and pedestrian paths. Also, in these parts of the city, a heavy traffic of trucks is noticeable, and arterial streets are heavily loaded.

Density of educational institutions.

An optimal network of schools exists in Klaipėda city. Most of the densely populated areas have the opportunity to reach at least one educational institution at a radius of 1 km and are accessible by walking. Also at least one primary or secondary school is accessible in the most compactly built areas of Klaipėda city. All the schools of Klaipėda city gets into zone of the accessibility of PT service.

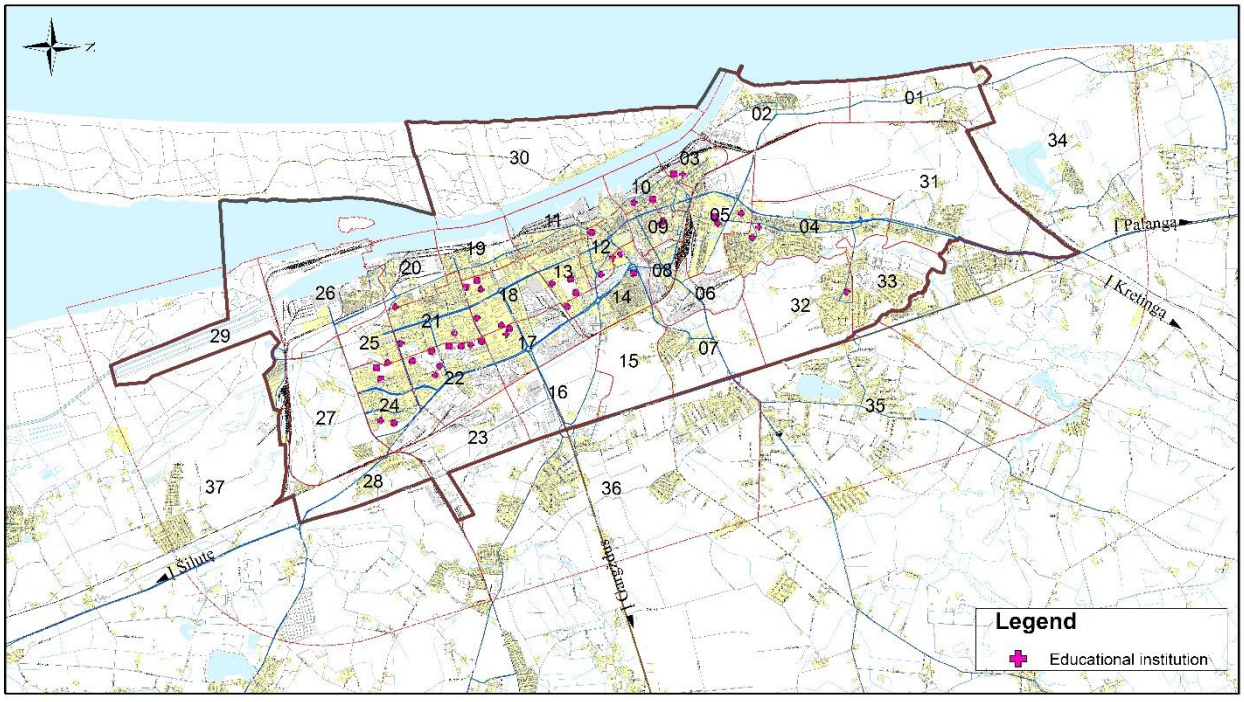

Fig. 4.13 Distribution of educational institutions in Klaipėda city with PT accessibility zones

The worst access to secondary schools is in the Northern part of the city - Melnragė and Giruliai and in the districts of Sendvaris and Labrenciškis, for the residents of these districts the closest schools are in the city center. The only primary school in analyzed peripheral area, was in Klemiškės II ditrict. It gets into the existing PT stop accessibility range.

The obvious shortage of schools is in the peripheral areas of Klaipėda city. But the development of the schools network in this area is not expedient due to the very low population density and due to the very small number of residents living within the walking distance of the school. Therefore, more appropriate in this area would be the organization of school drop-outs, school bus system.

