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Faculty of Technical Sciences
Department of Traffic Engineering

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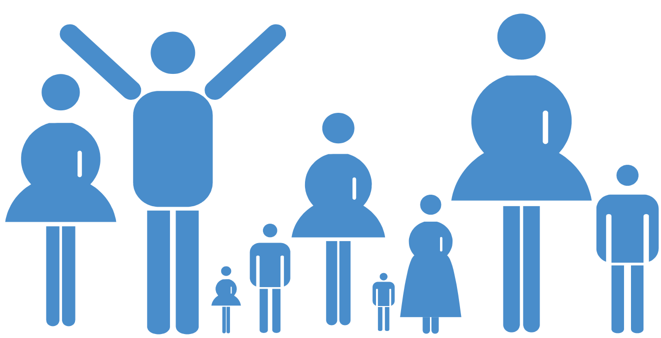

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TOWARDS A HUMANE CITY
Reshaping Mobility
Novi Sad, 19th and 20th October 2023

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Reshaping Mobility

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SCIENCE & TECHNOLOGY PARK NOVI SAD
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Република Србија
МИНИСТАРСТВО НАУКЕ, ТЕХНОЛОШКОГ РАЗВОЈА И ИНОВАЦИЈА

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Novi Sad, 19th and 20th October 2023

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Slobodan Mišanović[1]
E-mail: slobodan.misanovic@gsp.co.rs
[1] Project manager
JKP GSP ''Beograd'', City Public Transport Company-Belgrade-

E-MOBILITY DEVELOPMENT STRATEGY IN PUBLIC URBAN TRANSPORT-INTRODUCTION OF ARTICULATED ELECTRIC BUSES

Keywords

The articulated electric bus
E-mobility development strategy
Public transport
Energy efficiency
Ecological benefits
Economic feasibility

Abstract:

Electric buses have a steady trend of increasing usage in many cities in Europe and the world. In the previous period, electric buses with a standard length of 12m were the most represented, while articulated buses of 18m had a lower representation due to poorer technical and operational performance (lower passenger capacity, limited autonomy of movement, long charging time at the depot or terminus...) compared to conventional articulated buses. With the development of new generations of electrical energy storage systems (batteries, supercapacitors) and fast charging systems using high-power chargers, articulated electric buses have become increasingly competitive with conventional buses. In the coming period, one of the E-mobility development strategies related to public urban transport is the introduction of articulated electric buses instead of conventionally driven buses, primarily on central city lines as well as on the lines of the BRT system.
The paper will present the results of the trial operation of the Higer UC 18 articulated electric bus on city line No. 31 (Studentski trg-Konjarnik) in Belgrade, which was carried out in October 2022, from the aspect of energy efficiency and environmental advantages. Through a case study of the replacement of articulated buses with diesel engines currently operating on line no. 31 with articulated electric buses, an analysis of the economic feasibility of introducing articulated electric buses into operation will be carried out.

1. INTRODUCTION

The transport sector has a significant place in meeting the needs of society in the transport of goods and passengers, but at the same time, it is also a source of emissions of harmful gases and carbon dioxide as a result of the burning of fossil fuels. The use of fossil fuels is directly proportional to the industrial and economic development of a country, region, or city [1]. The emission of carbon dioxide (CO2) originating from the transport sector in 2020 amounted to 24% [2], as a result of the combustion process, primarily of oil derivatives (diesel fuel, gasoline), which has a share of 57% of the total oil consumption at the global level [3]. In the European Union, heavy-duty vehicles, such as trucks, coaches, and buses, are responsible for about 6% of total greenhouse gas emissions [4]. The bus subsystem of public urban transport as part of the transport system in cities is one of the most important segments of urban mobility in cities. Diesel-powered buses are still the most prevalent in public transport systems. They emit gases (CO, CxHy, NOx, PM...) that are harmful to human health and carbon dioxide that causes the greenhouse effect [5]. Many cities around the world are replacing their existing fleets of conventionally fueled city buses with electric buses to reduce the negative effects of pollutant emissions on the environment and public health. The application of buses for public city transport with zero emissions, which includes electric buses in the European Union, should additionally reduce the level of emissions of harmful gases from traffic in cities and contribute to the strategy of using vehicles with zero emissions in cities, which is planned after 2050 [6, 7]. The Clean Vehicle Directive 2019/1161 entered into force in August 2021 and is binding on EU member states. It defines representation in the procurement of M3 class buses with low and zero emissions for the period until December 31, 2025, and from January 1, 2026, to December 31, 2030 [8]. An important goal of using electric buses is to increase energy efficiency in the passenger transport sector. Electric buses have better energy performance compared to conventional technologies [9,10,11].

2. PRESENTATION OF PREVIOUS PRACTICE IN THE APPLICATION OF ARTICULATED BUSES ON ELECTRIC DRIVE IN THE WORLD

Currently, almost all world bus manufacturers have electrically powered buses of different lengths in their product range: midi (8-9 m), standard (11-13 m), articulated (18-19 m), and double-articulated (24-27 m), which have become part of the standard offer on the bus market [12]. Electric buses fall into the category of zero-emission vehicles now available on the market and are gaining an increasing share of purchases from cities and public transport companies. At the beginning of 2022, 9,354 electrically powered buses were registered in Europe, of which only 2% were buses over 18 m in length [13]. The rapid development of battery technologies and supercapacitors for the storage of electrical energy, the system for fast charging of vehicles that have been present in the last 5-6 years have influenced that, in addition to the electric buses of standard length, which have the largest representation, electric buses with a length of 18 m (articulated) and 24m (two articulated), which make them adequate competition for buses of the same type with conventional drive. Depending on the concept of the articulated electric bus, the most common electrical energy storage systems are batteries: LTO (lithium titanate) with a capacity of 125-170 kWh, LFP (lithium iron phosphate) with a capacity of 480-700 kWh, as well as supercapacitors with a capacity of more than 100 kWh.

LFP batteries are only suitable for charging with lower powers, meaning these buses must be charged overnight at the depot [14]. LTO batteries and supercapacitors accept high charging powers and are used for fast charging at the terminals. Fast 400-600 kW power chargers are used to charge vehicles with LTO batteries or supercapacitors. LFP batteries used in electric articulated buses are charged in depots (night charging) using chargers with a power of up to 150 kW. The reduction of the empty vehicle weight allowed the capacity of the number of passengers that can be transported to be 140-145 passengers, which is about 10% less compared to the diesel-powered articulated bus. The possibilities of using articulated electric buses in Europe were realized for the first time in May 2013 in Geneva (Switzerland) with the "TOSA" project, when the company TPG Geneva started operating 11 fully electric buses manufactured by "Hess", line no. 7 (Airport - Hospital via CFF main station). Considering that these are articulated vehicles that use supercapacitors to store electrical energy, recharging is done via pantographs at the terminals but also at some stations along the route [33]. The power of the chargers at the terminals is 200 kW, which allows a charging time of 3-4 minutes. Chargers with a power of 400 kW were installed along the route at a total of 12 stops. The charging time is about 15 seconds during the regular wait for the vehicle at the station. The average consumption is 2.6 kWh/km [15]. The Chinese bus manufacturer "BYD" presented an 18m-long articulated electric bus at the Houston (USA) fair in October 2014, which used an LFP battery with a capacity of 480 kWh as a storage system. The charging time with the 80 kW plug-in charger was about 5 hours. The transport capacity of the vehicle was 120 passengers [16]. As part of the Zeus project, in Barcelona on the H16 line, exploitation began in April 2016 with two Solaris Urbino 18 articulated buses. The battery capacity was 125 kWh. Using a mobile pantograph mounted on the roof of the vehicle, fast charging was performed with 400 kW chargers installed at the terminus as well as with a 50 kW slow charger installed in the depot. The number of seats in the vehicle was 135 passengers [17]. An example of good practice in the application of a large number of articulated electric buses is the city of Eindhoven (Netherlands), wherein 2016 the first 43 electric articulated buses manufactured by VDL were put into operation, which had the concept of "convenient-fast charging" in the depot and central terminus, using a movable pantograph on the roof of the vehicle [13]. The successful application of electrically powered articulated buses was realized in 2018 in Amsterdam on line No. 316 (Amsterdam-Volendam-Edam) with 10 articulated buses operated by the manufacturer VDL. The average electricity consumption was 1.4 kWh/km, while the average charging time was 12 minutes with a 450 kW charger [18]. The capacity of the LTO battery is 170 kWh. In March 2019, the first 13 articulated electric buses were put into operation in Osnabruck (Germany) on Metrobus line M1. In 2020-2022.year, 49 more articulated electric buses operating on lines M2, M3, and M4 were acquired. A total of 62 articulated electric buses manufactured by VDL provide 60% of the transport work on the network of lines in Osnabruck [19]. The bus subsystem in Mexico City is one of the largest in the world, with approximately 22,300 buses in operation. In 2021, 10 articulated electric buses manufactured by "Yutong" [13] were put into operation on BRT line No. 3, so at the beginning of 2023. year there will be 60 articulated electric buses in operation [20]. Since December 2019, the city of Nantes (France) has put into regular operation 22 fully electric buses of the manufacturer "Hess" with a length of 24.5 m, which operate on the BRT line "Busway". Average electricity consumption is in the range of 1.7-2.5 kWh/km. The charging time is 4.5 minutes and is enabled via a fast charger with a power of 600 kW [21]. LTO battery capacity 130 kWh. Positive experiences in the exploitation of bi-articulated buses in Nantes on the BRT line were the inspiration that some cities in Europe and the world (Barcelona, Amsterdam, Athens, Prague, Istanbul, Bogota, plan to introduce articulated electric buses 18-24.5 m on BRT lines, by participating in the EC funded project EBRT-2030 [22].

3. TRIAL OPERATION OF THE ARTICULATED ELECTRIC BUS IN BELGRADE

Testing of the articulated bus Higer 18 UC Electric bus in the conditions of exploitation in JKP GSP "Belgrade", which was carried out in the period 29.9.-5.10.2022. represents a joint project of GSP "Belgrade" and Consortium CHARIOT Motors a.d. , 10 Tsar Osloboditel Blvd., 1000 Sofia, Bulgaria PIB BG202659250, I DAT Holding d.o.o. Belgrade [23]. The trial test of the Higer 18 UC Electric bus is important for assessing the possibility and justification of using this bus concept for public city transport in Belgrade. The acquisition of new electric-powered buses and their significant presence in the PT system represents the policy of developing E-mobility in Belgrade, which together with the trolleybus and tram subsystem of public urban transport and the affirmation of non-motorized movement (cycling, pedestrian zones) should contribute to improving the quality of the environment in Belgrade [24].

3.1. Aim, space, methodology, and period of the trial test

The trial operation aims to assess the technical-operational performance of the Higer 18m UC electric bus (electricity consumption, charging time, vehicle-dynamic characteristics, and ergonomic characteristics...). Considering that at the terminal SRC Milan Gale Muskatirovic, there is a charger for fast charging used by E-buses operating on the EKO2 line, for the test with the articulated Higer 18 UC Electric bus, an extended line No.31-test was established (SRC Milan Gale Muškatirović-Konjarnik) to more realistically compare the technical performance with diesel-powered buses operating on the existing route 31 (Studentski trg-Konjarnik).

Line No. 31, the central city line, from the point of view of environmental requirements (emissions, noise) is very suitable for replacement with E-buses. It is the only line with diesel buses that currently runs along the central corridor: The Slavia-Kralja Milana-Trg Republike. The average length of the line is 7.3 km. There are 15 stops on line 31 in direction "A" and 16 stops in direction "B". Line No. 31-test has an average length of 9.2 km. The number of stations in direction "A" is 20, and in direction "B" is 21. The spatial position of the routes of lines No. 31 and 31-test is shown in Figure 1.

Figure 1. Routes of line No. 31-test and line No. 31

Line No. 31-test is characterized by the presence of longitudinal ups and downs on certain sections of the route. They are especially pronounced on the section along Franska Street, Oslobodjenja Boulevard, and Ustanička Street. Figure 2 shows the geometric characteristics of the route of line No. 31-test.

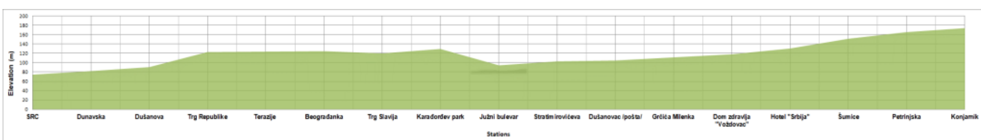

Figure 2. Geometric characteristics of the route of line No. 31-test

During the test on line No. 31-test, the vehicle was evenly loaded with a load (sandbags) with a total mass of about 4500 kg, which simulates an average load of 66 passengers (Figure 3). During the test, there were 3-4 members of the expert committee in the vehicle who were present throughout the test [23].


Figure 3. Loading the E-bus with sandbags

The bus stopped at all the stations along the route, which simulated the real number of acceleration cycles, driving and braking constants, and stopping at the station. The results of measuring the electricity consumption of Higer 18m UC electric, expressed in kWh/km, were performed for each half-turn of operation (Direction "A", directionn "B") in different periods of the day (peak load, intermediate load, with and without using the system for cooling the passenger compartment (Air-Condition).

Electricity consumption was measured:
• By reading SOC (State of charge) values, mileage status, and time from the dashboard of the E-bus at the beginning and end of each trip, based on which the approximate value of the consumed electricity from the supercapacitor was calculated for each trip.
• Acquisition of data related to the current values: supercapacitor SOC charge level, voltage, current, vehicle speed, accelerator, and brake pedal positions, via S-CAN and V-CAN E-bus network. (Figures 4 and 5).

Figure 4. Laptop computer for data acquisition

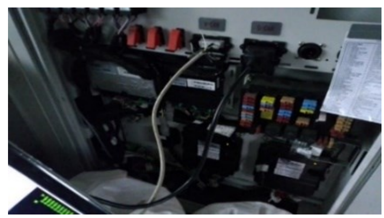

Figure 5. Connectors for S-CAN and V-CAN E-bus network

Considering that data acquisition: SOC, current strength, voltage via V-CAN and S-CAN E-bus network is performed at an extremely short time interval of 0.1 s, the processing of the downloaded data achieves a higher precision of the results compared to the first method. The differences in the obtained results of electricity consumption expressed in kWh/km are up to 5%, which makes the first method simpler with sufficient accuracy for processing a larger measurement sample than the methodology where the results of electricity consumption are obtained by processing data downloaded via S-CAN and V-CAN E-bus network. The test with the Higher 18m UC electric articulated bus was carried out in the period September 29-October 5, 2022. years. In the same period, the operation of the Solaris Urbino 18 buses operating on the existing line No. 31 was analyzed from the aspect of diesel fuel consumption. (Table 1).

Table 1. Test execution plan

Examination day	Line	Line description	Factor of weight	Vehicle to be compared
1,2,3,4,5,6	Line 31-test: (SRC M.G. Muskatirovic-Konjarnik) Line 31 (Studentski trg-Konjarnik)	Radial, urban, with distinct ascents	High	Higer 18 UC E-bus Solaris Urbino 18 (Euro 5)

3.2. Technical characteristics of the bus Higer 18 UC Electric bus

The low-floor bus Higer 18 UC Electric bus (Figure 6) is intended for the transportation of passengers on city lines. The vehicle meets all requirements regarding homologation for the EU market according to WVTA (Whole Vehicle Type Approval). The technical characteristics of the electric bus Higer (Chariot) 18m UC Electric bus are shown in Table 2.

Table 2. Technical characteristics

Higer 18 UC Electric bus
Dimensions: (L, W, H): 18.090 x 2.550 x 3300 mm
Curb weight: 19,100 kg
Number of seats: 44+1
Number of standing places: 95
Number of doors: 4
Maximum speed: 70 km/h
Drive electric motor:
Dana TZ488XSPE352WH-E,
permanent magnet, central position
Max. power of the driving electric motor: 350 kW
Max. torque: 3700 Nm
Controller and management: Higher control system
Supercapacitor: AOWEI
Capacity: 108 kWh
Charging time: 3-10 min

Figure 6. Higer 18 UC Electric bus

The basic characteristics of fast chargers installed at the line terminal are shown in Table 3

Table 3. Technical characteristics of the charger

Input Voltage	3x380 V (AC)
Max. Power	400 /600 kW
Max. Output current	500/800 A (DC)
Max. Output Voltage	750 V (DC)
Charging efficiency	97%
Height of the pylon	4.5-4.6 m

The chargers are connected to the AC distribution network, via substations located near the chargers. The high power of the charger guarantees an average charging time of 3-10 minutes for the 108 kWh supercapacitor built into the E-bus Higer.

4. RESULTS OF THE RESEARCH

From the point of view of the test run of the Higer 18m UC electric bus, the following especially were examined:

- driving cycle characteristics
- travel time and achieved transport speeds
- electricity consumption, expressed in kWh/km
- charging time at SRC M.G Muskatirovic terminus

• energy efficiency compared to diesel-powered buses
• environmental advantages compared to diesel-powered buses.

4.1. Characteristics of the driving cycle on line No. 31-test

Considering that the route of the line is located in the central city area, passing through corridors (Dusanova, Francuska, Kralja Milana, Slavija Square, Oslobodjenja Boulevard, Ustanicka) with high traffic intensity, a large number of traffic lighted intersections, one of the characteristics of the driving cycle is relatively low transport speeds. Based on the results of measuring travel time by direction for each half-turn, it follows that the average transport time in direction "A" (SRC-Konjarnik) is 00:39:15 while in direction "B" (Konjarnik -SRC) 00:39:33, i.e. transport speeds of 14.1 km/h and 13.8 km/h were obtained. Figure 7 shows the achieved transport speeds by achieved turn and directions.

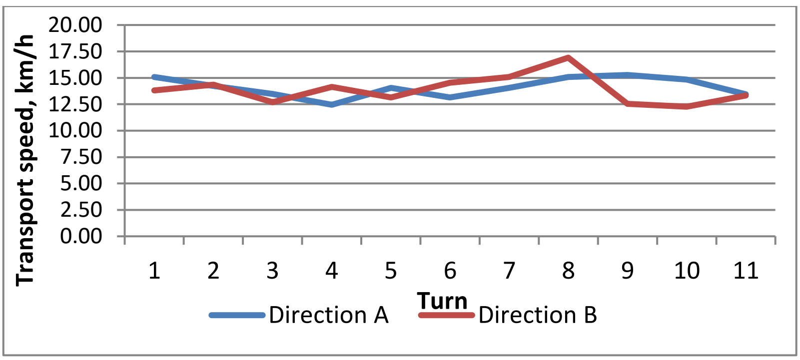

Figure 7. Achieved transport speeds

An example of a drive cycle recorded on October 3, 2022, in direction "B" (Konjarnik-SRC M.G Muskatirovic) in the period from 11:58 to 12:42 is shown in Figure 8.

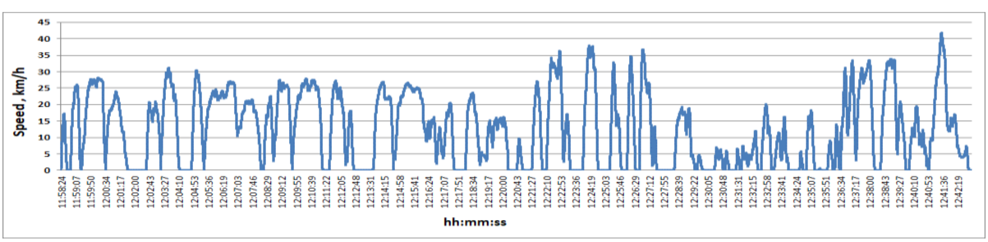

Figure 8. Driving cycle on line no. 31-test Konjarnik-SRC M.G. Muskatirovic

Based on the shown driving cycle, the transport speed was 12.5 km/h. On the largest part of the route, the maximum speeds achieved are up to 30 km/h [23].

4.2. Electricity consumption of Higer 18 UC on line no. 31-test

Electricity consumption represents one of the most significant operational indicators of E-bus operation on the route, which allows for comparison of energy efficiency with buses that use other types of propulsion energy (diesel, CNG), calculation of costs for consumed electricity, assessment of real autonomy of movement with one charging, etc. Table 4 shows the results of the measured electricity consumption of the E-bus Higer 18 UC in the operating mode when the air conditioner was not used.

