ASSESSMENT OF THE AVAILABILITY OF CITY BUS SERVICES IN JELGAVA IN THE CONTEXT OF A COMPOSITE SERVICE

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Abstract
The dynamic development of urban areas and the phenomenon of suburbanization forces public transport operators to develop changes to ensure the accessibility of public transport. The accessibility of public transport services increases mobility and can also be a factor accelerating urban development. It should be emphasized that public transport services perform a social function, ensuring the right of citizens to free movement and meeting the needs of citizens for movement and demand for public transport services. The aim of the study is to assess the availability of city bus route services in the city of Jelgava in the context of the interconnection of bus and train schedules. To analyse the availability of public transport in relation to the interconnection of city bus route trips with regional train route trips, the study used a cumulative method – an assessment of destinations and effort available at a given time. The study found that in Jelgava there is an insufficient connection between the organization of regional and national city public transport, where as a result of divided planning, intercity and urban transport infrastructures are often incompatible, and there is no unified regional and urban route network and billing system. In practice, this means that the railway and urban infrastructure and public transport connections are not sufficiently coordinated and thus do not ensure easy movement for inhabitants.
Keywords: sustainability, public transport, accessibility, composite service.

Introduction

The transport sector is one of the most important sectors of the national economics, and its development and competitiveness is an essential prerequisite for ensuring the economic stability and overall development of the country in both – national and international level. In all sectors, including transport, the importance of new technologies, innovations and digitalization, environmental (climate change) aspects are increasing, taking into account the emissions generated by the transport sector. The public transport services perform also a social function, ensuring the right of citizens to free movement and satisfying the movement needs of citizens and the demand for public transport services (Ministru Kabinets, 2021). The rate of motorization is increasing in cities, which is defined as the ratio of the number of vehicles to the number of residents in the given area. This is the result of changes in people's lifestyles, created habits and increasing conveniences associated with personal transport. However, individual transport also has a negative impact on the environment due to air pollution, noise and energy consumption, which in turn can lead to deterioration of the health of citizens (Barchański et al., 2022).

The European Green Deal aims to achieve climate neutrality by 2050 (Eiropadome, 2019), indicating that **automated and connected multimodal mobility**, as well as smart traffic management systems and intermodal services, will play an increasingly important role, that will be influenced by the growing topicality of digitalisation solutions. The European Union (EU) transport system and infrastructure are planned to be prepared for new sustainable mobility services that can reduce congestion and pollution, especially in urban areas (Ministru Kabinets, 2021). Reducing the use of private transport primarily requires improving the possibilities for using public transport. The Public Transport Development Concept for 2021-2030 identifies railways as the 'backbone' of the public transport system and buses complement rail transport (Satiksmes ministrija, 2019).

Public transport must meet many requirements and passenger expectations in terms of directness, frequency, availability, reliability, low cost, speed, punctuality, regularity, accurate information, comfort, level of crowding, cleanliness, connections, environment, staff courtesy, safety and security. Accessibility research allows identifying areas where improvements are needed (Żochowska et al., 2022). **Accessibility** is widely described in the literature, but it does not have a single, united definition. Access to transport is defined as the ability to use transport services and reach certain destinations with them (Kaszczyszyn & Sypion-Dutkowska, 2019), while accessibility to public transport is defined as easy **access** to public transport options and easy **reach** of destinations with this transport (Żochowska et al., 2022).

Research hypothesis: Jelgava city bus services ensure accessibility to regional train services. The aim of the research is to assess the accessibility of city bus route services in the city of Jelgava in the context of the interconnection of bus and train schedules. To achieve the aim, the following tasks are set: 1) to identify and assess public transport accessibility assessment indicators; 2) to characterize and analyse the interconnection of Jelgava city bus services with regional train services.

The research concluded that several measurement methods can be identified for measuring the accessibility of public transport services. To analyse the accessibility of public transport in terms of linking city bus routes with regional train routes, a cumulative method was used – an assessment of destinations and effort available at a given time. The research provides the insight into the level of interconnection between public transport modes - trains and city buses, providing conclusions about its accessibility in

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Jelgava. According to the data of the Jelgava City Municipality, in 2022 the total number of employed Jelgava residents was 32,754, of which 39.4% (12,910) worked in Jelgava, while 35.5% (11,644) worked in Riga. Based on these conditions, a limitation of the research was set – the accessibility of public transport in Jelgava was studied on weekdays.