Table 4.5 Density of educational institutions by transport districts, objects/km^2

No.	Educational Institutions	Density of educational institutions, objects/km^2	No.	Educational Institutions	Density of educational institutions, objects/km^2	No.	Educational Institutions	Density of educational institutions, objects/km^2
1	0	0,00	15	0	0,00	29	0	0,00
2	0	0,00	16	0	0,00	30	0	0,00
3	2	5,97	17	2	2,40	31	0	0,00
4	2	0,99	18	5	3,44	32	1	1,12
5	3	2,87	19	0	0,00	33	0	0,00
6	0	0,00	20	1	2,29	34	0	0,00
7	0	0,00	21	2	1,15	35	1	0,44
8	2	7,20	22	8	7,44	36	0	0,00
9	2	3,34	23	0	0,00	37	0	0,00
10	2	3,08	24	4	3,12			
11	0	0,00	25	1	2,68			
12	3	3,54	26	0	0,00			
13	3	3,66	27	0	0,00			
14	3	2,86	28	0	0,00			

Distance from the city center

In the case of Klaipėda city, the maximum limit of public transport service area established at 30 km from the city limit. All analyzed peripheral urban areas make into this zone, within the maximum limit. It satisfies the 5 criteria for the introduction of public transport in newly built areas. However, the fulfillment of this condition alone does not provide sufficient conditions for the introduction of public transport routes in the peripheral area of Klaipėda, because it also covers non-occupied territories. This criterion is more of a constraint for established higher rankings indicators.

The minimum limit of public transport, where PT service is not mandatory is 2 km distance from city center. This distance is set as it is a walkable measure for most of the people independently from age, gender etc.

Density of I level service centers

All I level service centers (post, healthcare institutions etc.) are located in the area within the limits of Klaipėda city. These objects are located nearby popular living, working areas and are well served by the existing PT service network. In peripheral areas there are no such objects due to the low peripheral densities, which are too small for this area to function effectively

The minimum number of objects of the first level service centers for PT service introduction is defined to 5 objects/km^2.

The indicator value of minimum number of objects of the first level service centers is dynamical and have to be considered for every city individually. For cities with the population less than 100k, the limit for PT introduction range from 3 to 5 objects/km^2. For bigger cities >=5 objects/km^2.

If the density of service centers is lower, for example, 1 or 2, they are usually meant for the local residents of the area and do not attract large population flows. Local residents usually reach such institutions on foot and it is not efficient to implement a public transport route there.

5 METHODOLOGY CREATION FOR PUBLIC TRANSPORT DEMAND IDENTIFICATION IN NEW DEVELOPING DISTRICTS OF KLAIPĖDA CITY

To identify public transport demand in new developing areas of Klaipėda city and its peripheral areas, the methodology had been created. The identification process is presented in a form of flowchart below and with little changes is also applicable to other cities (Fig. 5.1).