Table 4. Measured values of electricity consumption

Direction "A" number of measurements (ride)	Consumption kWh/km	Direction "B" number of measurements (ride)	Consumption kWh/km	Consumption Average (A+B)/2 kWh/km
1	2.114	2	0.678	1.396
5	2.103	4	0.727	1.415
7	2.280	8	0.870	1.575
9	2.245	10	0.814	1.529
13	2.435	14	0.660	1.547
15	1.923	16	0.828	1.375
17	2.241	18	0.690	1.465
19	2.352	20	0.791	1.572
	2.192		**0.752**	**1.472**

In the direction "A" the average electricity consumption is 2.192 kWh/km with a standard deviation of ±0.160 kWh/km. The average measured electricity consumption in direction "B" is 0.752 kWh/km with a standard deviation of ±0.08 kWh/km. If we look at the average electricity consumption for both directions for line No. 31-test, it amounts to 1.472 kWh/km with a standard deviation of ±0.081 kWh/km. It is observed that there is a significant difference in the consumption of electricity observed by directions as a consequence of the different geometric configurations of the line's route. In the direction "A", sections of the route with climbs dominate, where a higher engaged power of the propulsion system is required to overcome the resistance of the E-bus movement, compared to the direction "B", where sections with longitudinal drops dominate, where the utilization of regenerative braking is significantly higher vehicles when the drive system works in generator mode and realizes the return (recovery) of electrical energy to the supercapacitor. The test drives were carried out during two characteristic periods of vehicle operation in public city transport, the off-peak period and the afternoon rush hour. Considering that the vehicle was loaded with a constant mass, the influence of the duration of the drive, which in direction "A" was from 35 to 45 minutes and in direction "B" from 33-45 minutes, did not significantly affect the consumption of electricity E- bus. This is explained by the fact that when the E-bus stops due to traffic congestion, at a traffic light, or a station..., the engaged power is minimal and amounts to only 0.7 to 1.4 kW, which is necessary for the operation of light signaling, displays, and dashboard.

An example of data acquisition from the S-CAN network is the display of the measured current values of the electric current and voltage of the supercapacitor for ride no. 17, which was realized on October 3 in the period from 11:13:50 to 11:45:01 in the direction of "A" (Figure 9) [23].

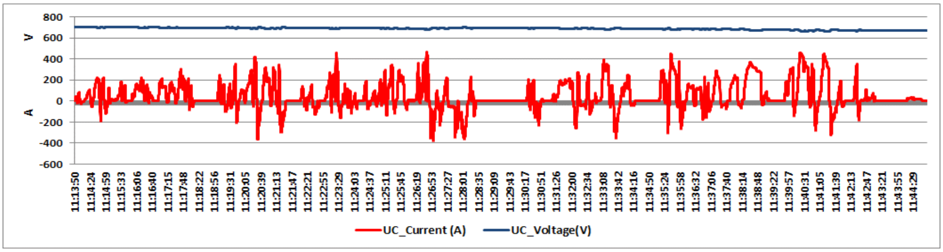

Figure 9. Current values of the supercapacitor, current and voltage for line No. 31-test, direction "A" Konjarnik-SRC M.G Muskatirovic, October 3, 2022, 11:13-11:45

The maximum measured value of the current in the drive mode is 468 A, while the maximum recovery current is -369 A. By processing the data taken from the S-CAN network of Higer 18 UC Electric bus, October 3, 2022, for direction "A" 11:13-11:45 and direction "B" 11:50-12:30 the results are obtained which are shown in Tables 5 and 6 [23].

Table 5. Energy balance of Higer 18 UC Electric bus, Direction "A", 11:13-11:45

Ep, kWh	24.567
Er, kWh	-7.372
λ_r , %	30.0
ΔE, kWh	17.195
L_a, km	7.94
E_{ebus}, kWh/km	**2.166**

Ep-taken electrical energy from the supercapacitor
Er- returned electrical energy to the supercapacitor
λ_r – recovery efficiency

Table 6. Energy balance of Higer 18 UC Electric bus, Direction "B", 11:58-12:42

Ep , kWh	14.997
Er, kWh	-8.787
λ_r , %	58.5
ΔE, kWh	6.210
L_b , km	9.25
E_{ebus}, kWh/km	**0.671**

La,b – length of line, Direction ”A” and ”B”
ΔE- the difference between the taken and returned electrical energy to the supercapacitor
E_{ebus} – electricity consumption of E-bus

Tables 5 and 6 show the level of recovery electricity generated in the braking and deceleration phases. In Direction "B" the recovery efficiency is 58.5%, while in Direction "A" it is 30.0%. The higher level of achieved recuperation in direction "B" is the result of the configuration of the route, i.e. the presence of slopes as well as greater intensity and frequency of braking.

4.3. Summary of electricity consumption Higer 18 UC on line no. 31-test

Based on the analysis of the average electricity consumption of the Higer 18 UC Electric bus on line No. 31-test in operating modes without using the Air conditioning system (AC) and heating vehicle systems (HV), with the use of the AC system and with the use of the heating vehicle system are given in Table 7 [23].

Table 7. Electricity consumption of Higer 18 UC Electric bus with and without using an AC and HV system

	E_{ebus} kWh/km	**$\eta_{ch.}$ %**	**E_{ebus}' kWh/km**
AC-off, HV-off	1.472	97	1.517
AC-on	1.810	97	1.865
HV-on	2.422	97	2.496

$\eta_{ch.}$ – charger efficiency, %
E_{ebus}' – consumption of E-bus included electrical losses in the charging phase

The significant impact of the operation of the cooling system and especially the heating system of the passenger compartment of the E-bus on the increase in electricity consumption of the Higer 18 UC Electric bus is evident. The heating system increases consumption by 64.5%, while the passenger compartment cooling system increases consumption by 22.9%. When analyzing the electricity consumption of the E-bus, the electrical losses that occur in the fast charger during charging should also be taken into account. Modern chargers have a charging efficiency of around 97%.

4.4. Analysis of the autonomy of movement of the Higer 18 UC on line no. 31-test

Based on the measured values of electricity consumption of the Higer 18 UC Electric bus in characteristic operating modes (with/without air conditioning system) and based on static and dynamic elements of line No. 31-test, it is possible to estimate the real autonomy of the E-bus operation with one charge of the supercapacitor, expressed through the number of turns on the line and the number of kilometers traveled, as shown in Table 8 [23].

Table 8. Expected E-bus autonomy

	E_{ebus} kWh/km	$2L_s$ Km	ΔE kWh	E_{uc} kWh	Number of realized turns	Mileage km
AC-off., HV-off	1.472	18.4	27.08	108	3.5	64.4
AC-on	1.810	18.4	33.30	108	3.0	55.2
HV-on	2.422	18.4	44.56	108	2	36.8

L_s – the average length of line No. 31-test, km

E_{uc} – electrical capacity of the supercapacitor, kWh

4.5. Analysis of the charging time of the Higer 18 UC electric bus

Charging of the E-bus during operation on line No. 31-test was carried out at the terminus of SRC Milan Gale Muškatirović, on the existing fast charger with a power of 400 kW. A view of the charging phase of the Higer 18 UC Electric bus is presented in Figure 10.

Figure 10. Charging phase of Higer 18 UC electric bus

The presentation of the required charging time expressed in minutes (mm: ss) required to charge the supercapacitor from the SOC value at the moment of arrival at the terminus to 99/100% SOC is shown in Table 9 [23].

Table 9. Charging time of the Higer 18 UC Electric bus at the terminal SRC

number of measurements (runs)	SOC_d %	SOC_k %	ΔSOC %	Time required for charging mm:ss
1-2	74	99/100	26	8:30
3-4	71.1	99/100	28.9	8:10
5-6	73.6	99/100	26.4	8:16
7-8	71.4	99/100	28.6	8:04
9-10-11-12	35.4	99/100	64.6	12:15
13-14	64.2	99/100	35.8	8:45
15-16	74.1	99/100	25.9	8:01
17-18	68.1	99/100	31.9	8:40
19-20	68.4	99/100	31.6	8:48

SOC_d – at the beginning of charging, %
SOC_k – at the end of charging, %

Charging of the E-bus was performed after each completed turnaround on line No. 31-test, except in the case of realization of runs numbered 9, 10, 11, and 12 when two turnarounds were completed on the line. The charging time depends on the degree of discharge, i.e. the current value of the voltage of the supercapacitor and the value of the current from the charger. The initial charging current is about 500 A and it decreases during the charging phase depending on the supercapacitor voltage reached. The average charging time was 8:24 minutes. The measured charging time after two revolutions was 12:15 minutes. Given that the average E-bus charging time is less than 10 minutes per completed turn, in practice it would not have an impact on the implementation of the planned timetable, where the planned waiting times at the terminus are 5 minutes per half turn. It should be noted that the Higer 18 UC Electric bus can also be charged with a 600 kW fast charger, with an initial charging current of 800 A. In that case, the required charging time would be significantly shorter compared to a 400 kW charger and would amount to about 5 minutes for one full turn.

4.6. The energy efficiency of Higer 18 UC Electric bus

One of the most significant advantages of using electric buses is their greater energy efficiency compared to buses that use conventional fuels (diesel, KPG). The electric motor in the E-bus has a higher degree of a useful effect than the IC motor and the possibility of operating in generator mode during the braking phase of the E-bus. Table 10 presents the consumption of diesel fuel for Solaris Urbino 18 articulated buses (Euro 5) that operated on the existing route No. 31 (Studentski trg-Konjarnik) in the period 26.9.-30.9.2022. year [23].

Table 10. Diesel fuel consumption for Solaris Urbino 18 buses on line no. 31

Garage	26.9.2022			27.9.2022			28.9.2022			29.9.2022			30.9.2022		
number	Km	L	L/100km	Km	L	L/100km	Km	L	L/100km	Km	L	L/100km	Km	L	L/100km
3116	265	177	66.8												
3112	197	135	68.5										180	100	55.6
3197	262	166	63.4	262	172	65.6				262	170	64.9			
3136				290	190	65.5	258	169	65.5						
3195				186	118	63.4	180	110	61.1	186	125	67.2			
3106							236	164	69.5						
3103										203	140	69.0			

In the mentioned period, the outside temperatures were between 13 ℃ and 23 ℃, so the vehicle's air conditioning system was not used, which in that case would have an impact on diesel fuel consumption. The average consumption of diesel fuel for Solaris Urbino 18 buses in the observed period was 65.07 L/100km. If the consumption of diesel fuel expressed in L/100km is shown in kWh/km to compare the energy balance with the electricity consumption of the E-bus, the results shown in Table 11 are obtained.

Table 11. Comparative view of energy efficiency on line No.31-test and line No.31

Drive Type	Average consumption kWh/km
Higer 18 UC Electric bus	1.472
Solaris Urbino 18 (Euro 5)	6.507

Based on the average energy consumption for city articulated buses, it follows that the Higer 18 UC Electric articulated bus has more than 4 times the energy efficiency of the Solaris Urbino 18 articulated bus.

4.7. Analysis of the environmental performance

From an environmental point of view, electrically powered buses are classified as zero-emission vehicles. This practically means that during operation, the vehicle's propulsion system does not emit harmful products such as CO (carbon monoxide), CxHy (hydrocarbons), NOx (nitrogen oxides), PM10 (suspended microparticles), there are no local emissions of CO2 (carbon dioxide), but it is indirectly present at the level of the wider environment, i.e. state level, given that 70% of electricity production in the Republic of Serbia comes from thermal power plants. The environmental advantages of using the Higer 18 UC Electric bus compared to Solaris Urbino 18 diesel buses (Euro 5) in the example of line No. 31 and line No. 31 test are shown in Table 12. The emission results obtained are shown on an annual basis for one vehicle. assuming that the vehicle exceeds 70,000 km [23].

Table 12. Comparative view of the ecological performance of articulated buses Higer 18 UC Electric bus and Solaris Urbino 18 (Euro 5)

Pollutant	Higer 18 UC Electric bus kg/per year	Solaris Urbino 18 (Euro 5) kg/per year
CO (carbon monoxide)	0.0	252.63
CxHy (carbon-hydrogen),	0.0	77.49
NOx (nitrogen-oxides),	0.0	336.84
PM_{10} (micro-particles)	0.0	3.36
CO_2 (carbon dioxide)	88340	143724

When comparing the CO2 emission, it is higher by about 62.6% for the Solaris Urbino 18 diesel-powered bus (Euro 5). The monetary value of generated emissions as an impact on human health and removal of the consequences of air pollution can be expressed according to Directive EC/33/2009 [25].

4.8. The level of emitted noise

The Higer 18 UC Electric bus is characterized by extremely quiet operation, especially at low speeds, where the drive system of the E-bus is the dominant source of noise. At low speeds, the E-bus is equipped with a system for emitting a characteristic sound that should warn passers-by (elderly people, people with impaired hearing...), especially in the area of pedestrian crossings and stops where the vehicle is in the immediate vicinity. The E-bus has a lower noise level compared to diesel buses by at least 11% [11].

5. CASE STUDY

The economic effects of the application of the Higer 18 UC Electric bus can be shown through a "case study" of the analysis of the total costs of exploitation in the entire life cycle (LCC), which would refer to line No. 31, is, to the replacement of existing articulated diesel buses with articulated electric buses drive. On line no. 31 (Studentski trg-Konjarnik), there are currently 17 articulated buses in operation according to plan. An overview of static and dynamic work elements is presented in Table 22.

Table 13. The existing number of buses in operation and indicators of operation on line 31

Line	Number of buses in operation (Nr)	f (bus/h)	i (min)	Type	Cmax (places/h)	Lsr (km)	To (min)	Vo (km/h)	Zmax (passengeres/h)	Kik
31	17	13.2	4.53	18m	2119	7.36	77	11.47	1280	0.60

With the introduction of electric-powered buses on line 31, the same or approximately the same level of passenger transportation service must be maintained in terms of providing the necessary capacity, arrival intervals, and utilization coefficient of the offered capacity, as in the case when diesel-powered buses are operating. The introduction of electric buses would mean extending the route of the existing line no. 31, to the SRC M.G. Muskatirovic terminal, where the existing chargers are. In this sense, the proposal for dimensioning the required number of E-buses on the new line EKO 31 is given in Table 23.

Table 14. Proposed number of articulated E-buses in operation and performance indicators on line EKO 31 (SRC M.G. Muskatirovic-Konjarnik)

Line	Number of E-buses in operation (Nr)	f (bus/h)	i (min)	Type	Cmax (places/h)	Lsr (km)	To (min)	Vo (km/h)	Zmax (passengeres/h)	Kik
EKO 31	19	12.6	4.73	18m	1764	9.2	90	12.2	1280	0.72

The case study was done under the assumption that vehicles and equipment are purchased through a loan with a repayment period of 7 years. The warranty period is 2 years for vehicles, 5 years for chargers, and 10 years for supercapacitors. It would be necessary to install two fast chargers of 400 kW each at the Konjarnik terminus. The prices of energy products (diesel fuel and electricity) are taken according to the valid market prices as of October 24, 2022. as well as the average Euro exchange rate of 117.5 din/€ and the discount rate. The total costs of operating a bus in its lifetime represent the sum of individual costs and can be represented as:

$$T_{uk} = T_{inv} + T_{iop} + T_{ios} + T_{ood} + T_{oen} + T_{oek} + T_{oot} \quad (1)$$

T_{uk} – total costs in the lifetime of a vehicle or group of vehicles, €,

T_{inv} – investment costs of vehicle acquisition, €,

T_{iop} – investment costs of purchasing equipment (chargers), €,

T_{ood} – vehicle maintenance operating costs, excluding labor costs, €,

T_{oen} – operating costs of driving energy, €,

T_{oek} – operational costs of environmental pollution from vehicle use, €

T_{oot} – operating costs, other costs: registration, mandatory insurance, comprehensive insurance, annuities, €.

Table 15. Overview of input elements costs in the lifetime

Input elements	Unit	E-bus 18 UC	Diesel bus 18m (Euro 6)
Number of vehicles to be purchased	[комада]	19	17
Annual mileage	[km]	70000	70000
The lifetime of the vehicle	[year]	16	16
Discount rate	[%]	2.5	2.5
Interest rate	[%]	2.5	2.5
Loan repayment period	[year]	7	7
Electricity consumption	[kWh/100km]	151.7	
The price of electricity	[€/kWh]	0.095	
Diesel fuel consumption	[L/100km]		65.07
The price of diesel fuel	[€/L]		1.70
Ad-Blue consumption	[L/100km]		3.0
Ad-Blue price	[€/L]		0.22
E-bus maintenance costs	[€/km]	0.0567	
Supercapacitor service costs	[€/E-bus)	10000	
Diesel bus maintenance costs	[€/km]		0.1380

Table 16. Overview of investment costs for the purchase of articulated buses

Investments	Unit price [€]	Number of units	Total [€]
E-bus with a supercapacitor, capacity of 108 kWh	750,000.00	19	14,250,000.00
Diesel articulated bus, Euro 6	335,000.00	17	5,610,000.00
Charger for fast charging power 400 kW	220,000.00	2	440,000.00
Charger for slow charging power 50 kW (for depot)	40,000.00	3	120,000.00

Table 17. Overview of operating costs on an annual level

Annual exploitation costs	Unit price [€]	No. of units	Total [€]
Maintenance costs of E-bus UC 18	3,969.00	19	75,411.00
Supercapacitor service costs after 10 years, for E-bus UC	10,000.00	19	190,000.00
Diesel bus maintenance costs	9,660.00	17	164,220.00
Maintenance costs for fast chargers after 5 years	350.00	2	700.00
Electricity costs for driving the E-bus UC	10,088.05	19	191,672.95
Diesel fuel costs for driving diesel buses and "Ad-Blue"	77,895.30	17	1,324,220.10
Air pollution costs from E-buses UC (CO2 - WtW)	3,092.44	19	58,756.33
Air pollution costs from diesel buses (CO2-WtW, CO, CxHy, NOx, PM)	5,325.48	17	90,533.16
Loan repayment - Annuity for E-bus UC, chargers			2,332,507.31
Loan repayment - Annuity for diesel buses (Euro 6)			883,549.36
Casco-for E-buses UC 18	5,250.00	19	99,750.00
Casco for diesel buses	2,310.00	17	39,270.00

Based on the case study done, which refers to the substitution of existing diesel-powered articulated buses with articulated electric buses, it follows that the total costs in a lifetime of 16 years are 22.28 million € for electric-powered buses or 31.39 million € for diesel-powered buses. The difference is 9.10 million Euros in favor of electric buses.

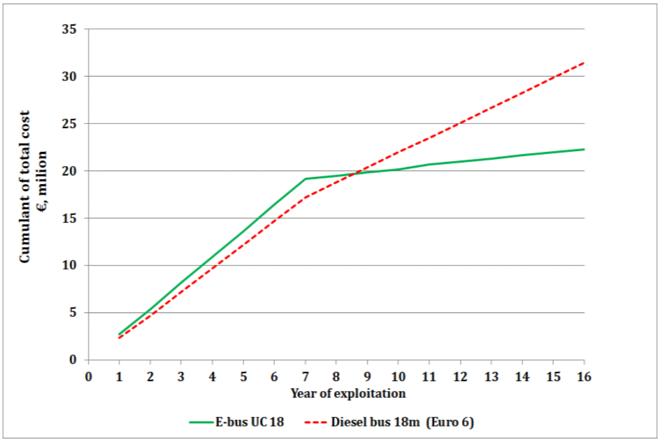

Figure 11. Cumulative costs over the lifetime of the buses

If the criterion related to the investment payback time is analyzed, it follows that the total costs are equalized after 8.5 years of exploitation. After that period, we have direct benefits (savings) which are the consequences of the exploitation of electric buses. Using the minimum net present value criteria (min T_{nsv}).

$$T_{nsv} = \sum_{t=0}^{n_{zv}} \frac{T_{uk}}{(1 + d_{sk})^t}, \qquad (2)$$

T_{nsv} – the net present value of total costs over the lifetime of the vehicle, €,
T_{uk} – total costs in the lifetime of a vehicle or group of vehicles, €,
d_{sk} – discount rate, %,
n_{zv} – a lifetime of the vehicle (years).

The net present value of the total lifetime costs of electric-powered articulated buses is 19.70 million Euros, while for diesel-powered buses that amount is 26.15 million Euros. And according to this criterion, the difference in total costs is 6.45 million Euros in favor of electric buses.

6. CONCLUSION

The use of articulated electric buses will have a further upward trend in many cities of Europe and the world as an effective way of decarbonizing the public transport system due to the substitution of existing diesel buses with electric ones, as well as a great potential for use on BRT system lines.