Materials and Methods

In the regulatory framework of the Republic of Latvia, accessibility of public transport is explained as access to public transport, which is ensured by **connections** with various types of public transport and the possibility for passengers to transfer to another type of public transport (Ministru Kabinets, 2010). In the Law on Public Transport Services, the term accessibility is understood much more broadly, as it is included in the purpose of the law, which is *to ensure the availability of public transport services to residents* in the route network (Ministru Kabinets, 2007).

Scientific studies distinguish **two basic components of accessibility**: *the transport component* and *the land use component*, as well as two additional components: *time* and *individuality*. The transport component reflects the ease of movement between two stops, while the land use component is the attractiveness of a particular place as a destination in the transport system (Barchański et al., 2022). The time component determines the availability of public transport within a 24-hour period, while the individual component focuses on the individual characteristics and needs of passengers (Olsson et al., 2021). All these components are interconnected.

Although several **methods for measuring transport accessibility** can be found in the scientific literature, five main ones can be distinguished in R. Żochowska's research: the infrastructure equipment method; the distance method; the cumulative method; the potential method and the personified method (Żochowska et al., 2022).

To analyse the availability of public transport in terms of linking city bus routes with regional train routes, in this research **a cumulative method** is used – *an assessment of destinations and effort available at a given time*.

Several public transport accessibility indicators are also used to determine the accessibility of public transport. P. Śleszyński (2014) describes six transport **accessibility indicators**: spatial (determines accessibility that occurs between two points in space); communication (determines accessibility that occurs using means of communication – transport); time (determines accessibility that can occur at a certain physical time); socio-cultural (the subject of accessibility is individuals and human communities); economic (availability of technical, financial, etc. aspects); goal (determines accessibility after effort that occurs as a result of cause-and-effect relationships, according to the classic Weberian definition, actions can result from a goal, values, habits and emotional nature). The most important among the indicators are the time and spatial indicators (Sierpiński et al., 2020),

which are analysed in this study in conjunction with the cumulative method.

The time accessibility indicator can refer to both the time needed to reach a bus stop from a starting point and the time needed to travel between two bus stops using public transport (Żochowska et al., 2022). When studying time accessibility, three groups of accessibility measures are most often used: the frequency of public transport, which is usually determined by the number of trips in the period under consideration; vehicle availability, which is described as the time needed to get to the stop; and the time needed to travel by vehicle, which is also described as the time needed to get to the destination by vehicle (Żochowska et al., 2022). Waiting time at bus stops is one of the elements that also significantly affects passengers' opinions about the quality of transit services (Psarros et al., 2011).

Y. Hadas et al. (2023) conducted a study on the attitude of public transport passengers towards a dynamic fare model in Israel, based on the level of vehicle congestion and additional waiting time, and found a relationship – *the longer the waiting time, the less willing they are to wait for the next vehicle*. The study analysed 4 waiting times (5, 10, 20 and 40 minutes), where the waiting time was chosen to compare short waiting times (5 and 10 minutes) and long waiting times – starting from 20 minutes (20 and 40 minutes).

The spatial accessibility indicator is related to the distance travelled and is most often determined by the access to public transport infrastructure in a given area (Washington et al., 2021). The concept of spatial accessibility can be identified with transport accessibility in certain circumstances, but usually it operates as a narrower concept. The maximum walking distance, which is adopted in most cases in research, is 300 meters in city centres and 800 to 1000 meters in areas with single-family housing (Pot et al., 2021).

Results and Discussion

An important term that is linked to the accessibility of public transport is public transport **connectivity**. It describes the ease with which a journey can be made on the public transport system, from any public transport stop to another public transport stop or station in an area. Public transport services operate in a networked market, in which the ability of a customer to consume a particular service depends on location, and no single service provider can satisfy all customer demand given the location-specific nature of these different demands. Therefore, in a networked market, a combination of different services (and service providers) is needed to create **composite services** that can satisfy the majority of customer demand. The more these composite services become a seamless product, the more viable the market becomes and the more meaningful the services become for larger customer demand (Public Transport EGUM Subgroup, 2022).