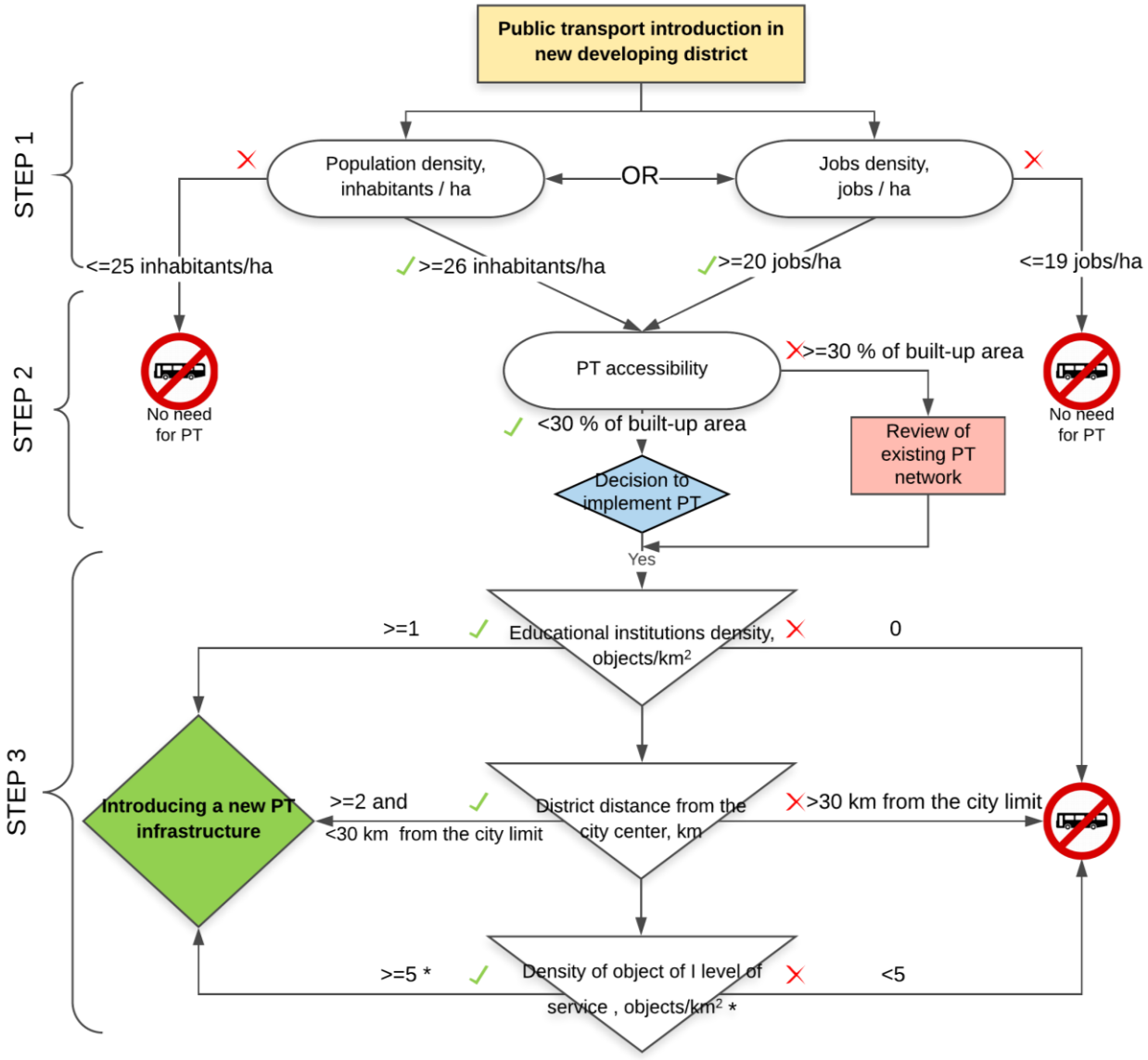

Fig. 5.1 Public transport demand identification in new developing districts in Klaipėda city

** Exception is healthcare institutions. They must reach the public transport accessibility zone, and the frequency of operating vehicles should be at least 15 minutes*

The methodology was developed as a 3-step process. The maximum or minimum limit values for the evaluation criterions were chosen according to the comprehensive analysis and recommendations of the foreign and Lithuanian literature sources.

Step 1

The two most important criteria selected by the experts were considered to be equally important and identified as a reference point for determining the need for public transport.

In Klaipėdas' peripheral areas case, neither population nor jobs density satisfy these initial conditions. The results of population density can be inaccurate and do not represent the real demographic situation of today in this place. The data used in the analysis are collected according to the 2011 population census data and according to the prevailing trends of population migration, now could be significantly increased. As a result, the possibility of introducing public transport in these areas should not be rejected.

Step 2

Analysis of PT accessibility in Klaipėda peripheral areas provided the results of insufficient PT accessibility in 37th district (here only 17.1 % of all built-up area in the whole district is accessible by PT), especially in Gručeikiai. By this indicator, the increase of PT service access area is recommended.

In this case, other indicators of the PT network require checking, to evaluate whether the parameters needs change and improvement, for example, accessibility increased, frequencies changed etc.

Step 3

Last three indicators more determine the qualitative requirements for a previously made decision on the need for the introduction of public transport infrastructure in the developed area.

1. In the case of Klaipėda, there is one educational institution in the peripheral zone and it gets into the public transport service area. The development of educational institutions is not carried out due to the low population density, therefore the children must go to schools located in the central part of the city.
2. The distance from the city center indicates the maximum limit which the operator of PT should not exceed providing PT services. In the case of Klaipeda, the defined distance from the city limits does not cross the radius of 30 km around the city.
3. The minimum number of objects of the first level service centers is 5 objects / ha. In Klaipėda case, there are no such conglomeration of I level service centers in peripheral areas.

5.1 Methodology application to other cities

An expert survey carried out by the author highlighted the most important indicators of public transport demand:

1. Population density;

2. Jobs density;
3. PT accessibility;
4. Density of educational institutions;
5. Distance from city center;
6. Density of objects of I level of services.

The same methodological process as for Klaipėda city is also possible to apply for other cities. In order to accurately assess the need for public transport, firstly it is necessary to conduct a quality urban analysis of existing PT service network, population, jobs and other important objects distributions. Steps present flow chart of the whole process (Fig. 5.2).

Step 1

The minimum required population density is 26 inhabitants per hectare and the minimum number of jobs is 20 jobs per hectare. The values of these indicators are unchangeable. At least one of these conditions must be met in order to determine the need for public transport in the area to be developed.