The test operation of the articulated bus Higer 18 UC Electric bus presented all the specifics of the use of an articulated bus with electric drive compared to buses that use diesel fuel, on the representative city line No. 31-test (SRC M. G Muskatirovic-Konjarnik). From the point of view of requirements in real exploitation: traction-speed characteristics, braking dynamics, stability, controllability, vehicle capacity, electricity consumption, charging time, the autonomy of movement, and environmental and ergonomic requirements, the vehicle met all criteria.

The test proved that the articulated bus Higer 18 UC Electric bus has more than 4 times higher energy efficiency compared to the bus Solaris Urbino 18 (Euro 5) in approximately the same operating conditions that are present on the line No. 31 (Studentski trg-Konjarnik) and line No. 31-test (SRC M.G. Muskatirovic-Konjarnik). The environmental effects of using electric buses instead of diesel buses are reflected in the reduction of air pollution and noise levels as a result of the withdrawal of articulated diesel buses from the existing line No. 31 and the introduction of electric buses. This practically means that with the introduction of electric articulated buses, the effect of reducing the emission of harmful gases would be lower by: 4294.2 kg (CO-carbon monoxide), 1317.3 kg (CxHy-carbon hydrogens), 5725.6 kg (NOx-nitrogen oxides), 57.12 kg (PM10 – suspended microparticles) as well as a smaller emission of 941.5 tons (CO2 – carbon dioxide). The economic evaluation on the example of a case study of the complete substitution of diesel buses with electric ones on line No. 31 proved the profitability of the project from the point of view of comparing the total costs in the lifetime, the net present value, and the investment return time.

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Deni Krevesic[1]
E-mail: dkrevesic@glanvillegroup.com; denikrevesic@gmail.com
[1] Glanville Consultants
3 Grovelands Business Centre, Boundary Way, Hemel Hempstead, United Kingdom

DRIVING TOWARDS THE FUTURE: THE IMPACT OF CONNECTED AND AUTONOMOUS VEHICLES ON TRANSPORT PLANNING

Keywords

Connected and Autonomous Vehicles (CAVs)
Transport Planning
CAVs in Public Transport
Infrastructure Impact
Legislation and Policy Frameworks
CAVs Case Studies

Abstract

This paper focuses on the potential impact of emerging vehicle technologies, particularly connected and autonomous vehicles (CAVs), on various aspects of transport planning, including active travel, road infrastructure, parking and public transport. CAVs are the future of transportation, and they are designed to make roads safer, reduce traffic congestion and improve mobility service. The paper examines the implementation of Level 4 and 5 autonomous vehicles in public transport across the UK, summarising the initial findings, benefits and challenges during the early stages of deployment. A holistic approach is taken to evaluate CAVs' future impact on highway design, parking management, transport modelling, changes in travel behaviour and safety. The analysis highlights how CAVs affect highway design, parking management, and transport modelling, illustrating the significance of these factors in the overall planning process. Considering available data, this paper highlights critical issues that need to be addressed to maximise the benefits of this innovative technology, such as developing transport models that predict traffic patterns and travel behaviour in a real traffic environment. In addition, it is essential to examine the role of CAVs in reshaping road infrastructure, such as lane allocation, traffic signs, communication markers, signal timings, and parking facilities, optimising street space utilisation while maintaining accessibility for all users. Ultimately, the paper seeks to provide a comprehensive understanding of how CAVs could transform various aspects of transport planning, offering insights that could help decision-making processes and promoting sustainable growth.

1. INTRODUCTION

Connected and Autonomous Vehicles (CAVs) refer to advanced vehicles that leverage artificial intelligence (AI), sensors, and other technological advancements to operate with little or no human assistance. The term "Connected" refers to the vehicle's ability to communicate with other devices, infrastructure, and other vehicles through networks, while the term "Autonomous" corresponds to the vehicle's capacity to navigate and drive itself [1]. CAVs have the potential to advance much-needed changes within the transportation industry, offering solutions to current and future transport planning challenges, disrupting both local and strategic planning processes. This could have a lasting impact on active travel, highway infrastructure, parking, and public transport. Decision-makers, transport planners, architects, engineers, and other professionals are actively seeking a comprehensive understanding of how CAVs will impact future travel demands and infrastructure.

This paper aims to address the integration of emerging vehicle technology within the realm of transport planning. The primary focus is on the substantial changes needed for conventional infrastructure to adapt. The secondary focus highlights the requirement for legislative and policy adjustments to accommodate new technologies. By reviewing and analysing the initial findings of case studies undertaken in the UK, the objective is to understand the impacts of future changes on the transport landscape.

2. UNDERSTANDING THE EMERGENCE OF CAVS

The benefits of CAVs are presented in five major perspectives: road safety, highway capacity, mobility, environment and economy. In the realm of transport planning, they have the potential to positively impact the reduction of traffic congestion and travel times, improving traffic flow, increase public transport accessibility, and enhancing road safety [2]. The introduction of CAVs could reshape how people travel, utilising services such as ridesharing and demand-responsive services, offering advanced flexibility and personalisation, bridging the gap in first/last-mile connectivity. Their deployment enables the implementation of intelligent transportation systems, leveraging advanced communication technologies to optimise traffic management and coordination [3]. CAVs integration is in its early stages and faces three core issues: high initial costs associated with expensive technologies, the need for significant infrastructure upgrades to accommodate current autonomous technology, and concerns regarding cybersecurity and data privacy, which impact safety [4].

2.1. Levels of Driving Automation

According to the Society of Automotive Engineering, emerging vehicle technology is categorised into five levels of autonomy. Each level represents a different degree of driver assistance, ranging from Level 0 (no automation) to Level 5 (full automation). The driving automation level begins at driver assistance features (Levels 1-2), partial automation (Level 3), then high (Level 4), and finally fully autonomous vehicles (at Level 5) [5].

2.2. Autonomous Vehicles Deployment in Public Transport

The UK has emerged as a pioneer in autonomous mobility, being the first country in Europe to allow hands-free driving technology with Level 2 autonomy on public roads. The country has also witnessed significant milestones, with the introduction of the world's first autonomous electric bus service for public use in Didcot, Oxfordshire, in March 2023, and a few months later, in May 2023, Edinburgh introduced autonomous bus service in operations on public roads. Both services operate with Level 4 autonomous buses. The transport industry has already seen the successful implementation of Autonomous Train Operation (ATO) technology, which significantly improved commuting, making it faster, safer, and more efficient. Autonomous trains have been in operation since the 1980s. The Docklands Light Railway (DLR) and London Underground have been utilising ATO for over a decade.

3. LEGISLATION, EVIDENCE AND PROJECT REVIEWS

The government has emerged as a significant partner in the drive towards transport automation by engaging in various activities, such as aligning policies and regulations and funding trials. This transformative journey includes significant changes required in areas such as regulation, technology, infrastructure, and consumer behaviour.

3.1. Regulatory and Policy Frameworks

Transition models are essentially political statements, that are provisional, only partially inclusive, and often unstable over time. The political implications of rushed decision-making and intervention strategies are valid concerns of determining when and how to make effective decisions. This poses a risk for the optimal timing of CAVs integration, which will certainly require the development of new regulatory and policy frameworks that address issues such as safety, data privacy, and liability [6]. The UK Government supported the growth and deployment of CAVs, by establishing The Centre for Connected and Autonomous Vehicles in 2015. The same year the government released two “Pathway to Driverless Cars” reports: one outlining an action plan and technology overview, and another delving into regulatory frameworks [7]. They were the foundation for introducing The Automated and Electric Vehicles Act in 2018, enabling testing of self-driving vehicles on public roads. The government's policy paper, "Connected and Automated Mobility 2025: Realising the Benefits of Self-driving Vehicles in the UK," outlines plans and addresses legislative reviews, emphasising the significance of data-based evidence in policymaking.

3.2. Research: Evidence Base Decision

The UK Law Commission has been publishing various consultation papers as part of a three-year review aimed at preparing driving laws for self-driving vehicles. This process ensures informed decision-making processes and the development of legislation that aligns with advancements in autonomous technology. The research results contribute to the proposal and introduction of a new regulatory framework, taking into account how self-driving cars impact traffic, public perception, data generation, and market forecasts.

Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow (2016) – ATKINS

This study uses VISSIM microsimulation to analyse driving behaviours, lane changes, acceleration profiles, and CAV penetration levels on both the strategic road network (comprising motorways and other major routes designated for strategic traffic) and the urban road network (comprising streets and roads with speed limits typically not exceeding 80km/h (50mph)). The study focuses on passenger vehicles to assess CAV technology adoption and network performance during peak hours, considering factors like congestion, vehicle delay, low speeds, and journey times.

Table 1. Network Modelling Results [8]

Scenario	Strategic Road Network						Urban Road Network					
	Average Delay		Average Journey Time		Journey Time Variability		Average Delay		Average Journey Time		Journey Time Variability	
	(s)	%	(s)	%	(s)	%	(s)	%	(s)	%	(s)	%
Base	35.84	-	539.7	-	20.17	-	65.9	-	277.7	-	88.38	-
25% penetration (1)	36.17	0.9	538.4	-0.2	19.38	-3.9	57.7	-12.4	219.5	-21.0	19.74	-77.7
50% penetration (2)	33.39	-6.8	533.6	-1.1	17.65	-12.5	54.4	-17.4	20535	-26.1	10.01	-88.7
75% penetration (3)	29.77	-16.9	527.7	-2.2	15.33	-24.0	51.8	-21.3	198.8	28.5	7.24	-91.8
100% penetration (4)	23.72	-33.8	517.7	4.1	10.52	47.9	48.0	-27.1	192.6	-30.7	6.00	-93.2
Upper bound (5)	21.38	-40.3	472.2	-11.2	9.14	-54.7	46.3	-29.7	184.2	-33.7	5.71	-93.5

The strategic road network results indicate a potential delay reduction of over 40% with 100% CAVs, but significant benefits require high CAV penetration. At a 25% CAV fleet composition, benefits are minimal. Conversely, the urban model shows substantial improvements even at 25% CAV penetration, with a 12% delay reduction, 21% quicker journeys, and an 80% enhancement in journey time reliability [8].

Connected Vehicle Data Research Project (2020) – ATKINS/Jacobs

This report outlines a strategy for optimising connected vehicle (CV) data for improved traffic management. The Department for Transport sought to leverage CV data to improve the transport network, benefiting the environment, reducing congestion, improving safety, and strengthening the economy. The proposed approach simplified data services such as asset management, parking, vehicle data analysis, and public transport. The study identified six key strategic themes: establishing a demonstrator, creating national facilities, addressing skill gaps, supporting CV data migration, offering procurement aid, and providing service design guidance [9].

Market Forecast for Connected and Autonomous Vehicles (2020) - Catapult

This report highlights the potential of CAVs development in the automotive market, bringing changes in transportation, improving safety, efficiency, and user experience. The automotive sector is a significant contributor to the UK economy, and CAVs offer opportunities for growth and job creation. The report aims to quantify those opportunities, with key findings including an estimation of the UK CAV market value of £41.7 billion in 2035 and potential job growth in CAV-related industries. These estimates are subject to uncertainties related to adoption rates, costs, and technology development [10].

The Great Self-Driving Exploration: A citizen view of self-driving technology in future transport systems (2023) - University College London (UCL) and Aurrigo

Self-driving vehicles (SDVs) could bring significant benefits, but the government needs to ensure their safety and public trust. To achieve this, the government undertook research to understand how people perceive SDVs and what they expect from them. Previous research showed that while people are excited about SDVs, there is a need for more understanding and trust in the technology. Those who participated in the shuttle and pod SDV trials shared an overall positive experience. These participants, including both passengers and pedestrians, consistently expressed a heightened sense of security. Notably, stress levels were found to be significantly reduced. This sense of safety surpassed initial expectations, indicating the successful implementation of the SDV trials. This research shows that giving people the chance to try SDVs is valuable. It helps them become accustomed to the technology and can lead to more informed views, ultimately contributing to the development of better SDVs in the future [11].

4. CASE STUDIES

4.1. MultiCAV: Mobility as a Service (MaaS)

The MutiCAV passenger-carrying trial aims to showcases the practical implementation of CAVs technology in Didcot, Oxfordshire. In March 2023, Mi-Link service was introduced at Milton Park, marking the launch of the first zero-emission bus service for public use on a private road operating with SAE Level 4 autonomy. Building on this success, the trial was later extended in September 2023 to include a public road connecting Milton Park with Didcot Parkway railway station [12]. This project utilises real-world transport data to evaluate user behaviour and commercial viability, with the goal of integrating MaaS and CAV into a multi-modal mobility solution. The project aims to set a benchmark for what integrated MaaS solutions.

4.2. CAVForth: Bus Service

The CAVForth Project successfully introduced the first fleet of 20 autonomous buses in the UK, operating at the SAE Level 4 of autonomy on public roads, launching in May 2023, covering a 22.5-kilometer route in Edinburgh. These buses have the capability to travel in mixed traffic at a maximum speed of 80km/h (50mph) and can transport up to 10,000 passengers per week [13]. Operating primarily on motorways managed by Transport Scotland, these full-size autonomous buses are responsible for safely interacting with other vehicles, navigating junctions, and making stops. In collaboration with the CAVForth and the overseeing authority, a comprehensive approach has been taken involving designing and implementing essential infrastructure measures, utilising the Traffic Scotland National Control Centre for real-time trial monitoring, ensuring an effective incident management response.

5. POTENTIAL IMPACT ON INFRASTRUCTURE

Infrastructure is crucial for the implementation of CAVs in the transport ecosystem, necessitating improvements in highway design, including lane markings and electronically readable signs [14]. With technological advancements, the operational efficiency of the highway network is expected to increase, enabling higher capacity at roundabouts and junctions, and potentially resulting in narrower carriageway lanes [15]. Designated locations for safe and convenient pick-up/drop-off should also be provided. The shift from private to shared vehicles has the potential to reduce total vehicle ownership and parking demand [14]. It should be noted that shared CAVs represent a long-term vision and may not be immediately evident. As CAVs become the majority on the road, traditional traffic signs, lane markings, and even traffic lights may become obsolete. While CAVs offering door-to-door service could reduce walking and cycling, this could have negative impacts on health and wellbeing [16]. This concern also extends to potential negative consequences, such as reduced opportunities for socialising and a diminished sense of public space ownership. The integration of CAVs would also require robust communications infrastructure to ensure reliable data services for CAVs and reduce network disruptions.

6. POTENTIAL IMPACT ON TRANSPORT PLANNING

The transport industry is currently navigating a future filled with uncertainties, posing significant challenges for long-term planning. Exploring the transition to CAVs and its impact on transport planning involves a comprehensive examination of how it influences policies, the evaluation of new transport initiatives, and design considerations. Governments will play a key role in developing legislation and standards to allow for interoperability, preventing manufacturers from creating monopolies by developing their own standards that might not be compatible with others, as has been seen in the electric vehicle charging sector [17]. Furthermore, with established technologies like vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) communication, CAVs can share real-time traffic information, allowing them to adjust their routes and speeds accordingly [3]. This can lead to a more efficient use of the road network and a reduction in travel times, giving them the potential to improve traffic management by reducing congestion and optimising traffic flow. The elimination of the need for traffic signals by CAVs is feasible but limited to areas where all traffic is autonomous [14]. As CAVs become more dominant, the need for parking spaces is expected to decrease. The introduction of CAVs will require changes in the design and functionality of transportation infrastructure. Highways may need to be adapted to accommodate dedicated lanes, while traffic signals and signage will need to be updated to facilitate V2X communication. CAVs have the potential to improve accessibility for people with disabilities, the elderly, and those without access to personal cars, by providing convenient and affordable transport options. The adoption of CAVs may lead people to choose to live further away from urban centres, resulting in changes in land use patterns and the emergence of new development patterns.

7. CONCLUSION

CAVs have the potential to significantly impact transport planning, from modelling and highway design to decision-making processes. This paper has discussed the multifaceted impacts of CAVs, covering road safety, highway capacity, mobility, the environment, and the economy. They hold the promise of reducing traffic congestion, improving travel times, enhancing traffic flow, and increasing accessibility to public transport. However, their integration presents challenges such as high initial costs, the need for infrastructure upgrades, and concerns about cybersecurity.

In conclusion, the effects of CAV adoption can be categorised into three key phases: introduction, transition, and full integration into the transport ecosystem. While the timing of each effect remains uncertain, short-term effects are expected to emerge within the first 3-5 years of CAV adoption, including improvements in travel time, convenience, and productivity. Conversely, medium-term effects, anticipated within 6-10 years, may involve shifts in car ownership, privacy concerns, and cybersecurity. Long-term effects, extending beyond 10 years, relate to impacts on the urban built environment, such as decisions regarding household and employment locations, and changes in parking demand [3].

One of the key benefits of CAVs is their potential to reduce energy consumption and mitigate environmental impacts. Studies show that CAVs can optimise routes and adapt to traffic conditions in real-time, minimising travel delays and reducing congestion [8]. Although private cars continue to dominate, CAVs have the potential to encourage a shift away from private cars by offering convenience, availability, and frequency. A remaining concern is whether the provision of highly accessible services could deter people from walking and cycling as they are attracted by the benefits CAVs have to offer.

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Sustainable Mobility Planning and Liveable Streets

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Ana Trpković[1]
E-mail: a.trpkovic@sf.bg.ac.rs
Stanko Bajčetić[1]
E-mail: s.bajcetic@sf.bg.ac.rs
Predrag Živanović[1]
E-mail: p.zivanovic@sf.bg.ac.rs
Sreten Jevremović[1]
E-mail: s.jevremovic@sf.bg.ac.rs
Strahinja Pantelić[1]
E-mail: s.pantelic@sf.bg.ac.rs

[1] University of Belgrade, Faculty of Transport and Traffic Engineering
Vojvode Stepe 305, Voždovac, 11010 Belgrade, Republic of Serbia

LOW VEHICLE OCCUPANCY RATES AS A BIG CHALLENGE FOR URBAN MOBILITY OR HOW TO CHANGE BAD HABITS

Keywords

Average vehicle occupancy
Traffic congestion
Single occupancy vehicle (SOV)
Urban mobility

Abstract

The problem of traffic congestion in modern cities is the result of numerous factors that must be addressed by various management, regulatory and design solutions. The average vehicle occupancy, especially passenger cars, is certainly one of the significant indicators of the street network condition. In general, with the increase of the motorization rate, there is a noticeable decrease in vehicle occupancy, which directly affects the level of service. This does not conform with the green agenda of the development of sustainable and resilient cities. As part of this paper, the methodology and the results of the latest vehicle occupancy survey on selected characteristic corridors of the city of Belgrade will be presented. The research showed that passenger cars occupancy is very low, and on average is equal to 1.47 persons/car. A more detailed analysis and discussion of spatio-temporal variabilities will be presented in a separate chapter of this paper. In the concluding part, the authors will provide preliminary guidelines and suggestions for potential solutions to overcome or at least mitigate the consequences caused by the low occupancy of passenger cars in correlation with their high presence on the street scene.

1. INTRODUCTION

The problem of low vehicle occupancy (LVO) is a pressing issue that contributes to traffic congestion in cities, ultimately affecting the quality of life for all residents. There are several factors that contribute to this problem, including the increasing number of vehicles on the road, limited road infrastructure, inadequate public transport services, and poor management of the city's transportation system. Sustainable urban mobility is an essential concept for creating livable cities, but the current state of LVO contradicts this idea. Passenger cars, being the most common category of vehicles, play a significant role in the transportation system. However, as the motorization rate continues to rise, there has been a noticeable decline in vehicle occupancy, which directly impacts the overall level of service of the transportation network.

For example, the average occupancy of passenger cars in the United States decreased from 1.87 persons per vehicle in 1977 [1] to 1.50 persons per vehicle in 2019 [2]. On the other hand, the motorization rate in the United States for the last 30 years was increased by 146% [3]. This trend is not limited to the United States but is observed worldwide, indicating significant problems regarding traffic congestion. Results of the survey conducted by Fiorelo et al. [4] suggest that the typical occupancy rate in European countries is 1.7 persons per car, although this varies across countries. In Denmark, the minimum occupancy rate is 1.4 persons per car, while in Romania, it reaches a maximum of 2.7 persons per car [4]. Based on the previous, countries with a high occupancy rate tend to have low availability of cars per person. This indicates that cars are predominantly viewed as a personal mode of transportation, and carpooling appears to be driven more by necessity rather than a deliberate choice. Apart from being a fundamental issue leading to traffic congestion, LVO gives rise to various additional challenges, like heightened emissions of exhaust gases, detrimental effects on the environment, increased costs for society, overcrowding of existing parking spaces, and more [5].