In order to specify the various interpretations of the

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term 'public transport accessibility' and to determine the boundaries of its scope, the following **definition of public transport accessibility** has been established within the framework of this research: *public transport accessibility is the interconnection of different modes of public transport (train and city bus, etc.), which ensures that passengers, in the shortest possible time and distance between these modes of transport, access related public transport services and continue their journey to reach their destination.*

The research found that on weekdays in Jelgava, public transport is used by an average of 10,000 passengers per day between 5:00 and 23:00. The highest passenger flow is around 7:00 and 8:00, when approximately 2,600 passengers use the service, see 'Figure 1'. Therefore, it can be concluded that residents use public transport more often to get to work and/or school, where a large part of the population travels to and from Riga.

Figure 1

Number of passengers transported on city bus routes of Ltd. 'Jelgavas autobusu parks' during working hours in March 2023
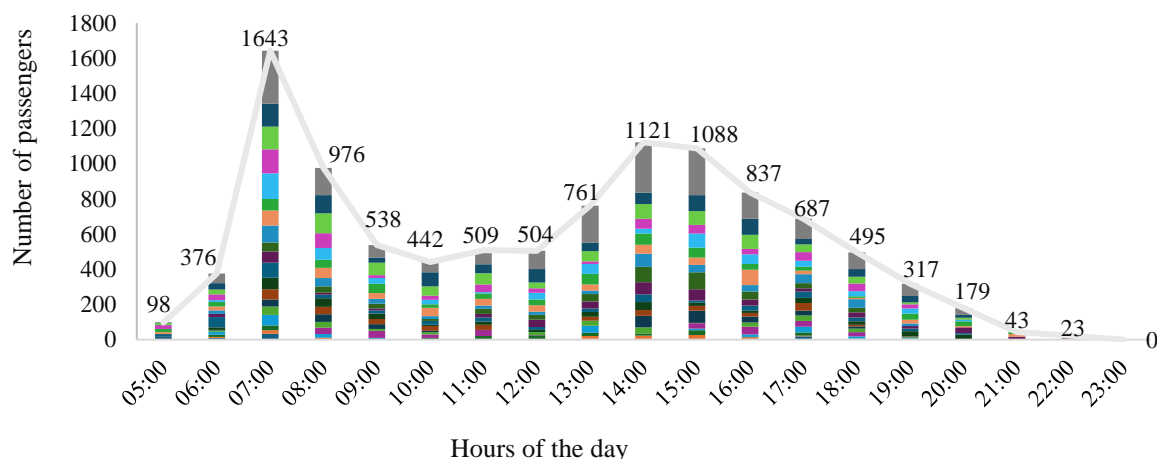
By studying the connection between train and bus schedules, which is an important factor in creating a coordinated public transport network and providing quality public transport services, several criteria and factors were evaluated to gain a comprehensive understanding of this connection.

In the cumulative method of assessing the accessibility of public transport, which takes into account the assessment of destinations available at a given time and the effort, a point system is applied to the assessment of destinations available at a given time, which is necessary to categorize and evaluate various criteria depending on their significance and importance. The criteria indicated as essential for the research are evaluated by points (Table 1), which show the level of interconnection of public transport modes (trains and city buses) and allow conclusions to be drawn about the accessibility of public transport.

Table 1

Scoring criteria

Connection	Connection evaluation by waiting time (evaluated each route trip)	Connection assessment based on destination accessibility
Short connection	From 3 or 7 minutes (according to specific bus stop) to 20 minutes – 2 points	Connect all 4 city zones (number of points scored multiplied by 4), connect 3 city zones (number of points scored multiplied by 3), connect 2 city zones (number of points scored multiplied by 2) if you connect 1 city zone (number of points scored multiplied by 1).
Long connection	From 21 to 40 minutes – 0.2 points	Connect all 4 city zones (number of points scored multiplied by 4), connect 3 city zones (number of points scored multiplied by 3), connect 2 city zones (number of points scored multiplied by 2) if you connect 1 city zone (number of points scored multiplied by 1).
Not considered a connection	From 41 minutes and longer (no points awarded)	-

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The determination of destinations is based on the zoning of the Ltd. 'Jelgavas autobusu parks' city territory into four zones: A, B, C and D. Points are awarded to each public transport connection - train and city buses - depending on the time factor, that is, the waiting time (how quickly the connection is provided) and the number of available destinations (with how many city zones the connection or accessibility is provided).