Step 2

Checking PT accessibility in built-up areas within a radius of 500 meters from the public transport network infrastructure. A lower than 30% indicator, when at least one of the first two conditions is met, is the sign for installing a new public transport route or infrastructure of the bus stop. A higher or equal to 30 % value of the indicator, means that public transport is at least little accessible to the residents of the analyzed area. In this case, other indicators of the PT network should be checked, to evaluate whether the parameters need to be changed and improved, for example, accessibility increased, frequencies changed etc.

Step 3

According to the results of an expert survey, the last three indicators for public transport demand identification are less important. These indicators more determine the qualitative requirements for a previously made decision on the need for the introduction of public transport infrastructure in the developed area.

1. Educational institutions have to reach the public transportation accessibility zone. Therefore, at least one such institution in the territory requires PT to provide public transport infrastructure close to it. For kindergartens, this condition is valid, but not necessary, because children do not go to them independently. In the absence of such institutions, there is no additional need for public transport.
2. The distance from the city center indicates the maximum limit which the operator of PT should not exceed providing PT services. This indicator is dynamic and should change depending on the size, urban structure of the city etc. For example the three biggest cities

of Lithuania has a maximum limit of 30 km from the city limits. For smaller cities it respectively have to be also smaller.

The minimum value is defined to be 2 km from city center – as it is a walkable distance for most of the residents.

3. The indicator value of minimum number of objects of the first level service centers is dynamical and have to be considered for every city individually. For cities with the population less than 100k, the limit for PT introduction range from 3 to 5 objects/km^2. For bigger cities >=5 objects/km^2.

   If the density of service centers is lower, for example, 1 or 2, they are usually meant for the local residents of the area. Local residents usually reach such institutions on foot and it is not efficient to implement a public transport route there.

Fig. 5.2 Universal method of PT demand identification in new developing districts

** Exception is healthcare institutions. They must reach the public transport accessibility zone, and the frequency of operating vehicles should be at least 15 minutes*

CONCLUSIONS AND RECOMMENDATIONS

1. The analysis of scientific literature on public transport defined that the most important indicators for the users of PT are indicators of service quality. European standard *EN 13816:2002* lists the main SQ indicators of PT, which are: availability, accessibility, information, time, customer care, comfort, security, and environmental impact. However, when determining the need for public transport in new territories, operators aim is to select the optimal location for a new infrastructure, so that PT is efficient and sustainable. In this case, the indicators include population and jobs density, accessibility of public transport, the distribution of object of attraction.
2. An overview of the GIS methodologies have shown that GIS is considered as a significant tool for transport management and modeling due to its spatial operation possibilities and query sets operations. GIS was used as the main software together with statistical techniques. GIS database of PT routes network was created to measure the accessibility of PT, to calculate and analyze spatial distribution of inhabitants, jobs, objects of attraction etc.
3. Six criterions have been selected for evaluation of the demand for public transport and a questionnaire survey of experts has been carried out. The estimated values of the criterion weights indicate that the population and jobs density in the district, accessibility of public transport, mostly influence the introduction of public transport in new developing areas. Experts concluded that the least influential for PT introduction is the distance from city center and density of objects of I level of services.
4. The compatibility of experts' opinions was calculated using the Kendall's concordance coefficient. The results of the calculations have shown that expert opinions are compatible and can therefore be based on the assessment of the need for the introduction of public transport.
5. The analysis of the public transport of Klaipėda proved that public transportation in the peripheral zone not sufficiently developed and not all inhabited, expanding territories have access to the city by public transport. Two of the four peripheral districts considered as not accessible (district 37 – 17.1 %) or little accessible (district 34 – 46.7 %). However, the peripheral zone has a low population, job and objects of attraction density, the indicators are too small to pay off investment in the construction of engineering infrastructure.

   Also, the tendencies of population migration to the suburbs indicate the potential to introduce new feeding route of PT in Gručeikiai, Leliai and Klemiškė I. It is proposed to specify guidelines for the urbanization of the suburban area to control chaotic development of newly built areas.

6. The methodology for determining the demand of PT service in Klaipėda city and its peripheral areas created. Indicator limits set for PT introduction:
    - Population density – >=26 inhabitants/ha;
    - Jobs density – >=20 jobs/ha;
    - Accessibility – <30 %;
    - Density of educational institutions – >=1 objects/km^2;
    - Distance from city center – >=2 km from city center and <30 % from the city limit;
    - Density of objects of I level of service – >=5* objects/km^2.