In response to these challenges, the authors of this paper have conducted a comprehensive research along selected corridors in the city of Belgrade. The objective of this research is to present and discuss the methodology and the results obtained from this study. By understanding the current situation in Belgrade, valuable insights can be gained into the broader issue of low vehicle occupancy and its impact on traffic congestion. In the concluding part, the paper will provide preliminary guidelines and suggestions for potential solutions to overcome or at least mitigate the consequences caused by the low occupancy of passenger cars in correlation with their high presence on the street scene.

2. METHODOLOGY OF THE RESEARCH

The research conducted within this paper is based on recording the traffic flow (traffic counting) and recording the occupancy of vehicles at specific locations in the city of Belgrade. The methodological framework foresees four stages.

The first, **preparatory phase**, defined the basic objectives of the research, and accordingly the method of its implementation. Within this phase, characteristic locations and time periods in which it was necessary to conduct research were selected. The survey was conducted on 15 locations (main traffic corridors) in the city of Belgrade from 6am to 10pm on representative weekdays (Tuesday, Wednesday and Thursday). Locations of the conducted research are shown in the next Table and Figure.

Table 1. Research locations

Location code	Location name	Research date
TCNS 1	Pančevo bridge	Wednesday, November 2nd, 2022
TCNS 2	Branko's bridge	Wednesday, November 2nd, 2022
TCNS 3	Old Sava bridge	Thursday, November 3rd, 2022
TCNS 4	Gazela bridge	Wednesday, November 2nd, 2022
TCNS 5	Ada bridge	Wednesday, November 2nd, 2022
TCEW 1	Shopping center "Zmaj"	Thursday, November 3rd, 2022
TCEW 2	Tošin bunar	Thursday, November 3rd, 2022
TCEW 3	Bulevar umetnosti	Thursday, November 3rd, 2022
TCEW 4	Milentija Popovića	Thursday, November 3rd, 2022
TCEW 5	Savska	Tuesday, November 8th, 2022
TCEW 6	Kneza Miloša	Tuesday, November 8th, 2022
TCEW 7	Bulevar Oslobođenja	Tuesday, November 8th, 2022
TCEW 8	Maksima Gorkog	Tuesday, November 8th, 2022
TCEW 9	Vojislava Ilića	Tuesday, November 8th, 2022
TCEW 10	Ustanička	Tuesday, November 8th, 2022

The second phase of the methodological process included the preparation and training of researchers for the subject recording. This includes 70 researchers and 10 supervisors.

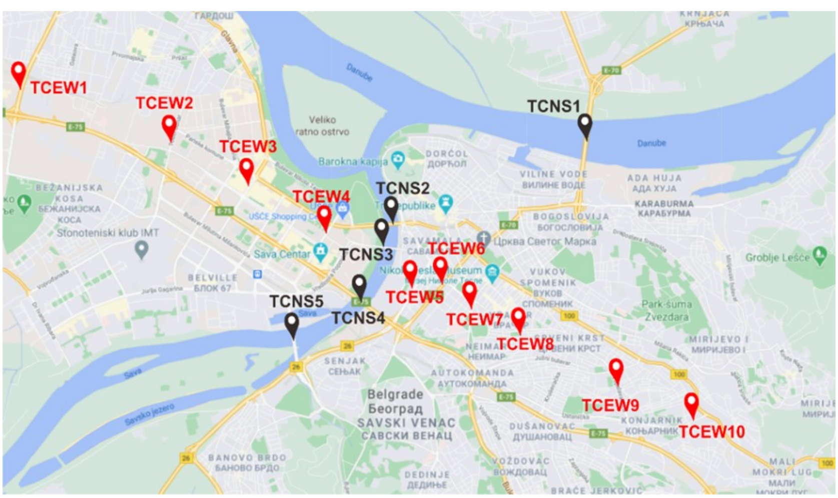

Figure 1. Research locations

The third phase of the methodology represents the implementation. The research was carried out using a manual data collection technique. For traffic counting, one researcher per traffic lane was provided at each location, while the number of researchers was modified (reduced as needed) in locations with less traffic load. One researcher per direction was provided for recording vehicle occupancy at each location. In accordance with the research methodology, traffic was counted every hour during the researched day, while vehicle occupancy was recorded for the first 20 minutes of the observed hour. Traffic flow and vehicle occupancy was recorded in relation to vehicle categories. However, since the focus of this paper is the occupancy of passenger cars, only data on the passenger car counting and occupancy will be presented in the section results. When recording vehicle occupancy, in the case of passenger cars, the researchers entered the number of persons transported in each vehicle (from 1 to 5).

The fourth phase included data entry, analysis and presentations of the results. For the needs of this phase, special software was developed in which data on traffic counting and vehicle occupancy were entered separately. The main results are presented in the following chapter.

3. RESULTS, DISCUSSION AND RECOMMENDATIONS

In this chapter, only a part of the most significant results obtained by the research will be presented, bearing in mind the existing limitations in the scope of the paper.

At the very beginning, it is important to refer to the general characteristics of the traffic flow at the analyzed locations. Diagram 1 shows the average hourly traffic flow by location.

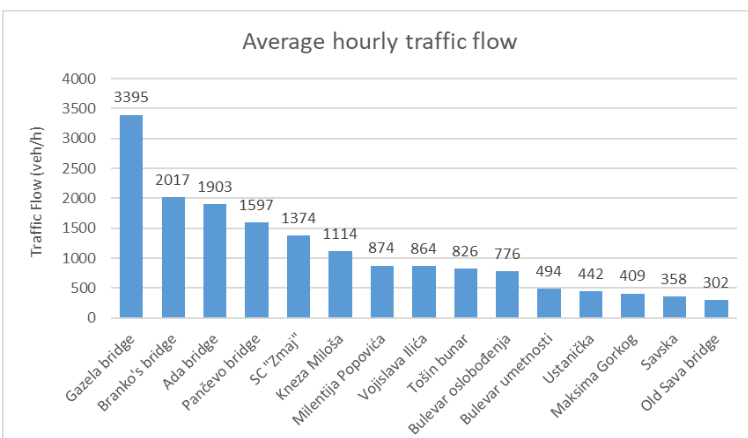

Diagram 1. Average hourly traffic flow for the analyzed locations

From the diagram, it can be seen that the bridges (with the exception of the Sava bridge) are the busiest connections, in Belgrade, with an emphasis on the Gazela bridge, which serves the largest number of vehicles during the day compared to the other locations.

Diagram 2 shows the average vehicle occupancy (AVO) by location. From the diagram, it can be seen that there are no significant deviations from the total average occupancy (1.47), except at the locations of Knez Miloš (1.73), which is also the location with the maximum AVO and Vojislav Ilić (1.64). The minimum AVO was recorded at SC "Zmaj" (1.34). What is important to note here is that locations where vehicle occupancy is higher than the overall average occupancy are actually important corridors that connect a large number of areas, that is, highly attractive parts of the city. Characteristic examples of such corridors are the locations Knez Miloš, Vojislav Ilić and Bulevar oslobođenja.

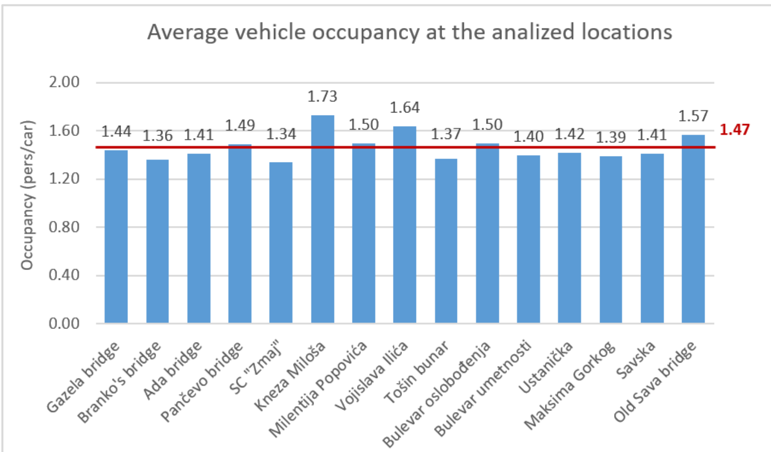

Diagram 2. Average vehicle occupancy at the analyzed locations

In order to observe some regularities, but also potential causes of differences in the AVO, the hourly fluctuations of this indicator are analyzed. Diagram 3 shows the results of AVO hourly fluctuations in four characteristic periods during the day.

The analyzed periods include the morning (7am-10am) and the afternoon peak period (3pm-6pm), as well as two off-peak periods (10am-3pm) and (6pm-10pm). From the diagram below, it can be seen that during the peak periods, a lower AVO of 1.36 and 1.39 was recorded, while off-peak periods are characterized by a higher AVO of 1.52 (10am-3pm), 1.58 (6am-10pm). Similar results were obtained in the research in Texas, where AVO of 1.49 (6am-10am) and 1.66 (3pm-7pm) were recorded, while in off-peak periods these values were 1.52 (midnight-6am), 1.78 (10am -3pm) and 1.81 (7pm-midnight) [6]. Such results are partly expected and can be interpreted in different ways, but what is worrying is the fact that during peak periods only 34% of vehicle capacity is used on average. For off-peak periods, this percentage is 39%, which indicates insufficient occupancy of passenger cars.

The previous results indicate that vehicle occupancy may have a certain dependence on the hourly traffic flow. However, on the basis of the conducted correlation analysis, a general conclusion about the existence of the aforementioned dependence cannot be made.

Analyzing the AVO by selected countries (Table 2) [7] it can be concluded that there is no apparent deviation from the total occupancy obtained in this paper (1.47). For example, the highest recorded average occupancy is in the USA (1.61), while the lowest measured value is in Denmark (1.42).

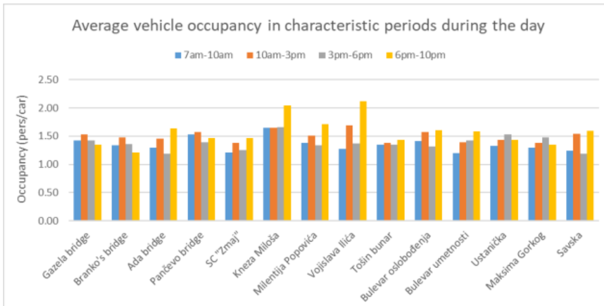

Diagram 3. Average vehicle occupancy in characteristic periods during the day

It is also interesting to note that the average occupancy of passenger cars in the EU is 1.7 people per vehicle [4], which only further emphasizes the fact that the majority of countries in Europe face the same problem.

Table 2. Passenger car occupancy by country

Country	USA	JP	CA	UK	FR	DE	IT	IN
PCO[1]	1.61	1.50	1.62	1.55	1.51	1.42	1.45	1.50

[1] PCO – Passenger car occupancy

This outcome should be used for the exchange of experiences and positive practices in order to develop the set of measures and recommendations for mitigating this problem. Table 3 shows the preliminary measures for potential solutions to overcome or at least mitigate the consequences caused by the LVO. These measures represent only a part of the general guidelines that should be further elaborated within the research.

Table 3. Proposed measures

Strategic and regulatory measures
Improvement of the existing regulation in order to provide Car pool, Car Share services, definition and use of HOV, HOT lanes.
Campaigns: about the advantages of Car pool, Car sharing services, and Public Transport, about combining tasks/jobs to avoid double trips, etc.
Personalized marketing initiatives to encourage users to plan the time and mode of travel/transport

Traffic-management measures	**Location of implementation**
Implementation of HOV lanes	TCNS 1, 2, 4, 5; TCEW 1
Implementation of HOT lanes	TCNS 4
Dynamic management of the yellow lanes in peak hours	TCNS 1, 2, 4; TCEW 7, 10
Implementation of Car pool and Car share services	City based
Road/street toll system for vehicles with an occupancy of less than 3 persons/vehicle.	City based

Strategic and regulatory measures	
Charges for entering the central city zones by vehicle	Central city zone
Increase in parking fees for vehicles with an occupancy of less than 2 persons/vehicle	City based
Reserved parking spaces at work, for users of the Carpooling system	City based

4. CONCLUSION

This paper presented the results of research conducted on 15 main corridors in Belgrade, through the analysis of two important parameters: traffic flow (traffic counting) and vehicle occupancy. Bearing in mind the various traffic problems faced by modern cities, the aim of this paper was to examine the current state of the mentioned traffic characteristics, and to propose potential solutions to overcome or at least mitigate the consequences caused by the low occupancy of passenger cars in correlation with their high presence on the street scene.

Bearing in mind the low overall AVO in the city (1.47), the measures are divided in two packages: strategic and regulatory measures and traffic-management measures, relative to the potential micro-location application. The given measures represent only part of the general guidelines that can be applied and should be defined on the basis of specific and detailed research and future strategic directions and policies of the city.

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Ivana Martinčević[1]
E-mail: ivana.martincevic@unin.hr
Predrag Brlek[1]
E-mail: predrag.brlek@unin.hr
Ana Globočnik Žunac[1]
E-mail: ana.globocnik.zunac@unin.hr
Ivan Cvitković[1]
E-mail: ivan.cvitković@unin.hr
[1] University North
Trg Žarka Dolinara 1, 48000 Koprivnica, Croatia

MOBILITY INDICATORS IN THE FUNCTION OF SUSTAINABLE MOBILITY

Keywords
Mobility
Mobility indicators
Sustainable mobility
Sustainable development

Abstract

This paper aims to explore and show the importance of mobility indicators and their connection with sustainable mobility. Mobility indicators are and should be parameters that may ensure sustainable development and approach supporting practical terms of sustainable mobility. To research and review novelties in the field of mobility indicators numerous world literature has been researched. In this research, papers within the Scopus databases were used to gather information on the research topic which shows that a large number of authors have researched the area of sustainable mobility but there is insufficient correlation and connection between mobility indicators in the function of sustainable mobility. A search of Scopus using the following approach (TITLE-ABS-KEY ("mobility indicators") AND TITLE-ABS-KEY ("sustainable mobility") resulted in 49 scientific papers. From the aspect of sustainable development, it is essential to determine mobility indicators' reliability and relevance in the function of sustainable mobility.

1. INTRODUCTION

This paper aims to explore mobility indicators, and their connection with sustainable mobility, sustainable growth, and development. To research and review novelties in the field of mobility indicators, numerous world literature has been researched. In this research, papers within the Scopus database were used to gather information on the research topic, thus showing that the field of mobility indicators has been researched by a sufficient number but not too many researchers, resulting in an insufficient connection between mobility indicators and its connection to sustainable mobility. To demonstrate the results of the research (and the scarcity of this research topic regarding the connection between mobility indicators and sustainable mobility), the results of a search of the Scopus database are presented, having led to 233 scientific papers dealing with mobility indicators, and 49 papers dealing with mobility indicators and its connection to sustainable mobility, with the observed period from 2002 – August 2023.

2. THEORETICAL FRAMEWORK

The concept of sustainable development is a key prerequisite for the growth and development of society as a whole. Sustainability has three essential areas: the environmental, the social, and the economic, and all of them are linked with transport. “The current European guidelines for the Sustainable Urban Mobility Plan (SUMP) promote a vertical (European, national, regional and local policy goals) and horizontal (sectorial and operational plans) integrated mobility planning approach based on the involvement of different target groups [1]. Managing transport activities adequately is critical in the pursuit of sustainable development [2]. “Sustainable mobility is an increasingly significant issue that both public and private organizations consider to reduce emissions by their members”[3]. A very important component of sustainable mobility are mobility indicators, while a lack of research in the field of mobility indicator is evident. An indicator is a general term used to define a parameter or to define a change within a process [4]. Silva et al. (2022) claim that a sustainable mobility system is a smart mobility "that is fully interconnected through the Internet of Things (IoT) and a seamless intermodal operation for passenger and goods transport “ [5]. Sustainable cities cannot survive without sustainable mobility [6].

3. FINDINGS

International researchers have dealt with and studied mobility indicators but a small number of them, and very few of them connect it with sustainable mobility. The focus and area of the research was the Scopus database to find data and studies that deal with mobility indicators and their connection to sustainable mobility. The first research results show results on mobility indicators, while the second step of the research presents results on mobility indicators and their connection to sustainable mobility. The first results are the results following the research approach TITLE-ABS-KEY ("mobility indicators") while the second step of the research presents results following the research approach (TITLE-ABS-KEY ("mobility indicators")) AND ("sustainable mobility"). The presented researched results are grouped into several areas according to (1) documents by type; (2) documents by subject area; (3) documents by year; (4) documents by country/territory; (5) documents by author. The first research results present an investigation of mobility indicators. This step resulted in 233 papers (articles (171 (73,4%)), conference paper (41 (17.6%)) review (11 (4.7%)), book chapter (9 (3.9%)), and data paper (1 (0.4%)) (Figure 1).

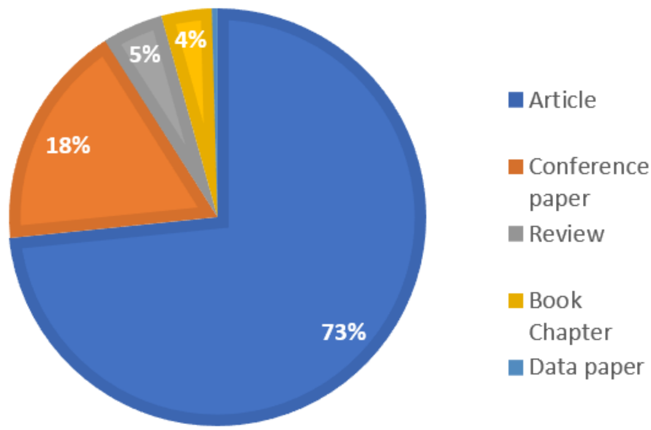

Figure 1. Documents by type investigating mobility indicators in the Scopus database (1973-April 2022) (Authors' work, 2022.)

The research area of the research topic presents the period from 1973 to August 2023 and includes various subject areas (Figure 2). Top three subject area are Social Science (21.2%), Engineering (12.4%) and Computer Science (11.6%).

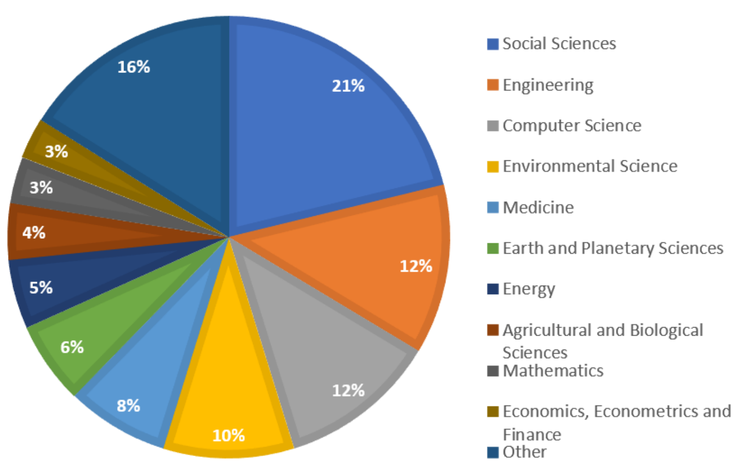

Figure 2. Documents by subject area investigating mobility indicators in the Scopus database (1973 - August 2023) Source: Authors' work, 2023.

The number of papers that investigate mobility indicators has increased in 2017 (17 papers). A growing trend is noticeable from 2015 (9 papers), 2016 (13 papers), 2017 (17 papers), 2018 (14 papers), 2019 (27 papers), 2020 (16 papers), 2021 (37 papers), 2022 (33 papers), and August 2023 (25 papers) (Figure 3).

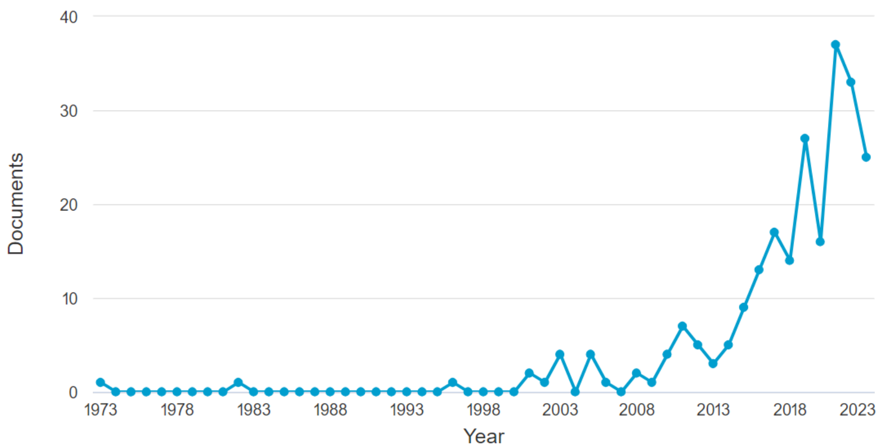

Figure 3. A number of papers investigating mobility indicators in the Scopus database (1973 – August 2023) (Authors' work, 2023.)