The research takes into account that two city bus stops are used in passenger transport with the destination (the railway station 'Jelgava'): 'Jelgavas stacija' and 'Stacijas iela'. Therefore, in this particular case, the spatial assessment criterion is also assessed. The mentioned bus stops are located approximately 300 meters from each other, which creates a different time for passengers at each stop, which they need to transfer from the bus to the train or from the train to the bus.

Using the online cartography service 'Google Maps', which provides directions to various locations around the world, the distance and time required for a pedestrian to get from bus stops 'Stacijas iela' and 'Jelgavas stacija' to the train stop at the railway station 'Jelgava' were determined, see 'Figure 2'.

Figure 2

The time required for a pedestrian to get from the bus stop 'Stacijas iela' and 'Jelgavs stacija' to the train at the railway station 'Jelgava'
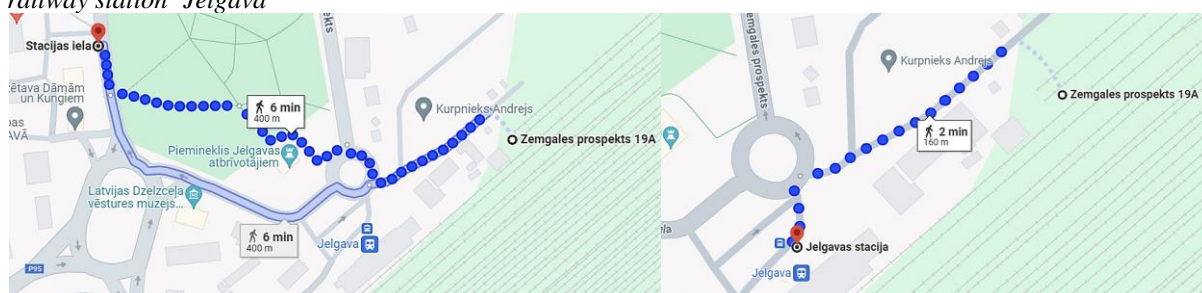
It is acceptable to use the built-in functions of your word processor to create equations. Note that while variables and numbers should be italicized, the following elements of equations should be set in roman type: function names, units, words, and abbreviations thereof. Formulas should be numbered (1), (2), (3), etc. and referred to in the text according to their numbers.

As part of the study, one additional minute was added to the calculated time (6 or 2 minutes), which is intended to safely cross the regulated pedestrian crossing on Pasta Street and to board the train. Taking the above into account, the latest bus arrival time at the stop 'Stacijas iela' is assumed to be 7 minutes before the train departure time from the railway station 'Jelgava', and at the stop 'Jelgavas stacija' – 3 minutes. An identical time is also determined for getting from the train arrival at the railway station 'Jelgava' to the bus stop.

A connection of up to 20 minutes, where the passenger waiting time is up to 13 or 17 minutes, is evaluated with 2 points (assessed as a short waiting time, usually 5, 10 or 15 min.), while a connection of 21 to 40 minutes, where the passenger waiting time can reach up to 33 or 37 minutes, is evaluated with 0.2 points (assessed as a long waiting time, usually 20, 25, 30 or 35 minutes, assuming that in most cases passengers will not choose a connection with such a long waiting time). Waiting times exceeding 33 or 37 minutes are not assessed in the study, and such public transport connections are not considered to be interconnected. A similar assessment of waiting times is also given in the study by Y. Hadas et al. (2023) on the attitude of public transport passengers towards the dynamic fare model.

In the final stage of the points system, for each train route, which creates a connection between city bus services and ensures public transport connectivity with Jelgava city zones, a total number of points is calculated, indicating the level of public transport connectivity. This approach cumulatively takes into account factors that affect the accessibility of public transport: *train and bus connections* (the accessibility of transport services provided by both trains and buses and their interaction are taken into account); *accessibility of city zones* (the accessibility of city zones is taken into account, checking whether each train is connected to city buses that transport passengers to all four city zones, thus ensuring wide accessibility within the city).