    * *Exception is healthcare institutions. They must be in the PT accessibility zone, and the frequency of operating vehicles is at least 15 minutes.*
7. According to created methodology, there is no demand for PT in Klaipėda peripheral area. Though, the data used in the analysis is collected according to the 2011 population census data and according to the prevailing trends of population migration, now could be significantly increased. As a result, the possibility of introducing public transport in these areas should be reconsidered.
8. The paper contains methodological recommendations and application for other cities. It is proposed to evaluate the demand for public transport services according to the defined indicators, but they must be adjusted to the parameters and specific features of a particular city. Prior to this, it is necessary to perform an analysis of the existing urban and public transport network, its accessibility, distribution of population and workplaces, location of objects of attraction and distance from the city center.

    The development of an adequate public transportation system is critical for achieving regional sustainability.

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ANNEX 1

PT quality criterions

Level 1	Level 2	Level 3
Availability	Modes	
	Network	- Distance to b/a-point; - Need for transfers; - Area covered
	Operation	- Operating hours; - Frequency; - Vehicle load factor
	Suitability	
	Dependability	
Accessibility	External interface	- To pedestrians; - To cyclist; - To taxi users; - To private cars users
	Internal interface	- Entrances/exits; - Internal movement; - Transfer to other PT modes
	Ticketing availability	- Acquisition on network; - Acquisition off network; - validation
Information	General information	- about availability; - about accessibility; - about sources of information; - about travelling time; - about customer care; - about comfort; - about security; - about environmental impact
	Travel information normal conditions	- streets directions; - b/a-point identification; - vehicle direction signs; - about route; - about time; - about fare; - about type of ticket
	Travel information abnormal conditions	- about current/forecast network status; - about alternatives available; - about refund/redress; - about suggestions and complaints; - about lost property
Time	Length of trip time	- trip planning; - access/egress; - at b/a-points and transfer points; - in vehicle
	Adherence to schedule	- punctuality; - regularity
Customer care	Commitment	- customer orientation; - innovation and initiative
	Customer interface	- enquiries;

Level 1	Level 2	Level 3
		- complaints; - redress
	Staff	- availability; - commercial attitude; - skills; - appearance
	Assistance	- at service interruptions; - for customers needing help
	Ticketing options	- flexibility; - concessionary tariffs; - through ticketing; - payment options; - consistent price calculations
Comfort	Useability of passenger facilities	- at a/b-point; - on vehicles
	Seating and personal space	- in vehicle; - at a/b-point
	Ride comfort	- driving; - starting stopping; - external factors
	Ambient conditions	- atmosphere; - weather protection; - cleanliness; - brightness; - congestion; - noise; - other undesired activity
	Complementary facilities	- toilets/washing; - luggage and other objects; - communication; - refreshments; - commercial services; - entertainment
	Ergonomy	- ease of movement; - furniture design
Security	Freedom from crime	- preventative design; - lighting; - visible monitoring; - staff/police presence; - identified help points
	Freedom from accident	- presence/visibility of supports, e.g. handrails; - avoidance/visibility of hazards; - active safeguarding by staff
	Emergency management	- facilities and plans
Environmental impact	Pollution	- exhaust; - noise; - visual pollution; - vibration; - dust & dirt; - odour; - waste; - electromagnetic interference
	Natural resources	- energy;

Level 1	Level 2	Level 3
		- space
	Infrastructure	- effect of vibration; - wear on road/rail etc. - demand on available resources; - disruption by other activities

ANNEX 2

Dear expert,

I am applying to you with the request that you, by using your personal competence, experience, qualifications and imagination, carefully read the description of the factors presented in this questionnaire and determine the meanings of these factors in the points.

The purpose of this study is to determine the factors that have the greatest influence on the introduction of public transport services in transport districts.

Values are determined by scores with this principle. Scores are set for each criterion on a 7-point scale. If we estimate that the factor has the greatest influence on the need for introduction of public transport service, then it receives 1 rank, with the least influential factor being assigned 7rd rank.

The significance of the factors influencing the introduction of the public transport service demand (rank). The most important criterion is attributed to rank 1, the second to the rank 2 etc.

Factor mark	Factor name	Unit of measurement	Rank
1 criterion.	Population density in the transport area.	people per km^2	
2 criterion.	Workplaces density in the transport area	workplaces per km^2	
3 criterion.	Accessibility of public transport.	%	
4 criterion.	District distance from the city center	km	
5 criterion.	Density of educational institutions	units./km^2	
6 criterion.	Density of objects of I level services	units./km^2	
7 criterion.	Other (please fill) _____		

Note. *Rank meanings can't recur in the form.*