Top three of the research papers were from the United States (38 papers per country), China (23 papers per country), Spain (22 papers per country) (Figure 4).

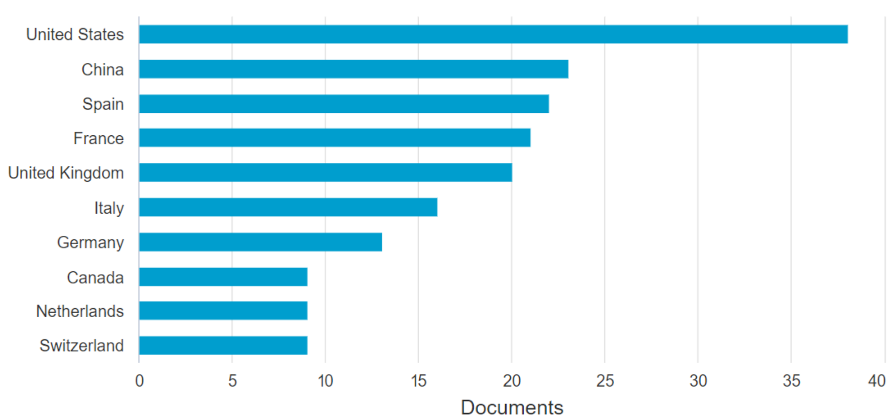

Figure 4. Country of origin of the authors investigating mobility indicators in the Scopus database (1973 - August 2023) (Authors' work, 2023)

Regarding authors who deal the most with the research topic, mobility indicators, are Shaw, S.L. and Xu, Y. (each author has 6 papers). Other authors have fewer than 4 papers that explore mobility indicators (Figure 5).

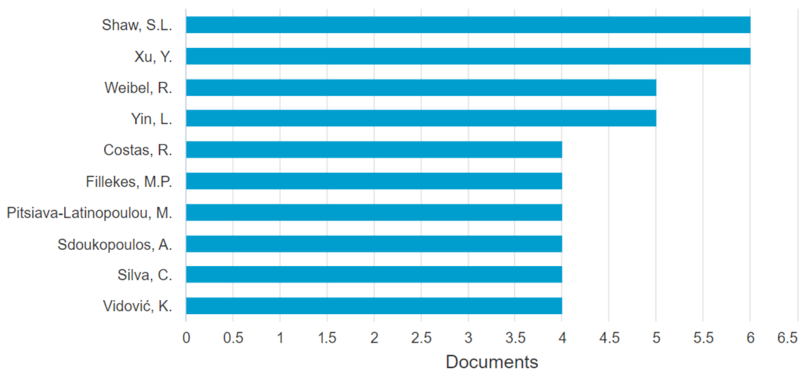

Figure 5. Documents by the author investigating mobility indicators in the Scopus database (1973 – August 2023) (Authors' work, 2023)

The second step of the research presents an investigation of mobility indicators and their connection to sustainable mobility. This step resulted in 49 papers (articles (24), reviews (18), Review (4), and Book Chapter (3). (Figure 6). The first paper that puts mobility indicators in relation to sustainable mobility was published in 2002, so the period of this research is from 2002 to August 2023.

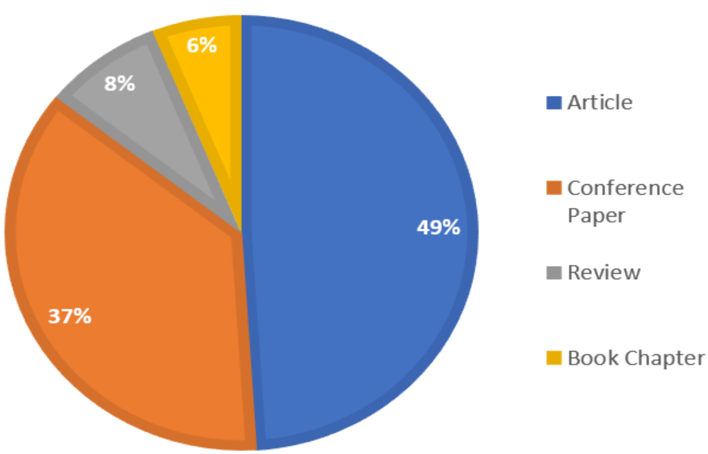

Figure 6. Documents by type investigating mobility indicators and their connection to sustainable mobility in the Scopus database (2002 – August 2023) (Authors' work, 2023)

Figure 7. presents the documents by subject area exploring the mobility indicators and their connection to sustainable mobility in the period from 2002 to August 2023 in the Scopus database. Top three areas are Social Sciences, Engineering and Environmental Sciences.

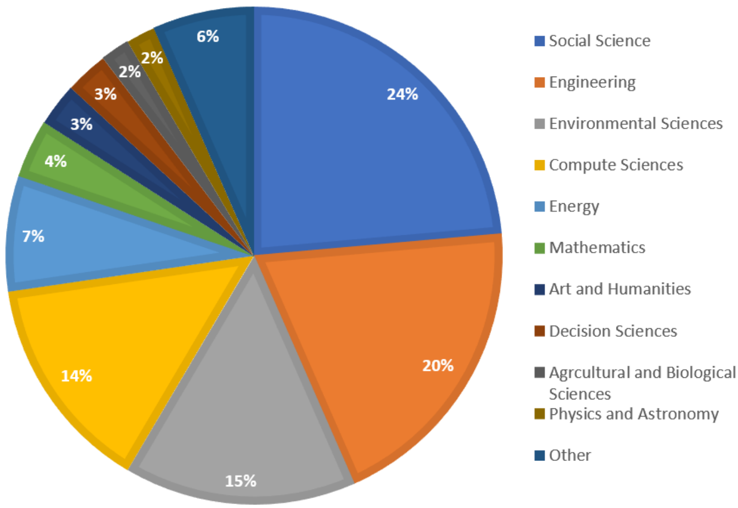

Figure 7. Documents by subject area exploring the mobility indicators and their connection to sustainable mobility in the Scopus database (1998-April 2022) (Authors' work, 2023.)

The number of papers that investigate mobility indicators and their connection to sustainable mobility has again increased in 2017 (9 papers). A growing trend is noticeable in 2019 (6 papers), 2020 and 2021 (5 papers), 2022, and August 2023 (6 papers) (Figure 8).

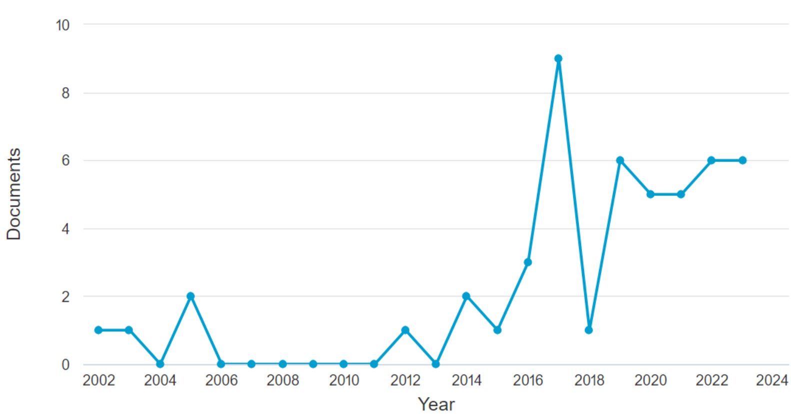

Figure 8. A number of papers investigating mobility indicators and their connection to sustainable mobility in the Scopus database (1998 -August 2023) (Authors' work, 2023.)

Most of the research papers were from Greece and Italy (6 papers per country), France (5 papers per country), Croatia and the United Kingdom (4 papers per country) (Figure 9).

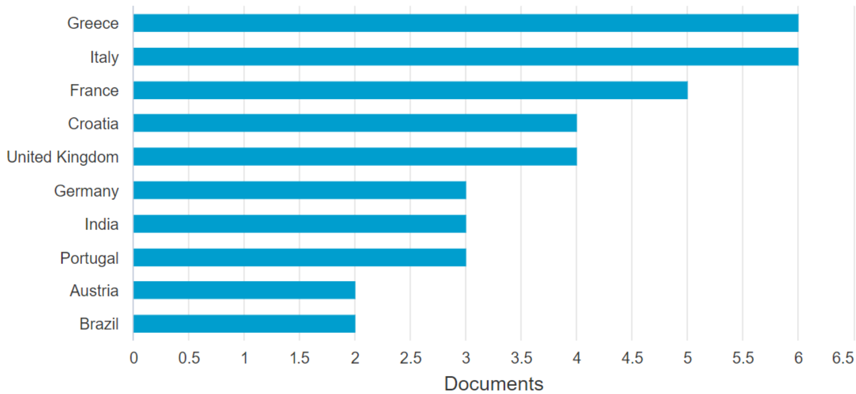

Figure 9. Country of origin of the authors investigating mobility indicators and their connection to sustainable mobility in the Scopus database (2002 -August 2023) (Authors' work, 2023.)

Authors who deal the most with the research topic and mobility indicators and their connection to sustainable mobility are Pitsiava-Latinopoulou, M. and Sdoukopoulos, A. (each author has 4 papers) (Figure 10).

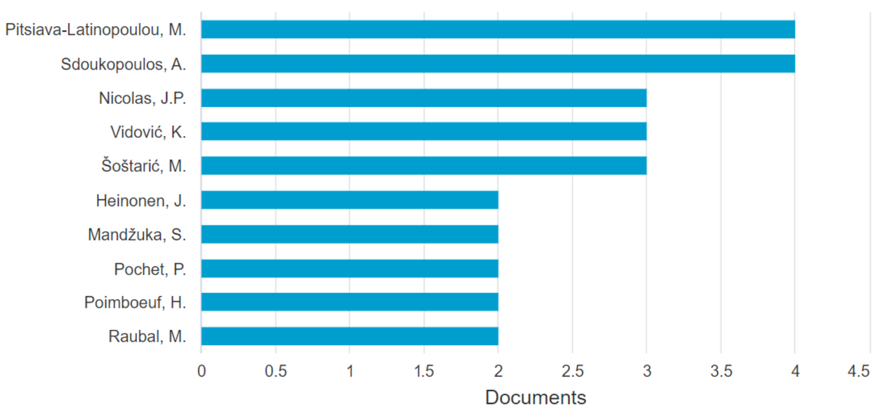

Figure 10. Documents by the authors investigating mobility indicators and their connection to sustainable mobility in the Scopus database (2002 –August 2023) (Authors' work, 2023.)

The presented research results are divided into two parts. The first part of the research presents data related to mobility indicators research, and the interest of researchers in this field in the period between 1973 and August 2023, when the first research covering this topic appeared. The second part of the research presents data that combines mobility indicators with sustainable mobility in the period from

2002 to August 2023, when the first document linked to this topic appeared. This research shows that researchers are engaged in exploring mobility indicators (233 papers, but still not enough researchers recognize and puts in connection the mobility indicators and sustainable mobility as shown by insufficient data and an insufficient focus in this area (only 49 papers through presented research).

4. CONCLUSION

This study was designed to survey articles on mobility indicators and its connection to sustainable mobility in peer-reviewed journals listed in the Scopus database. The research gains a total of 282 papers (233 of them regarding mobility indicators, and 49 of them regarding mobility indicators and their connection to sustainable mobility). This mapping considered a literature overview and had scope to review the current state and efforts of researchers in this area. The findings of this research indicate that the impact of mobility indicators in the function of sustainable mobility is an important and integral part but the area needs more empirical evidence, theoretical, and quantitative evidence, but also presents a baseline for future research.

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Maja Stojaković[1]
maja.stojakovic@fpp.uni-lj.si
Elen Twrdy[1]
elen.twrdy@fpp.uni-lj.si
[1] Faculty of Maritime studies and Transport
Pot pomorščakov 4, 6320 Portorož, Slovenia

CHALLENGES IN IMPLEMENTATION OF SUSTAINABLE PASSENGER MOBILITY IN THE URBAN CENTRE OF KOPER

Keywords

Urban passenger mobility
Sustainable transport
Urban space
Private cars

Abstract

Koper is located in Slovenia near the Italian border and is the fifth largest city in Slovenia with 53,000 inhabitants. The municipality covers an area of 303 km^2, 48% of which is protected by Natura. Since 2017, the municipality of Koper has been implementing an integrated transport strategy aimed at ensuring sustainable and environmentally friendly mobility for its citizens. To ensure accessibility and a better quality of life, pedestrians, cyclists and public transport are promoted in particular. Residents of Koper who do not live in the old town still predominantly use private cars to get to work, school, and university. Koper is an old city that has existed since the time of the Roman Republic and has many monuments. To reduce the number of cars, the city centre has been closed to traffic, and residents of Koper's old town can use parking garages or open parking lots for a small fee. For everyone else, parking lots with P+R facilities have been set up, but there is great dissatisfaction among the population. Another problem is the increasing freight traffic coming in and out of the Slovenian port of Koper. The port and the city live in harmony, but the problem of increasing freight traffic at critical times and on critical days is a big problem.In this paper we will outline the measures that should be taken in the area of public passenger transport and freight transport to ensure that the strategy is implemented.

1. INTRODUCTION

The number of people living in cities has increased rapidly in recent decades. Today, it is estimated that more than 55% of people live in cities, and the trend is increasing [1]. As a result, cities are facing the problem of urbanisation, which poses major infrastructural challenges in terms of establishing modern transportation systems in cities. The growing number of people living in cities is a major challenge for transportation planners. As the urban population grows, so do the daily trips, a large part of which are still made by car, which has a negative impact on the environment. Today, there are many alternatives to fossil fuels, but gasoline cars still predominate because they are the most affordable. As a result, car traffic is still one of the main sources of greenhouse gas and noise pollution. During peak periods, additional congestion occurs, further increasing pollution and compromising the safety of road users. Excessive use of private vehicles and insufficient use of sustainable forms of mobility are thus becoming a problem that cities are facing and trying to solve in different ways. One way to improve mobility and ensure accessibility for all is to develop a modern urban transport strategy that sets out the mobility goals that the city wants to achieve. Sustainable transportation is one that encourages the use of sustainable forms of mobility such as walking and bicycling, but also requires well-organised and efficient public transportation. In this way, the use of private vehicles can be reduced, urban road safety can be improved, and the goals set out in the strategy can be achieved. To achieve all this, it is essential to involve the city's residents in the preparation of such a strategy from the very beginning. Involving those interested groups can help decision-makers in the elaboration of sustainable mobility strategies, since they know best the problems and the real needs, and it can also help to reach more quickly final solutions acceptable to all, or at least to most, of the interested parties. This is even more important in the old cities that are not architecturally adapted to the transport needs. In this paper, we present the challenges of implementing a transport strategy in the old city of Koper, which is a historic city and at the same time a city with a modern cargo port, which brings additional challenges for transport planning.

2. URBAN TRAFFIC PROBLEMS

The rapid growth of cities has exceeded the planned framework for the development of urban transport, and the number of motor vehicles in urban transport has increased extraordinarily rapidly. The rapid increase in motorization initially brought many benefits, especially in terms of increased mobility for people, but at the same time had extremely negative impacts on the environment, as traffic negatively affected air quality in cities through emissions and noise. Air pollution is one of the biggest problems facing cities, affecting the quality of life and the health of the population. The increase in urban traffic has also led to an increase in the number of traffic accidents and fatalities on urban roads. The number of vehicles on the road, speed, the condition of infrastructure and vehicles, and driver behaviour are all related to the occurrence of accidents [2]. The space that cities must provide for parking is also a major problem. For these reasons, a key objective of modern cities is to introduce measures to reduce the use of private vehicles and encourage the population to use more sustainable urban mobility solutions.

2.1. Active mobility

Active mobility is a new trend in urban transportation planning and is therefore considered in all strategies. Active mobility is mainly defined as walking and cycling, as the promotion of these two elements brings a number of benefits to individuals by promoting a healthy lifestyle. At the same time, the implementation of such mobility can significantly reduce the share of car use in the city [3]. Although everyone knows that active mobility is better, there are still problems with its implementation, mainly because of inadequate infrastructure for pedestrians and cyclists [4]. According to [5] the cycling network should be connected to key points and attractions in the city that are easily accessible on foot and from the rest of the city. Building the right infrastructure therefore promotes active mobility as well as micromobility, especially through electric scooters, which reduces car traffic, improves road safety, and reduces negative environmental impacts. This is of great importance to the people who live there. Modern urban transport systems are now integrated with information and communication technology, which helps to further reduce pollution and congestion, and increases the safety and efficiency of the transport system without the need to build new transport routes. The idea, then, is to make better use of existing resources. Since not everyone can walk or ride a bicycle, efficient public transportation must also be provided.

2.2. Public transport

One of the solutions to reduce the number of private cars in cities lies therefore in the establishment of efficient public passenger transport [6]. Compared to private cars, public transport is much more economical, energy efficient, has lower emissions and requires little or no intervention in the environment. Bus transport is the most widespread form of public transport in cities, as it is the easiest to introduce and adapt, and is the most economical mode of transport on routes with fewer passengers. According to [7], the quality of public transport can be judged by how access to public transport is ensured for all categories of passengers, the extent to which transport safety has been improved, the standardisation of public transport and the improvement of passengers' needs and expectations, the efficiency of the public transport network, whether it allows the integration of different modes of transport (bicycle and public transport) and how it reduces waiting times for transport.

3. CHALLENGES IN THE PREPARATION AND IMPLEMENTATION OF A MODERN TRANSPORT STRATEGY IN THE OLD TOWN OF KOPER

Koper is an ancient city on the Gulf of Trieste, in the northernmost part of the Adriatic Sea. Its origins are connected with the Republic of Venice, and for many years Koper was an island. Later it was dredged and transformed from an island into a peninsula. All these basic features of the city have for a long time also determined its transport connections with the hinterland. As an island, it was connected to the rest of the island only by a road. Major changes occurred after 1957, when a port began to develop next to the old town centre. Usually, ports are built where there is the best connection to the hinterland, but this was not the case in Koper. Koper was politically chosen as a port because, according to the decision of the Osimo Agreement, the state border between the then Yugoslavia and Italy were located here. Since the port of Trieste remained in Italy, it was decided to build a new modern port also in Yugoslavia. The development of the port also shaped the image of the city of Koper and its transport links. Today, Luka Koper d.d. is a modern port that handled 23.2 million tonnes of goods in 2022. According to [8], 46% of cargo to and from the port is transported by road, with 399,291 trucks entering the port last year, or almost 1,100 trucks per day. As the city and the port are closely connected, this number of trucks poses a major problem for traffic management and ensuring sustainable mobility in the city.

3.1. Integrated Transport Strategy of the Municipality of Koper

The Integrated Transport Strategy of the Municipality of Koper is a 2017 document, which is the result of an intensive stakeholder engagement process that took place before and during the preparation of the document. During the preparation, all the specifics of the locality and the wishes of the residents were analysed and finally five strategic planning pillars were established, starting with walking, followed by cycling, followed by the use of public transport, optimization of road transport and ending with integrated transport planning [9]. The activities of each pillar carried out for the old town are already showing results. The first pillar of planning is perhaps the most difficult to realise, because the habits of the inhabitants are often different than planned. In Koper, the city centre was closed to car traffic, which initially caused great dissatisfaction among residents who were used to parking their cars in front of the house entrance. With the construction of a large underground parking garage, where residents of the city centre can buy monthly passes at a symbolic price, all cars were banned from the city centre. The second pillar follows on from the first, as the ban on car traffic makes room for the creation of bicycle lanes. Today there are about 25 km of bicycle paths in the municipality of Koper, and cycling is very popular among the population [9]. This has made Koper an efficient 15-minute city, which explained by [10] means that most daily needs and services easily accessible within 15 minutes on foot or by bicycle from any point in the city. The third pillar, which is about the establishment of efficient public transport, concerns only bus transport in the municipality of Koper. Electric buses, so-called mini couriers, have been introduced for the Old Town, providing free transportation in the Old Town, especially for elderly and disabled people who are not able to cover these distances on foot [11]. Modern buses with different capacity connect the old town with the outskirts of the city.