When analysing the interconnection of train and bus schedules, the train route schedule on the **Riga – Jelgava – Riga** line was used as a basis, against which all available bus routes of Jelgava city significance were compared, assessing their compliance with the previously set accessibility criteria and assigning an appropriate number of points, see 'Figure 3'.

Taking into account that the number of rout connections in itself does not indicate a good level of connection, as it is essential to ensure the availability of public transport services to residents of all city areas, the study conducted an evaluation of city bus routes, determining the city areas served by bus routes and, in accordance with the criterion of available destinations, determining the number of city zones from which train routes are provided to city bus passengers on weekdays.

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Figure 3

Number of Jelgava city bus routes available on weekdays by connection duration with trains to Riga

■ Up to 20 minutes until train departure   ▫ From 21 to 40 minutes until train departure
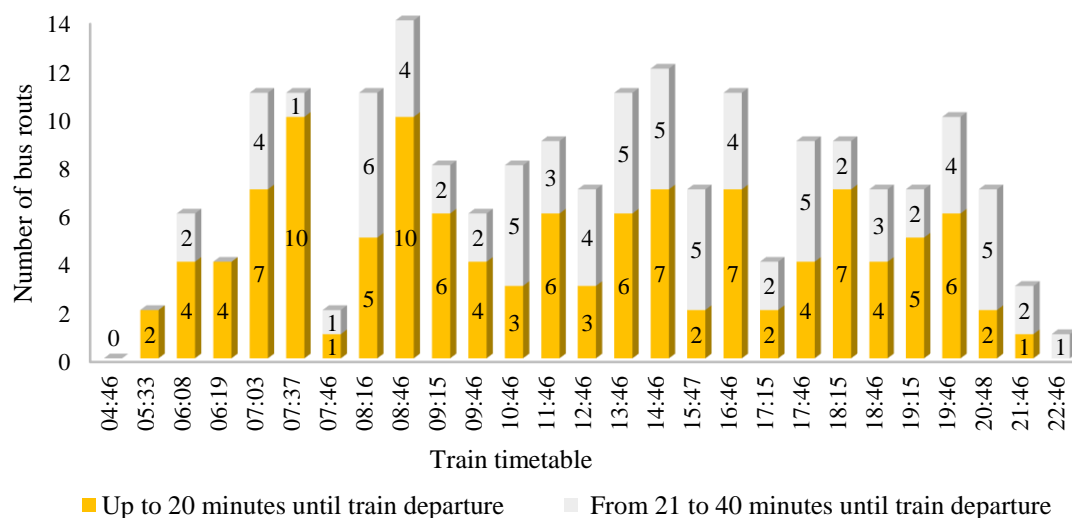
As the research data shows, according to the train travel times, the majority of them (16 trips) are available to all 4 city zones (A, B, C, D). However, several train trips are not available to some city zones. When assessing the availability of public transport provided to city zones for connections with short waiting times, it is seen that out of all four city zones, this level of connectivity is provided by only 10 train trips on weekdays, see 'Figure 4'.

Figure 4

Number of city zones (A, B, C, D) from which city bus passengers are provided with access to train routes to Riga on weekdays
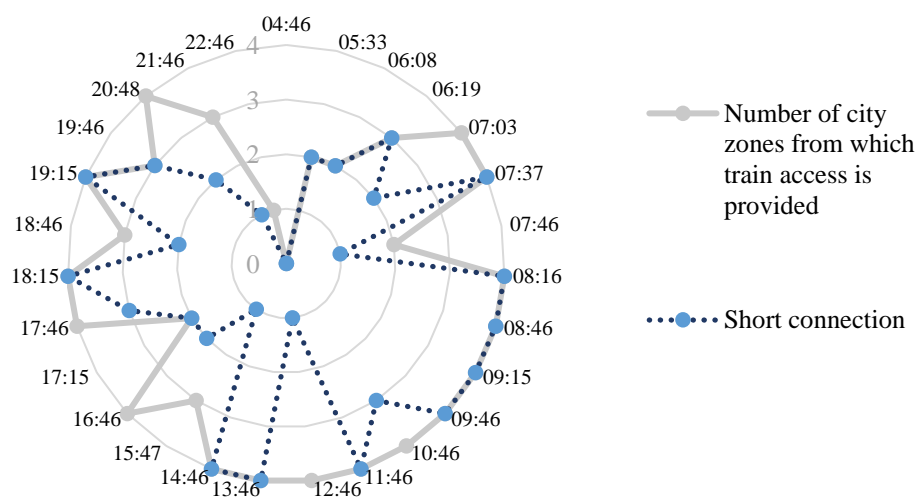
By summing up the points obtained for each train route Jelgava - Riga on weekdays, which creates a connection between city bus routes and ensures public transport connectivity with Jelgava city areas, an assessment of the accessibility of city bus services in points was obtained for the aforementioned train routes, see 'Figure 5'.

The connection of city bus routes with train routes on the Jelgava - Riga route on weekdays is provided at a very good level for 11 out of 27 routes, which makes up 41% of the total number of routes, while 16 out of 27 routes, which makes up 59% of the total number of routes, can be characterized as good connections.

Analysing the available train routes on weekdays that arrive at the Jelgava railway station every working day from Riga, it was found that the situation is similar with outgoing routes, see 'Figure 6'.

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Figure 5

Assessment of the availability of city bus routes at points for each train route Jelgava - Riga on weekdays
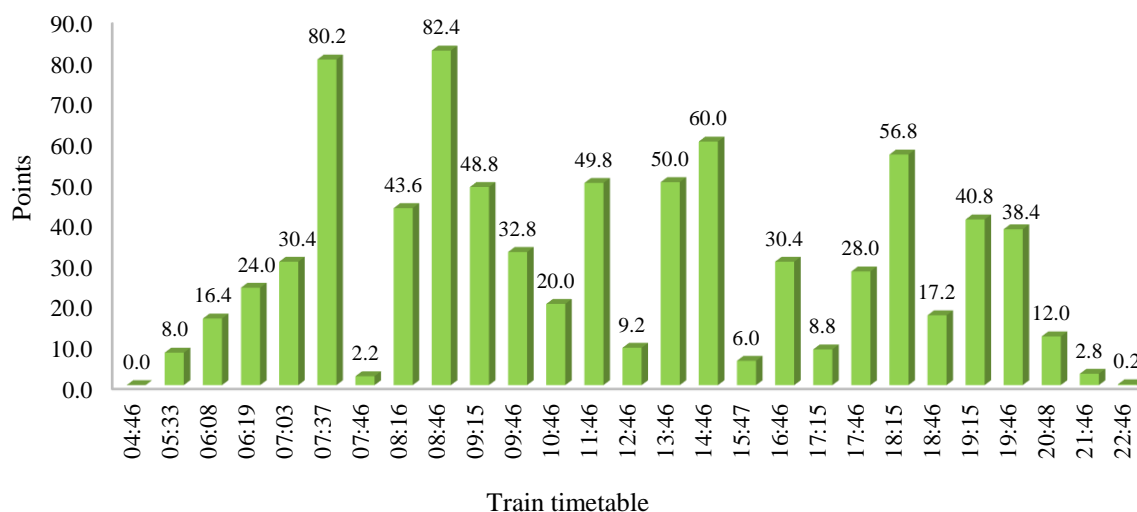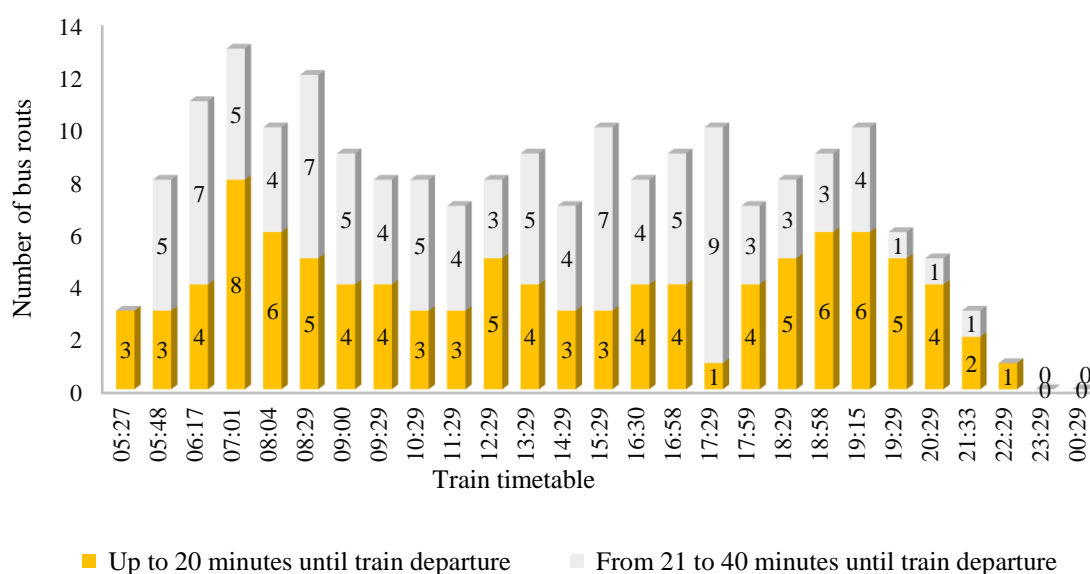