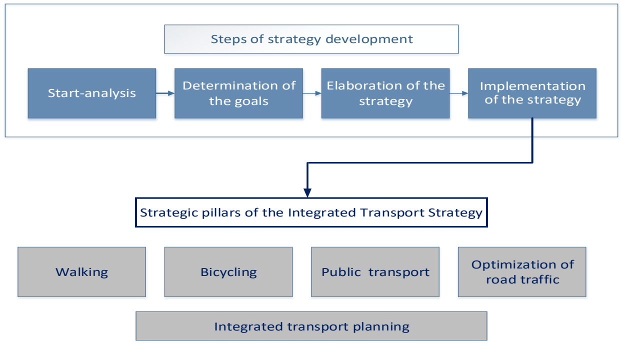

Figure 1: Link between the elaboration of the strategy and the strategic pillars (adopted from [9])

The fourth pillar - road traffic - is one of the most pressing problems in Koper, as the old town is closely connected to the port and about 1,100 trucks enter and leave the port every day. The main entrance to the port is located right next to the Old Town, and the truck terminal for trucks waiting to enter the Port of Koper is currently located right next to it [12]. By the end of 2023, the terminal will have to be moved to a new location next to the new port entrance (see Figure 2).

Figure 2: Truck terminal locations (Adopted from [8])

3.2. Challenges

In order to achieve the vision and meet the goals set in the Integrated Transportation Strategy, activities to reduce motorised traffic in Old Town must continue. This requires meeting the accessibility needs and expectations of residents, both those who live in Old Town and those who commute there daily for work, study, or other commitments. For this reason, as part of the improvement of stationary traffic, several P+R parking lots have been established, where it is also possible to purchase a ticket for the city's passenger transport system in exchange for a parking fee. This option is still underused, as residents are accustomed to driving to any office, shop or school. Two modern parking garages owned by the Municipality of Koper are now available to visitors and residents of Koper. The first is located in the city centre, under Belvedere Square, and has 466 parking spaces, while the second, Sun Parking House, with a capacity of 464 vehicles, is located at the entrance to the city, near the main entrance to the Port of Koper. In addition to the parking houses, there is a large number of open paid parking spaces, but unfortunately there are always too few of them, so new solutions have to be found in the form of more buses connecting the centre with the suburbs. At critical times (the beginning and end of the workday) there should be significantly more buses than there are now, and in the meantime there is less need for transportation. Lines should be better covered at these times, and the use of smaller electric buses could ensure that the different parts of the city are connected to the old city. If we want to promote active mobility, we need to make it possible to rent bicycles and electric bikes. Rental stations should be located near parking lots so that those who arrive by car can rent a bike and also in the old town centre, near colleges, offices, and the entrance to the port, which is a major employer of people from the broader area. However, from June 2023 a system of shared electric scooters has been implemented in the old town center. As stated by [13] and [14] promoting intermodal urban transportation modes, including public transport and active mobility, is key to developing sustainable transportation. The next challenge to be met is the cargo traffic entering the port of Koper. For the smooth operation of the port, it is essential to ensure the throughput of trucks entering and leaving the port. Care must be taken to ensure that not too many trucks block all access routes to Koper, preventing the arrival of buses and private vehicles. Therefore, a regulated access system should be established where only trucks with entry papers for the port of Koper are allowed to enter the city from a remote lorry parking lot or terminal. In this way, traffic can be controlled and, if necessary, stopped before congestion occurs.

4. CONCLUSION

Urban transportation planning faces a number of challenges stemming from the new demands for sustainable mobility, the architectural constraints of old cities, and the desires of residents and commuters. Transportation planning is no longer conceivable without the use of modern technologies, smart solutions and intelligent services. Today, it is the intelligent transportation systems that enable us to provide innovative transportation planning and management services through advanced applications of information technologies. These systems can help us solve mobility problems, increase the efficiency and fluidity of traffic, and improve traffic safety without requiring major interventions in existing infrastructure. Modern cities are striving to make progress in reducing traffic congestion, increasing control and management of emissions, ensuring the mobility of travellers and increasing traffic safety, and increasingly promoting the use of bicycles.

In this article we focus on the old town of Koper and analyse the elaboration of the strategy and its implementation. Here we can see the transition from the planning to the implementation of the mobility of the inhabitants, all activities are focused on sustainable mobility. At the same time, the Municipality of Koper is working on the implementation of other measures foreseen in the strategy and related to the urban area, such as the planning of bicycle infrastructure, pedestrian paths, sidewalks, the creation of a more efficient P+R system, the promotion of the exchange of electric bikes, etc., all with the aim of moving towards green mobility.

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Luka Dedić[1]
E-mail: dedic.luka7@gmail.com
Nikola Kožul[2]
E-mail: nkozul@fpz.unizg.hr
Karlo Babojelić[2]
E-mail: kbabojelic@fpz.unizg.hr
Luka Novačko[2]
E-mail: lnovacko@fpz.unizg.hr
[1] Prometis d.o.o.
Cvijete Zuzorić 5, Zagreb, Croatia
[2] University of Zagreb, Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb, Croatia

SUSTAINABLE URBAN MOBILITY PLAN IN SMALL SATELLITE CITIES, CASE STUDY OF THE CITY OF DUGO SELO

Keywords

Sustainable Urban Mobility
City of Dugo Selo
SUMP
Urban Development

Abstract

Rapid urbanization in the last few decades has completely changed the mobility pattern in large and small cities, with an increase in traffic congestion, traffic accidents, and greenhouse gas emissions. With the implementation of the Sustainable Urban Mobility Plan (SUMP), the goal is to reduce the negative effects of traffic and achieve a shift towards sustainable mobility in the cities. This paper presents measures included in SUMP of the City of Dugo Selo that aim to achieve a change of mobility pattern in the city, based on information and suggestions received during the citizens and stakeholder's workshops. The City of Dugo Selo represents the satellite city of Zagreb, where the population mobility activities are mostly related to commuting with private vehicles towards Zagreb. With the measures presented in the study, the main goal is to improve the use of public transport and to implement multimodality hubs for easy transfers between transport modes. Also, the study shows measures that are focused on reducing the road transit and private traffic in the city center to free up the space for pedestrians, and public and alternative transport modes to achieve positive effects in ecological and modal shift parameters. Presented work can be used as a guide for traffic planners that are developing measures for urban mobility development in smaller satellite cities of larger cities.

1. INTRODUCTION

A sustainable urban mobility plan (SUMP) is a strategic plan designed to meet the mobility needs of people and businesses in cities and their surroundings, with the main aim of improving their quality of life. In terms of the mobility situation, smaller cities and towns tend to be car-oriented communities with a low share of public transport, where getting around by car is the easiest option as there is little congestion and few parking constraints. Since many people commute to other towns for work, school, or other daily necessities, providing attractive public transport is often a challenge [1]. Dynamical urban development and inhabitant's lifestyle changes result in a continuous increase of transport needs with the effects of an increased number of vehicles on streets, increased number of accidents or exhaust and noise emissions. With that in mind, a sustainable approach to urban mobility and transport planning is becoming a crucial part of further mobility development [2].

The process of the plan development is defined by existing guidelines from the European Commission's Urban Mobility package, and it is based on eight guiding principles. Principles provide important information and focus points on which authors of the SUMP should focus to satisfy the aim and goals of the SUMP. The main goals of the SUMP should be improving accessibility and providing safe and clean mobility for the entire urban area, implementing cooperation with a wide range of departments within the city, identifying main problems and opportunities for sustainable mobility, and ensuring integrated development of all relevant transport modes while supporting a shift towards sustainable mobility [1].

2. REVIEW OF THE CURRENT STATE

A review of the current state is the main background for the evaluation of the current development of the urban part of the city. Through spatial coverage, socio-economic characteristics, and the purpose of the area analysis it is possible to predict population main generators and attractors.

The data collection methodology for the development of the SUMP was comprehensively carried out from September to December 2022.

2.1. Main information about Dugo Selo

The city of Dugo Selo is one of 34 municipalities in Zagreb County in Croatia. It is within the gravitational area of the city of Zagreb, and it is located approximately 20 km to the east of the Zagreb city center. The city covers an area of 53,94 km^2 and has a total of 17.676 inhabitants which is 5,89% of the total Zagreb County population. Based on data from the previous three Censuses provided in the Republic of Croatia, the population in the City of Dugo Selo is constantly growing which indicates a noticeable trend of urbanization of the city [3].

The street network in the urban area of the city is relatively developed and it meets the current demand. It is mostly an orthogonal network that indicates planned city development, while the outskirts of the city have certain elements of irregular network based on a “cul-de-sac” principle. The city’s business activities are oriented towards the city of Zagreb, with the main roads predominantly oriented in the west – east orientation, the same as the railway network that is one of the main transport modes in the city. It is important to note that despite east – west road connectivity, the city has primarily expanded in a north – south direction.

2.2. The characteristics of the existing mobility

Characteristics of existing mobility provide a foundation for understanding the current transportation state in the city and serve as a basis for identifying areas of improvement and future transportation planning. Data collection of the current mobility state was conducted via an online questionnaire which was available via Google Forms.

According to the collected data from a survey, the modal distribution of travel in the city of Dugo Selo indicates that over 85% of respondents who live in the city travel daily (at least 4 times a week) for work or education purposes. Among them, 68,6% use a car as their primary mode of transportation, 14,8% use the train, 13,6% utilize a combination of transportation modes, 2,2% walk, 0,6% use a bicycle or other micro-mobility modes, while less than 0,5% rely on buses for their commuting needs. The modal distribution in the city of Dugo Selo is illustrated in Figure 1.

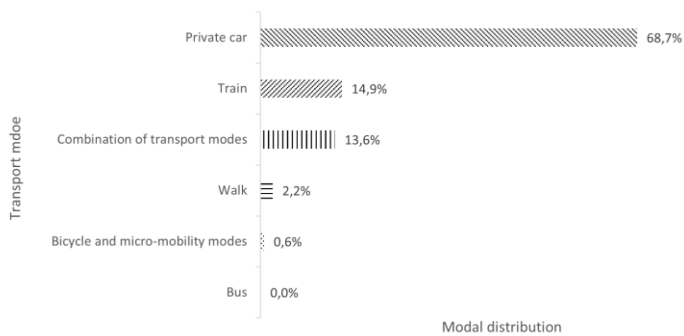

Figure 1. Modal distribution in the City of Dugo Selo

Based on the collected data, it is evident that efficient steps need to be taken at a strategic level to significantly reduce citizens’ reliance on private cars and to provide a healthy and sustainable mode of travel. In addition, it is necessary to implement additional measures that positively impact carbon footprint and reduce the number of cars relying on fossil fuels.

2.3. Existing state of road transport system

The City of Dugo Selo road network consists of a total of 144 km of road length, out of which 14,97 km (10,34%) are county roads, 20,03 km (13,83%) are local roads and 109,76 km (75,82%) are unclassified roads. The main road routes in the city are three county roads that connect the city towards Zagreb, Ivanić Grad, and Vrbovec.

Estimation of traffic volume on the road network in and around the City of Dugo Selo was based on 5-year period data from automatic traffic counters, located on the main county roads passing through the city, as well as with on-field traffic counting conducted during the work week. Analyzed data show that road traffic is constantly increasing, with small deviations during 2020 which was affected by the COVID-19 virus pandemic. The largest increase in traffic during the analyzed 5-year period is visible on counters that are located closer to the city center, which confirms the urbanization of the city.

The city of Dugo Selo does not have an implemented parking system, but it has over 750 parking spots in the city which are all free. Most of the parking spots are used by either residents in the nearby area or by the commuters that use a combination of transport modes which are using cars combined with the train.

Road safety in road traffic was analyzed using the data available from the Police Department of Dugo Selo. From the data available it was seen that in the last 5-year period there were a total of 781 traffic accidents, out of which 466 accidents (60%) were with material damage, 307 (39%) were with injured people and 8 (1%) was with death of people. With detailed analysis, 5 intersections and 3 critical crosswalks that had the largest number of accidents on the road network were classified as critical road network sports.

2.4. Existing state of public transport system

Public transport in Dugo Selo is based on two modes, rail, and bus. As shown in Figure 1., rail is commonly used by the respondents of the questionnaire, while buses have almost no passengers at all.

Rail infrastructure in the city of Dugo Selo is based on three international railways, that provide many daily departures from the main station. On workdays, Dugo Selo main station has 230 departures, with a total of 143 departures from or towards the City of Zagreb which is the main gravitational area. For the analysis of the demand, data from the operator (*HŽ putnički prijevoz)* was used. In 2017., at the Dugo Selo station there were 992.883 passengers, while in 2021. there were 691.027 passengers. Data indicates that in the 5-year span there is a 30% decline in the number of passengers which is alarming in developing sustainable travel habits.

Bus transport is currently done through county and inter-county lines, since there is no official municipal transport operator that provides service inside the city. The existing lines are operated by multiple operators, with low frequencies, old fleets, and insufficient provision of information for passengers. Also, analysis of existing bus stops in the city area revealed that many of them are inadequately equipped and poorly marked, especially those located off the county roads and main city streets. Given all the available data, the modal share of under 0,5% for bus service is not surprising and it is needed to implement strategic planning on improving public bus transport and establishing inner city lines that can provide a sustainable and reliable mode of transport for all the passengers.

2.5. Micro-mobility and walking demand

Demand for micro-mobility and walking was analyzed through a questionnaire as well as with on-field counting of traffic demand. Gathered data shows that 2,2% of people are walking daily, while only 0,6% are using a bicycle or some other type of micro-mobility. On-field data shows that the main routes for pedestrians and micro-mobility users are from Dugo Selo main station towards the city center and vice versa. Analysis of the existing bike lanes in the city has shown insufficient infrastructure with a shortage of bike lanes on main routes.

3. STRATEGY DEVELOPMENT

During the strategy development process, three scenarios were developed whose impact on traffic state were evaluated through traffic model developed in modelling software PTV Visum. Each of the developed scenarios were based on advantages and disadvantages of existing traffic state with focus on vision of future city development.

3.1. Scenario development

The first developed scenario was **Business as usual**. This scenario represents the expected development of the city if current policies and measures are carried out. This scenario does not include measures focused on urban mobility or modern types of traffic control, but it is more focused on the finalization of planned projects such as the construction of the city bypass and railways overpass. This scenario can be easily described as a scenario of the current state with minimal system changes without changes in modal share.

The second developed scenario was **Urban mobility** scenario, which includes measures with a focus on the development of transportation systems to meet existing demand, without significant implementation of sustainable mobility principles. In this scenario, there is an influence of external trends such as electromobility, but the focus remains on the private car as the primary mode of transport. This scenario includes all of the planned infrastructure interventions regarding the road network following the Spatial Plans of the City of Dugo Selo. It mainly represents the planned state of the transportation system development in the city, with the assumption of accelerated progress in road infrastructure. Also, this scenario predicts an increase in road traffic demand.

The third and last developed scenario is **Sustainable urban mobility** scenario describes the state of transport demand on the road network when implementing all measures outlined in this plan. In addition to the measures provided in “Urban mobility” scenario, this scenario includes significant changes in the transportation system of the City of Dugo Selo. Those changes include establishing a city square in the central area, creating bypass routes, developing public passenger transport, promoting cycling and micro-mobility, and focusing on the systematic development of multimodal public transportation with rail and bus as the main transport modes within the city. Due to increased investment efforts directed towards sustainable urban mobility, this scenario considers a shift in transport demand trends, favoring sustainable modes of transport.

3.2. Transport model development

For the development of a macroscopic traffic simulation model, the existing traffic model from Phase I and II of the Master Plan of the Traffic System of the City of Zagreb, Zagreb County, and Krapina-Zagorje County from 2018 was used as a basis. During the process of updating the model, a subnetwork module was used to extract the area specifically related to the City of Dugo Selo from the entire region. Traffic count data from automatic counters and field surveys were used for calibrating the traffic model. The accuracy of the model was evaluated by comparing the field-collected data with the data obtained from the simulation model. Next step of model development included prediction of traffic demand increase in the future. Using a calculation method, the projection of the demand increase on the road network is estimated for scenarios up to the year 2050. Using the average traffic growth in the previous 5-year period, AADT increase of 40,33% is expected compared to the data from 2021. Furthermore, AADT increase of 91,17% is expected in 2050, also compared to the data from 2021. Given data shows' large dependency on private cars and indicates much needed measures to control the traffic growth in the future.

4. SUGGESTED SUMP MEASURES

In 1981, Doran [4] developed "SMART" goals with aim to achieve goals that are specific, measurable, assignable, realistic and time related. In the process of the goal development for our SUMP, the main aim was to implement SMART goals that are easy to implement and evaluate during the definite time period.

SUMP goal development was based on a list of steps derived from various sources, including the data on the current state, public and stakeholder opinions, best practices in other European cities, sustainable urban mobility guidelines, and professional standards. Based on given elements, main conclusions drawn from the analysis are as follows:

- Personal motor vehicle transport is the dominant mode of transport,
- Focus on developing infrastructure for all modes of transportation, especially multimodal and sustainable modes,
- Improvement of traffic safety,
- Enhancing connectivity with the outskirts of the city and distant settlements,
- Improvement measures should be implemented for each mode of transport.

Suggested measures were separated into six groups, with each group focusing on the dedicated essentials for creating sustainable urban transport.

As a first group of measures increasing traffic safety in the city was presented. Measures included improvement of critical intersections and crosswalks, improving visibility and longevity of road markings, and conducting promotional campaigns to increase traffic awareness.

The second group of measures were focused on measures whose aim was to ensure comfortable, efficient, and available public transport with a focus on multimodality. Since analysis has shown that the majority of people use cars as their main type of transport, it was needed to implement measures to stimulate modal change. The first and the main suggested measure included establishment of local public transport with modernization of bus stops. Also, development and implementation of multimodal hubs present an important part of this group's measures. Other important goal is to introduce Intelligent transport systems into the city through measures like the digitalization of ticket purchases, prioritization of public transport on the intersections and modernization of passenger information systems.

The third group of measures focuses on improvement and extension of bicycle and micro-mobility infrastructure with the aim of increasing the number of users. Main measures include further development of bicycle infrastructure, implementation of public bicycle parking spots and introduction of bike sharing. Also, as an improvement in multimodal sector, introduction of Park&Bike and Bike&Ride services are important measures in this group.

The fourth group puts focus on walkable and safe city for pedestrians. Throughout presented measures, the goal is to improve and extend infrastructure for pedestrians and handicapped, implementation of shared space and pedestrian zones to improve and ensure safe environment for pedestrians in the city.

The fifth group focuses on clean and sustainable modes of transport. Measures presented in this group include subventions for “green” and hybrid vehicles, construction of fast chargers and parking spots for electric vehicles, implementation of ITS solutions for traffic control in the city as well as reduction of private vehicles in the city center.

The sixth and the final group focuses on sustainable road transport and parking policies. Measures include reconstruction of the city network, optimization and regulation of traffic flow, implementation parking policies led by the city, and introduction of Park&Ride and Car sharing systems that would have positive effects on the modal share.

As a final step in measure development, prioritization of measures was completed by the method of multicriteria analysis. The criteria for the ranking were based on socioeconomic benefits, costs, complexity, public and stakeholders stance and complementary with the other measures. After the process of the prioritization process, highest scoring measures were implementation of public transport lines, improving the pedestrian infrastructure and introduction of Park&Ride and Car sharing systems. Given the results, those measures were pointed out as the main priority for the future development.

5. CONCLUSION

Implementation of SUMP measures in small cities are crucial, particularly with constant population growth and increased dependency on cars. This study emphasizes the importance of implementing measures that effectively reduce car dependency and promote urban and sustainable mobility such as walking, cycling and public transit.

The study highlights the need to invest in infrastructure for multiple modes and promote multimodality, ensuring seamless integration and connectivity among different modes of transport. Additionally, it underscores the significance of enhancing safety, accessibility and convenience for sustainable transport options. To achieve the desired outcomes, it is essential to engage citizens and stakeholders throughout the planning process, incorporating their perspectives and feedback.

Implementation of SUMP measures in small cities presents great potential to reduce car dependency and to create sustainable communities. By embracing a holistic approach and implementing comprehensive strategies, cities can pave the way for a more environmentally friendly, socially inclusive and economically vibrant future.