Figure 6

Number of city bus routes available to Jelgava city areas on weekdays for passengers on the Riga - Jelgava train route


Similar to the first route connection analysis, the evaluation of city bus services was carried out, determining the city areas served by bus services and, in accordance with the destination accessibility assessment criterion, the number of city areas to which city bus services are provided for train passengers on weekdays was determined.

According to the train timetables, most of them (18 trains) provide connections with buses that transport passengers to all 4 city zones (A, B, C, D). However, there are several train services that do not provide bus connections to certain city zones, see 'Figure 7'.

Overall, the research concluded that the connection of city bus trips with train trips on the Riga - Jelgava route on weekdays is provided at a very good level on 6 out of 27 trips, which makes up 22% of the total number of trips, while 17 out of 27 trips, which makes up 63% of the total number of trips, can be characterized as good connections.

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Figure 7

Number of city zones (A, B, C, D) to which city bus access is provided for train passengers from Riga on weekdays
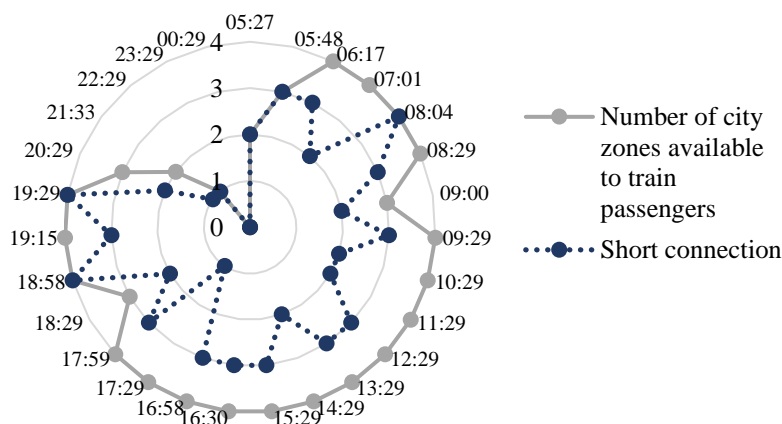
Conclusions

1. Approximately 35% (~11,650 Jelgava residents) of all working Jelgava residents work in Riga, of which approximately 20% (~2,400 Jelgava residents) use the train to get to Riga. The approximate number of passengers transported by city buses on routes to the Jelgava railway station on a working day is 722 passengers, while the number of passengers transported from the Jelgava railway station on a working day is 703 passengers.

2. The connection of city bus trips with train trips on the Jelgava - Riga line on weekdays is provided at a very good level in 41% of cases (connections with 27 train trips were assessed), while 59% of train trips are considered well connected. The connection of city bus trips with train trips on the Riga - Jelgava line on weekdays is provided at a very good level in 22% of cases (connections with 27 train trips were assessed), while 63% of train trips are considered well connected.

3. The hypothesis put forward in the research has been partially proven, as Jelgava city bus services provide partial connectivity with regional train services.

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