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Mustafa Mehanović[1]
E-mail: mustafamehanovic1@gmail.com
[1] Faculty of Traffic and Communications, University of Sarajevo
Zmaja od Bosne br. 8, 71000 Sarajevo, Bosnia and Herzegovina

ANALYSIS OF THE TRAFFIC AND TRANSPORTATION SYSTEM IN THE PLANNING PROCESS WITH REFERENCE TO THE EXAMPLE OF SARAJEVO

Keywords

Planning
Traffic
Transport
Road network
Transport modes
Urban mobility

Abstract

The oversaturation of the city itself and the problems of the already existing infrastructure, which cannot handle the sudden increase in traffic dynamics and the demands of modern transportation, require a solution that should be preceded by plans. The main goal is to most painlessly resolve conflicts due to various requirements that are imposed, and they cannot be resolved by reconstructing only individual roads, but it is necessary to optimize movement at the level of the entire traffic network. Since finding the optimal solution is very demanding, it is very useful for consultants to clearly define the expertise procedure for the analysis of the traffic-transportation system. On the concrete example of the analysis of the traffic-transportation system in Sarajevo Canton in the urban area of the Canton, aspects of the expertise methodology were analyzed with the aim of defining the best solutions for existing and planned areas, and according to the purpose of the same, defining the relevant traffic parameters for planning.

1. INTRODUCTION

Planning in traffic and transportation is a specific process that determines the necessary capacities to meet the needs of traffic and transportation in the future in a certain planning area. The planning process should be linked to the design processes of traffic systems in order to make the projects more efficient. The planning process is inseparable from the design process. As a result of the planning process, a plan is created, which, depending on the period for which it is adopted, is a relatively static category.

When planning the transport system, it is basically based on the transport needs and the way in which these transport needs are solved. Thus, the flows of goods and passengers, distributed over a certain area in time and transformed into flows of train units, represent a task that the transport system needs to overcome.

Of particular importance is the choice of methodology when preparing expertise that is the basis for planning, which should provide a proposal for resolving conflicts of all types of traffic and transportation in the area covered by the plan.

On the concrete example of the analysis of the traffic and transport system in the Canton of Sarajevo in the urban area of the Canton, with a special emphasis on the narrower urban area of Sarajevo, aspects of the methodology of expertise were analyzed with the aim of defining the best solutions for existing and planned areas, and according to the purpose of the same, defining the relevant traffic parameters for planning [1-3].

2. SCOPE OF ANALYSIS OF THE TRAFFIC-TRANSPORT SYSTEM

The analysis of the traffic-transportation (transportation) system should be based on the following two basic premises (the premise from which the court starts its reasoning process) [4]:

1. The global transportation system of an area should be viewed as a multimodal system
2. The analysis of the transport system cannot be separated from the analysis of the social, economic and political system of the region.

Therefore, in the analysis of the global transportation system, the following should be observed: All modes of transportation; All elements of the transportation system; All movements through the system including passenger, pedestrian and goods flows from any origin to any destination (traffic); The total journey from the point of origin (source) to the destination (destination) by all means and by all means for each flow separately.

3. BASIC CHARACTERISTICS OF THE TRAFFIC AND TRANSPORTATION SYSTEM ESSENTIAL FOR PLANNING

3.1. Place of traffic and transportation system

Understanding the place of the transportation system in the global system is extremely important for planning. From the aspect of functionality, it can be said that the traffic and transport system is only one of many systems that enable urban areas to exist [5].

Relevant issues of planning the traffic-transportation system in the hierarchy include:

1. What is the relationship of the traffic-transportation system with other hierarchical systems acceptable from the point of view of the community?
2. What is the cause and what is the effect of investment in traffic and transportation in relation to other infrastructure systems important for community development?

3. What are the demands placed on traffic and transportation systems during changes in the urban system?

3.2. Purpose, limits and components of the traffic and transportation system

The purpose of the system according to functioning, observing only the traffic-transportation function, is reflected through mobility and accessibility [4].
Since transportation systems are parts of other systems, planners often establish a system boundary that allows them to focus on key relationships within and across that boundary. The border itself can become an important part of the analysis by exploring entrances, exits and transitions.
Multimodal transport systems consist of numerous components whose interaction becomes a key factor for system efficiency. These components include: System users; Types of transportation; Infrastructure (networks, facilities and services); Intermodal connections; Interest groups.
The challenge for traffic and transportation planning is to ensure coordination and forecasting for all of the above components to function effectively together [6].

3.3. Performance of the traffic system

The definition of a system's service offering is related to its success or efficiency realized on the basis of its performance. With simple systems, it directly depends on the level of service quality: city traffic; city transport (space per passenger); signalized intersections; sidewalks and stairs; unobstructed cycling facilities. In more complex systems, the performance is extended in accordance with the impact of the production of the service of the system on the community and the environment. The performance of the system can be presented as (Table 1) [7].

Table 1. Performance measures for environmental and economic analysis (author)

Measures performance (measure of service) / Roads	Travel speed	Driving time	Delay due to regulation	v/c relationship	Queue length	Space	Delay	Speed	Obstacle	Events	Time spent tracking	Density	Vehicles per day	Interlacing speed	Speed without	Frequency of service	Hours of service	Entry of passengers	Reliability
City streets	+	+	+																
Signalized intersections			+	+															
Unsignalized intersections			+	+	+														
Pedestrians						+	+	+											
Cyclists	+		+						+	+									
Expressways with 2 lanes								+			+								
Expressways with >2 lanes				+				+				+							
Expressway facilities		+						+				+	+						
Basic segments of the expressway				+				+				+							

Measures performance (measure of service) / Roads	Travel speed	Driving time	Delay due to regulation	v/c relationship	Queue length	Space	Delay	Speed	Obstacle	Events	Time spent tracking	Density	Vehicles per day	Interlacing speed	Speed without	Frequency of service	Hours of service	Entry of passengers	Reliability
Interweaving on the expressway												+		+	+				
Ramps and hub ramp								+				+							
Interchange ramp terminals			+																
Public transport																+	+	+	+

3.4 Capacity of the traffic and transportation system

The capacity of the transport system (the flow of people or the flow of vehicles per hour is an important factor in transport planning. The transport policy, which aims to reduce the individual use of vehicles, has led to an increase in the application of capacity utilization measures. The capacity of individual facilities or services may depend on a number of different factors, most often included in the design of facilities or services. [8]

Network and system capacity is directly related to the capacity of the "weakest" link in the network. [9] So, in planning, a lot of attention is paid to improving the flow efficiency or increasing the capacity of the aforementioned bottlenecks. Similar bottlenecks can occur at intersections, city bus stops, cargo terminals and passenger entrance areas.

Terminal capacity can be an important factor in the overall performance of a transportation system [9]. In passenger terminals, capacity can be defined as the volume at which acceptable waiting occurs.

3.5 Traffic system management

A traffic or transportation system is usually planned, designed, built, managed and maintained by organizations and individuals with different goals, mandates, positions and defined problems.

The most important mechanism of feedback to the users of the transport system is the "cost" of travel, determined on the market of the interaction of supply and demand.

A change in the cost of transportation for the user can affect the choice of route, travel time, frequency of travel and connecting trips in the short term. In the long term, these changes could affect urban form through decisions about residential and business locations, car ownership and transportation technology.

Transportation service providers are increasingly using more sophisticated management systems and advanced technologies to provide traffic tracking, monitoring and control. These types of technologies are essential for the efficient management of the transportation system, so they should be taken into account during the planning process.

4. TRAFFIC PLANNING MODEL

Forecasting traffic and transportation in the city is directly related to forecasting activities in the city. Those activities are e.g. work, shopping, recreation, selected from a set of demand activities. This set contains all city activities that an individual or household could claim and depends on socio-economic characteristics. E.g. the set of household demand activities depends on the size of the household, total income, number of employees, etc. [8]. For the travel forecast, a four-phase sequential-aggregate travel forecast model was used, consisting of phases or steps [4]: Generation of travel; Spatial distribution of travel; Visual distribution of trips - split mode; Load on the road network, i.e. assigning flows to routes.

5. APPLICATION OF THE MODEL IN AREA OF CANTON SARAJEVO

Analyzing the previous research on the road network in Sarajevo Canton according to the described procedure, the following can be distinguished [10-11]:

- The longitudinal shape indicates the need to build roads of greater capacity that will connect the city both longitudinally and along the river with the wider environment, that is, connecting with the network of European roads, an initiative of SEETO (South-East Europe Transport Observatory).

- Longitudinal roads (southern and northern) have not been completed in the area of Sarajevo Canton, so in certain parts of the city, there is a transition from longitudinal to transversal roads, which creates congestion at intersections.

- The lack of construction of primary traffic roads (longitudinal and transversal type) makes it impossible to efficiently connect all areas of the Canton into one unit.

- The discrepancy between the physical condition (dimensions, horizontal and vertical elements and condition of the roadway) and the functional characteristics of the network is also evident.

- Capacity, level of service and operating speeds are unsatisfactory on the largest part of the primary traffic network, so a good connection of several centers in the city cannot be expected.

- Intersections in the road network are mostly built on one level and are equipped with traffic lights. A special problem is the intersections built by longitudinal and transversal roads. Their capacity cannot meet the flows on the approaches to the intersection. Solutions are sought at roundabout intersections, which in certain cases can satisfy expectations for a shorter period. During the reconstruction of intersections on primary routes, it is necessary to analyze the construction of intersections in two levels in order to solve the problem in the long term.

- Road network services in Sarajevo Canton are at a relatively low level, which results in high traffic costs, loss of passenger time, traffic jams and negative impact on the environment.

The capacity of the network in Sarajevo Canton was analyzed on the cross-sections presented in (Figure 2).

Based on the analysis of the public urban passenger transport system in KS, guidelines can be given that should be taken into account during planning:

- It is necessary to optimize the routes of the lines and the location of the stops in accordance with the requirements of passengers and the standard of the maximum walking time to the stop.

- Determine transfer stops and terminals, and arrange them to provide the required level of service.

- Reconstruct the contact network of trolleybuses in parts where necessary.

- The existing public transport system needs to be: popularized; bring closer to passenger requirements; modernize; to optimize the costs incurred during the transportation of passengers.

It is important to point out that traffic parameters and norms for stationary traffic would be more reliable if a policy, plan, law and regulations related to parking in KS were prepared and adopted.

The car-restricted zone policy promotes car-free zones throughout the KS area, especially in the inner centre(s). There must be a regulatory change in the application of car-free zones. Clearly demarcated car-free zones can take the form of a complete and permanent restriction of certain streets and roads.

The offer of parking spaces should be optimized in order to meet demand and ensure the efficiency of management of parking spaces in central and commercial zones.

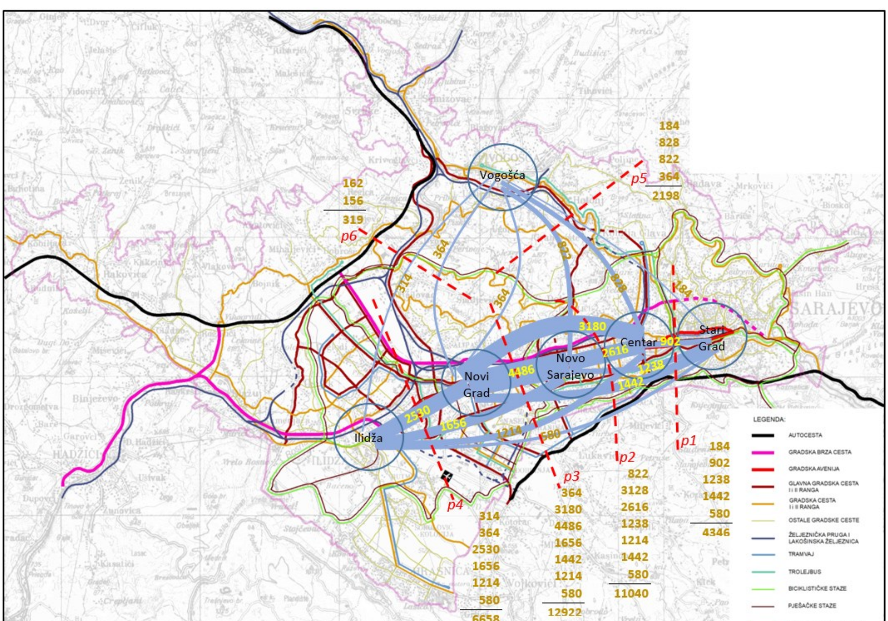

Figure 2. Analysis of the capacity of the road network in Sarajevo Canton

6. CONCLUSION

Planning in urban areas can be successful if all elements of the traffic and transportation system are included in the previous research. In doing so, it is of crucial importance to use the procedure and methods that give the best results of the analysis of the situation and assessment of the traffic and transportation demand, in order to design solutions in the area of the offer of traffic and transportation services.
For example, in the expertise for the preparation of the Urban Plan in Sarajevo, the proposed procedure gave results that lead to the establishment of a balance between demand and supply.

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Robert Mrvčić[1]
E-mail: robert.mrvcic@autotrolej.hr
Damir Pilepić[2]
E-mail: damir.pilepic@gmail.com
Goran Tovilović[2]
E-mail: gogo.tovilovic@gmail.hr
Mihael Seleš[2]
E-mail: mseles129@gmail.com
[1] KD Autotrolej d.o.o.
Školjić 15, Rijeka, Croatia
[2] Polytechnic of Rijeka
Vukovarska ul. 58, 51000, Rijeka, Croatia

TRANSPORTATION OF ONCOLOGICAL PATIENTS IN THE CITY OF RIJEKA

Keywords
Oncology patients
Patient transport
Therapy
Pilot project

Abstract
The city of Rijeka is the first city in the Republic of Croatia that in April 2023 launched a pilot project of free transportation of oncology patients from their place of residence to the Clinic for Radiotherapy and Oncology KBC Rijeka. The project was initiated in cooperation with the Communal Company Autotrolej d.o.o. and Rijeka Clinical Hospital Center. Oncology patients are a particularly vulnerable group of people who very often go to therapy and go through a long process of treatment, and along with painstaking therapy, financial problems often occur, and transportation from home to therapy is a significant problem. The goal of starting a pilot project is to care for patients and to strive to maintain the therapy process continuously in order to primarily contribute to the quality of life and the fight against malignant diseases. MC Autotrolej Ltd., which provides public transport services in the area of the City of Rijeka and surrounding local self-government units, already has experience in transporting groups of citizens with reduced mobility, given that it has been transporting people with disabilities using specially adapted vans for years. The initiative to start a pilot project resulted in the satisfaction of all involved participants, which ultimately led to the second phase of the project and the transport of patients to radiotherapy, i.e., radiation, while in the first phase it was only possible to go to the Day Hospital of the Clinic for Radiotherapy and Oncology of Rijeka hospital center.

1. INTRODUCTION

Municipal company Autotrolej for many years performs the service of the transportation of persons with disabilities within the territory of the City of Rijeka and its surrounding so it has an experience in the transportation of the most vulnerable group of patients. The pilot project of the transportation of oncological patients was developed in cooperation with the City of Rijeka and the Clinic for radiotherapy and oncology of the Rijeka hospital. With that, Rijeka became the first city in the Republic of Croatia that has ensured free transport to this group of patients. This project has started at the beginning of April 2023 and it has received positive reactions of the public sphere, as well as the patients. This project has started with the aim of facilitation of the course of the therapy for the patients that very often give up on it or they don't attend therapies regularly due to the financial situation or impossibility of the transport in the Rijeka hospital

2. THE DEVELOPMENT OF THE PILOT PROJECT OF THE TRANPORT OF ONCOLOGICAL PATIENTS

Unfortunately, the number of oncology patients is not decreasing, and the course of therapy itself is extremely exhausting for all patients. According to KBC Rijeka, between 55 and 60 patients from the area of the City of Rijeka receive oncology therapy daily. In many European countries, oncology patients are transported by taxi, while in the Republic of Croatia, transportation is still carried out independently. Many patients do not work during therapy, that is, they use sick leave if they are employed, which is an insurmountable problem in financing the cost of transportation by private car. At the same time, the City of Rijeka decided to launch a pilot project with MC Autotrolej d.o.o., which has been providing transport services for people with disabilities in the City of Rijeka for several years. The transport service is performed based on the list provided by MC Autotrolej d.o.o. delivered by the ordering coordinator of the Radiotherapy and Oncology Clinic of KBC Rijeka. Pre-bookings for transportation are made the day before in order to organize and schedule the transportation. In the first phase of the project, only the transport of patients undergoing therapy in the Day Hospital is included, and for this reason only two vehicles of MC Autotrolej d.o.o. are provided.

2.1. Transport of patients in the Republic of Croatia

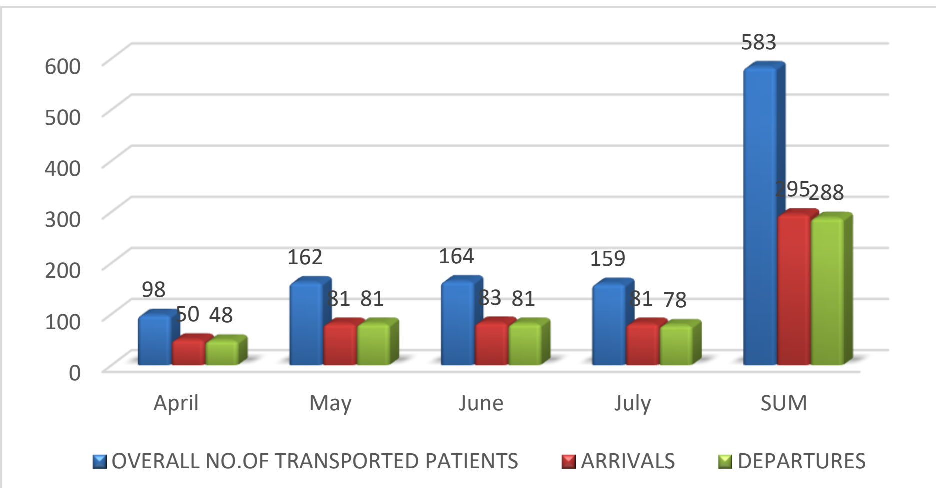
As previously stated, free oncology patient transport is a novelty in the way of transporting patients. The majority of the public believes that transport can only be carried out by means of medical transport, which differs in many details. The right to medical transport has the right to immobile, difficult-to-move persons and persons for whom it is not advisable to move alone. In addition, the insured person has the right to medical transportation to the nearest contractual entity of the HZZO, which has a contract with the HZZO and can provide the requested health care. For medical transportation, it is necessary for the doctor of primary health care to issue an order for medical transportation, which must include the name of the headquarters of the contractual entity of the HZZO and its name, whether it is a case of transportation within the place of residence or stay, to a contractual institution outside the place of residence (https://hzzo.hr/obvezno-osiguranje/sanitetski-prijevoz). When transporting oncology patients, a referral is not required, but the transportation process itself is agreed with the coordinator at KBC Rijeka, and the transportation is done "door to door". Transportation of oncology patients is organized in Zagreb and Glina, but not in the same way as in Rijeka. In 2018, the association "Nismo same" launched an initiative to transport cancer patients exclusively for therapy in cooperation with taxis. The service can be provided by women who are being treated for cancer in public health institutions in the area of the City of Zagreb and its immediate surroundings. The service can be ordered via a form on the website, via a message to an e-mail address, and via an SMS message. When performing the service, the user must sign the form she receives at the end of each ride, which serves as proof that she used the service. It is necessary to provide personal information to the association, and the transport can also be used by persons who are not at their residential address at the time of treatment and come to the transport by bus or train, after which taxis transport them to the hospital for treatment. In addition, information on the type of tumor, type of treatment, work status and family support must be reported to the Association. The service must be booked two days in advance in order to make a schedule and distribute the rides to the taxi vehicles in a timely manner. Transportation for female users is always contracted by the Association, while Radio Taxi Zagreb transports only those persons whose data it possesses and, in accordance with the contract, uses the most favorable route for the Association (https://nismosame.com/naruci-taksi/ 1.7.2023).

2.1. Transport of patients in the Republic of Croatia

In addition to Zagreb, oncology patients are transported to therapy in Glina, where the Association of St. Agata Glina organized the transport of patients for chemotherapy, radiation and controls. The transport is carried out by the members of the Association from the area of Glina and its surroundings, and the cost of fuel is financed by applying for tenders or through donations. The vehicle in which the transport is carried out was donated, which makes it much easier for the patients to get to the most common destination, which is Zagreb. At the beginning of July 2023, the transportation of oncology patients began to be carried out in Opatija in such a way that a pilot project of free transportation of oncology patients in Rijeka was launched with the joint cooperation of the City of Opatija, the company Opatija 21 and KBC Rijeka. Considering the arduous treatment for malignant diseases, transportation by private car is often too much for the patients, and this project has made it significantly easier to get to and from the hospital on your own. The transport service is provided by the company Opatija 21 based on the list delivered from the Clinic for Radiotherapy and Oncology KBC Rijeka between 8 am and 3 pm. By rebalancing the budget in May, PGŽ launched a program for transporting oncology patients to therapy from local self-government units in the county. The public call for cities and municipalities will be announced by the end of July.

2.2. Statistics on transportation of oncology patients in the City of Rijeka

In the first phase of the pilot project, which began work at the beginning of April 2023, patients were provided transportation to the day hospital where they received therapy, and after the evaluation of the first phase, the project entered the second phase from the beginning of May, where the free transportation service expanded. Patients are now able to be transported to the Radiotherapy and Oncology Clinic of KBC Rijeka, that is, patients can perform radiotherapy according to the radiation schedule. According to the available data, the statistics of the transportation of oncology patients from the beginning of the project to the end of June are shown below

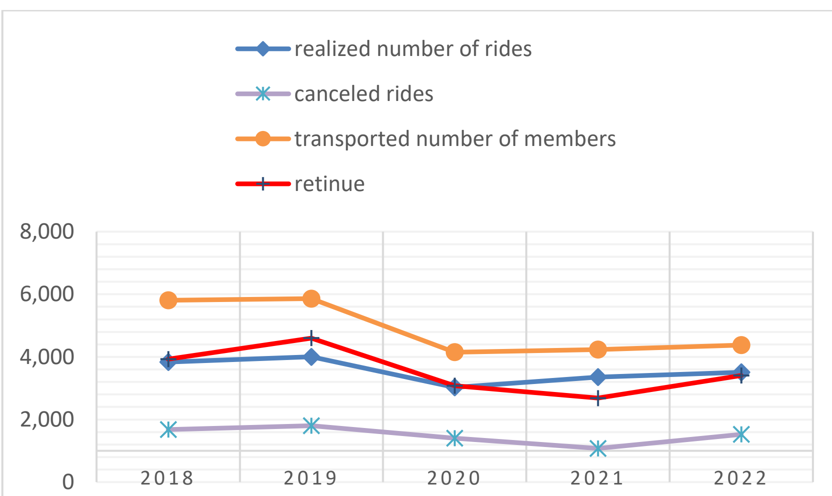


Graph 1. Transportation of oncology patients in the period from April to July
Source: internal data of MC Autotrolej d.o.o.

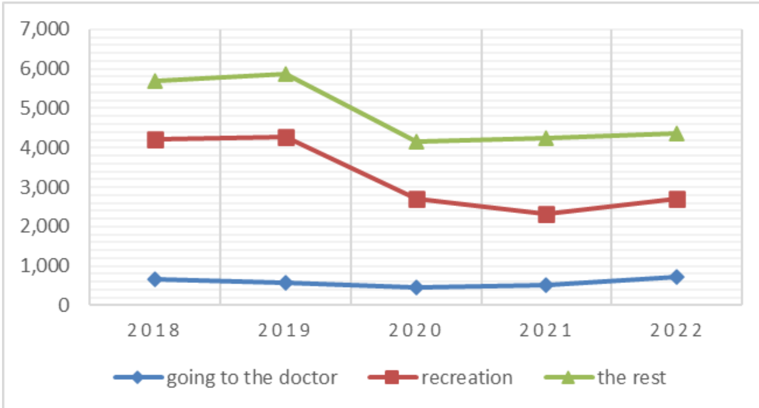
The transport of patients is carried out with two vehicles, and it is evident that 583 patients actively used the transport. The table does not indicate companions, but only oncology patients. The City of Rijeka, for the year 2023, has provided EUR 65,000.00 in the budget through the Administrative Department for Health, Social Protection and Improving the Quality of Life. The funds are intended for all transportation costs, i.e. for the maintenance of vehicles used to transport patients (obligatory technical inspection, vehicle insurance, fuel, spare parts), telephone costs, work clothes and driver's salary, and part of the dispatcher's salary, i.e. everything is regulated by the Contract . For all incurred expenses, MC Autotrolej d.o.o. issues monthly invoices to the City in the actual amount, and the stated amount is refunded. Obligation of MC Autotrolej d.o.o. is also the submission of written reports to the competent Department on the use of transport in order to prepare half-yearly and annual reports.

3. TRANSPORTATION OF PEOPLE WITH DISABILITIES IN THE CITY OF RIJEKA

MC Autotrolej d.o.o. is also the organizer of transportation of persons with disabilities in specially adapted vans owned by the City of Rijeka. Transport users are persons with disabilities residing in the area of the City of Rijeka who move with the help of wheelchairs and persons with difficulty in mobility. Transportation can only be used by persons included in the list of transportation users. For persons who do not reside in the area of the City of Rijeka, a transport contract is concluded between MC Autotrolej d.o.o. and local self-government units in whose territory the person resides and pays the agreed amount per kilometer. Transportation is only available in the area of the City of Rijeka, with the possibility of transportation to health institutions outside the area of the City of Rijeka, namely: Thalassotherapia Opatija, Thalassotherapia Crikvenica, Orthopedic Clinic Lovran, Psychiatric Hospital Lopača. When transporting people with disabilities, it is very important that drivers are familiar with assistance operations, i.e. setting up ramps on a specially adapted van. It is important to secure passengers with seat belts and help them when getting in and out of the vehicle and adjust the speed not only to the road conditions but also to the condition of the persons being transported. The following shows data on transportation from 2018, while transportation began in 1998.



Graph 2. Transportation of persons with disabilities from 2018 to 2022
Source: internal data of MC Autotrolej d.o.o.



Graph 3: Trips by purpose
Source: internal data of MC Autotrolej d.o.o.

From 2021, the transport of disabled persons is carried out with a maximum of two vehicles, while three specially equipped vans owned by the City of Rijeka are available. Graphs 2 and 3, show data from 5 years ago. It can be seen that the number of transported persons was lower in 2020 due to the Covid pandemic and the impossibility of regular transportation. In addition to persons with disabilities, the transport can also be used by their companions, who are also shown in the list.

4. CONCLUSION

Transportation of seriously ill persons, specifically oncology patients, has not yet been resolved at the level of the entire Republic of Croatia. Many patients encounter difficulties when performing therapy, primarily financial problems that are an obstacle to regular therapy. The example of the City of Rijeka is an excellent example for other cities that the problem of transportation can be solved and thus provide support to all patients. Of course, the projects need to be developed while monitoring the wishes and needs of all users, of which the plan is to purchase new vans/passenger vehicles that would be exclusively intended for the transport of patients. In addition to the help of the cities in the Republic of Croatia, it is necessary for the competent ministry to start finding a way to co-finance and facilitate the course of therapy itself, while it is planned for the Primorje-Gorski Kotar County to start co-financing the project.

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Majda Kodžaga[1]
E-mail: makodzaga@unin.hr
Ivan Cvitković[1]
E-mail: icvitkovic@unin.hr
Nives Domjan Kačarević[1]
E-mail: nidomjan@unin.hr
Katarina Stojanović[2]
E-mail: katarina.stojanovic@fimek.edu.rs
[1] University North
Trg dr. Žarka Dolinara 1, Koprivnica
[2] Faculty of Economics and Engineering Management in Novi Sad
Cvećarska 2, 21107 Novi Sad

INDICATORS OF MOBILITY IN THE URBAN ENVIRONMENT – SMART CITY CONCEPT "CITY OF VARAŽDIN"

Keywords

Mobility
Smart City
Sustainability
Traffic

Abstract

Every day we witness global urbanization that leaves mark on the environment and climate. This alone poses a challenge to numerous scientists and experts when it comes to urban planning and solving mobility problems in urban areas. In order for the urban environment to continue to develop, a sustainable transport system must be ensured. Precisely that will be showed at the example of the city of Varaždin. The indicator that will be addressed in this paper is Smart Mobility. It is extremely important to pay attention to mobility indicators in the transport sector, because they are the crucial basis for obtaining consistent and comparable data, establishing a knowledge base, establishing the possibility of communication with the rest of the environment, enabling the identification of good practice, enabling the monitoring of the implementation of projects that are being implemented as well as monitoring process of improvement and progress.

1. INTRODUCTION

The concept called "Smart City" is one of most popular concepts for the cities right now in Europe and all around the world [1]. In the very beginnings in Republic of

Croatia, especially in big cities, Smart City concept grows in popularity. As all around the world, cities in Republic of Croatia are also facing with strong structural changes which are caused by economical, political and environmental challenges. [2] We can define Smart City concept as an investment in people (society), modern ways of transport (sustainable mobility) and ICT which will have for result higher quality of life [2]. As far as is currently known, especially the concept of Smart city rests on foundations of sustainable development, respectably creating more environmentally friendly social and economical community. Within the concept of Smart city traffic and mobility are the key points for cities to function in qualitative ways. With that said, new ideas generate that can ensure better availability, safety and efficiency in city menagment. At the list of priorities cities have confirmed that becoming Smart city is their high priority. In that way they achieve numerous benefits, which some are: sustainability, efficiency, better society inclusion which automatically means better quality of life [3]. There is a six characteristics and indicators according to Colldhal [4] which refers to Smart City (Figure 1): 1. Smart Mobility, 2. Smart Economy, 3. Smart Governance, 4. Smart Environment, 5. Smart People and 6. Smart Living.

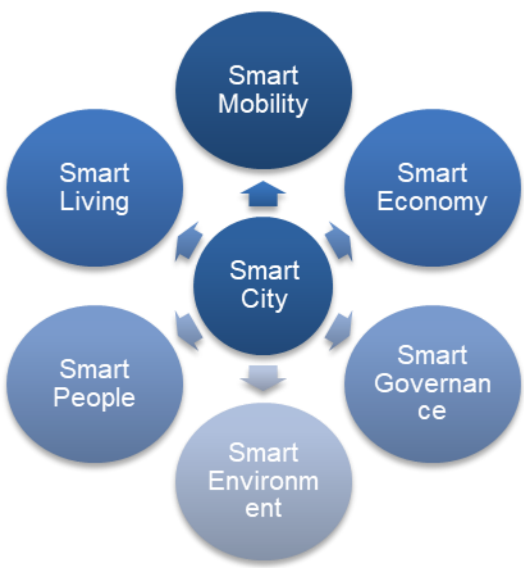

Figure 1: Smart City model - 6 characters [3]

The city of Varaždin is one of the urban areas in the Republic of Croatia that wants to be declared as Smart city. The city itself has developed the „Urban Mobility Plan of City of Varaždin – City Walk" which represents the backbone of the further development of the city within the Smart City concept [5]. Smart mobility indicators that are observed through this work are traffic, people, goods and information.

2. SMART MOBILITY INDICATOR – THE SMART CITY OF VARAŽDIN

For many years, the city of Varaždin has been investing in the development of transport infrastructure in order to achieve positive effects on urban mobility and create a desirable environment for living. Before actively taking steps to transform the city of Varaždin into a Smart City, spatial planning and strategic development documents were created, through which the characteristics within the Smart City concept were influenced, that is, in this case, Smart Mobility in correlation with Urban Mobility. The city of Varaždin has set itself the task of making walking and cycling key components of the development and development of a sustainable transport system. The mentioned types of mobility are characterized by zero emission of harmful gases as well as low costs, and at the same time they contribute to maintaining the health of the individual because they lead a more active lifestyle.[6] Smart Mobility at this point means the area of a Smart City which representing Smart Mobility and broadly defined, the components which comprise not only the traditionally understood transport of people and goods, but also the dissemination of information by digital means. The main role of the Smart Mobility indicator area is to connect all the city's resources [7]. At this point Smart Mobility indicator means people, information and goods [7].

2.1. The current state of smart and urban mobility in the city of Varaždin

In the last few years, the city of Varaždin has been investing significant funds in the development of bicycle and pedestrian paths, which is certainly justified considering that they are working on the Smart City concept under the Smart Mobility component. Varaždin is one of the important destinations for daily trips and is one of the few cities in the Republic of Croatia that has an established public transport system. The city has developed an urban mobility plan, which outlines the current state of the city in terms of mobility and traffic safety when it comes to pedestrians and cyclists, as well as bus transportation [6]. In the Urban Mobility Plan, the city of Varaždin covered every segment of traffic, including city logistics and traffic safety, as well as environmental and nature protection, as well as the public and private sector in terms of service providers which indicates that the Plan covers every segment of sustainable development and that the city is really moving towards a "Smart City". In 2017, an analysis was carried out in the Plan, where Šimunović and his colleagues presented a conclusion in which it is emphasized that it is necessary to pay attention to the quality of existing sidewalks, lighting, and that it is necessary to carry out an analysis of the curbs that are part of the city streets because they represent a potential danger and prevent safe movement through the city [5]. It is stated that the bicycle paths are not sufficiently well connected to each other, but also that there is a very high level of danger to cyclists from motor vehicles [5]. In support of this, traffic accidents are one of the "typical" Smart City factors that traffic experts deal with when it comes to the Smart City concept, because through it they try to reduce them, as well as reduce the traffic jams caused by them. In this case, the analysis of road accidents revealed that there were no fatalities in road accidents where cyclists were involved, but there were those who were seriously and lightly injured, while in road accidents where pedestrians were involved, 1 person died, and the most common reason was inappropriate speed of a motor vehicle (collision with a pedestrian).[5] Namely, in 2017, a traffic count was carried out in the city of Varaždin at characteristic points, and in the same year the "Urban Mobility Plan of the City of Varaždin - City walk" was drawn up, then the count was carried out at the same characteristic points (12 of them) in 2023, when Evaluation of the said Plan was carried out, which showed the current state of the city of Varaždin in terms of urban mobility. The obtained results are shown in table 1.

Table 1. Comparison of peak loads in 2017 and 2023 on the traffic network of the city of Varaždin [6]

	Street	Peak load 2023 (EJA)	Peak load 2017 (EJA)
1.	Koprivnčka street (before crossroads with Međimurska)	7436	9650
2.	Međimurska street (before crossroads with Koprivnička)	12210	12703
3.	Optujska street (around house number 67)	14337	10358
4.	Brače Radića (at the old entrance to the hospital)	9328	8880
5.	Jelkovečka street (around house number 89)	5247	5351
6.	Zagrebačka street (at the Hyundai saloon)	14850	12806
7.	August Cesarec street (at the park)	11594	7928
8.	Preradovićeva street (at the gymnasium)	1991	6332
9.	Preradovićeva street (at the street market)	5390	4582
10.	Vrazova street (at the McDonalds)	12936	12786
11.	Zrinski i Frankopana street	12980	13358
12.	Gospodarska street (at the Vindija)	14135	-

The table shows that in certain parts of the city there was an increased load compared to 2017 for example Zagrebačka street and Optujska street. Also, increase is visible on the first city ring, and is especially noticeable in Augusta Cesarca Street. The plan defines the goals and measures that need to be implemented in order to contribute to the realization of the Smart City concept in the

Smart Mobility component, and the goal that is observed through the work is: "Increasing the attractiveness and quality of non-motorized traffic". In this case, the planned measures for the fulfillment of the stated goal were: preparation of the elaboration of the expansion of the pedestrian zone and incorporating the bicycle infrastructure and defining the stages until 2026.; draw up an elaboration of the construction and renovation of pedestrian routes and define the stages until 2030; create a traffic study of the bicycle network, within which the phasing of the addition and expansion of the bicycle infrastructure and network will be defined until 2030; preparation of the elaboration of the construction and renovation of pedestrian routes and define the phasing until 2030 (completed); preparation of the elaboration of the bicycle network, within which the phasing of the addition and expansion of the bicycle infrastructure and network will be defined until year 2030. preparation of studies on the introduction of a bicycle service system on call, implementation of campaigns with the engagement of an external specialist contractor (completed), regular replacement of old and installation of new lighting fixtures with LED technology (completed) and implementation of campaigns with the engagement of a public expert [6]. Only 3 measures were implemented, which was not enough to reduce motorized traffic and increase non-motorized traffic.

2.2. Proposals and measures for a more sustainable and smarter city

Given that the "Urban Mobility Plan of the City of Varaždin - City Walk" has defined goals that aim to influence the creation of more sustainable traffic (zero emissions, low costs), based on the previously presented data, it is evident that additional measures should be taken, i.e., measures should be implemented to fulfill general and specific goals defined by the Plan [5]. However, it was noticed that the measures and objectives of the Plan were not defined precisely enough, although the measures around the objectives were precisely formed. Taking into account that one of the defined goals is: "Increasing the attractiveness and quality of non-motorized traffic", based on the data from Table 1, it can be seen that not much has changed in this direction, considering that motorized traffic has increased significantly in certain previously mentioned sections [6]. In order for the given goal, which is actually a combination of measure and goal, to be fulfilled, it is necessary to define it more clearly, as this will facilitate the implementation of the planned measures. If the stated goal could not be met, it is suggested to count the traffic more often in order to get a more precise picture of the real situation, if all the proposed documents as measures to fulfill the goal could be prepared as high quality as possible and obtain concretely visible results.

3. CONCLUSION

The city of Varaždin is one of the few cities that has prepared the necessary strategic documentation that supports the Smart City concept and achieves it. Since the aim of the work was to show whether anything is being done in the City of Varaždin regarding the characteristics related to the Smart City concept of Smart Mobility, it is evident that it is being done. Significant funds are allocated by the City to improve the transport system in order to meet the goals prescribed by the strategic documents and thus realize the Smart City concept. For now, it is still necessary to implement a large number of prescribed measures in order to improve the current situation and increase the sustainability of the transport system. This is indicated by the presented data on the number of motorized traffic as well as the number of traffic accidents involving non-motorized traffic. In the spirit of environmental awareness, but also of human health, it is necessary to implement measures primarily closely related to non-motorized traffic, and then also to motorized traffic, which will at the same time meet the conditions of the Smart City. The city of Varaždin has good prerequisites to become a Smart City in the full sense of the word in the foreseeable future.

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Marta Cvijan[1]
E-mail: marta.cvijan@gmail.com
Ivan Ivanović[2]
E-mail: i.ivanovic@sf.bg.ac.rs
Dragana Petrović[2]
E-mail: d.petrovic@sf.bg.ac.rs
Vladimir Đorić[2]
E-mail: v.djoric@sf.bg.ac.rs
[1] Transfera – Transport and Logistics, Savski nasip 7,11070 Belgrade
[2] University of Belgrade - Faculty of Transport and Traffic Engineering
Vojvode Stepe 305, 11000 Belgrade

TRANSPORT POVERTY IN URBAN MOBILITY PLANNING

Keywords

Transport poverty
Sustainable urban mobility
Transportation planning

Abstract

The development of the "Transport poverty" concept is based on availability, accessibility and affordability analysis of different transport options. Provided level of transport quality by proposed transport options is also considered, especially for certain categories of transportation system users. In addition to transport system quality parameters application of this concept also requires good quality databases on travel patterns and socio-economic characteristics of the population.

The current challenges facing the transport system can be treated by sustainable urban mobility planning. Air pollution emissions as a result of traffic, increase negative impact on health of urban residents and climate change. Insufficient level of analysis detail, wrong approach and lack of participative approach in urban mobility planning could lead to transportation system that is not custom-made for users. In this sense, the application of the Transport poverty concept would improve the quality of existing practice in the urban mobility planning.

This paper presents the essence of the concept of Transport poverty, as well as the possibility of integrating the basic postulates of this concept into the planning of sustainable urban mobility.

1. INTRODUCTION

The right to freedom of movement, education, and work should be equally ensured for everyone. Considering that these activities are often spatially dispersed, one of the key preconditions for fulfilling this is the ability to move or travel. Without sustainable and accessible transportation alternatives, people can be excluded from job opportunities, healthcare, social connections, and may be disadvantaged when it comes to shopping or accessing cultural activities, which all significantly affects their quality of life.

The definitions of transport poverty vary, but most commonly used is: Transport poverty is a state in which people are prevented from participating in the economic, political, and social life of the community due to reduced accessibility to opportunities, services, and social interaction [1].

Individuals are considered transport poor if they meet at least one of the following conditions: they have no transportation alternative that suits their needs; they cannot reach their destinations to fulfill their daily activities such as education, healthcare, and work; their weekly transportation expenses exceed the poverty threshold; travel time is long; travel conditions are unsafe, dangerous, or unhealthy.

The major factors that contribute to transport poverty include location, age, budget, and economic opportunities, making them "key indicators of transport poverty". Various approaches have been proposed regarding accessibility, affordability, mobility, and external effects criteria, which enable a more comprehensive understanding of the concept of transport poverty [2].

2. TRANSPORT POVERTY, TRANSPORT AFFORDABILITY, MOBILITY POVERTY AND ACCESIBILITY POVERTY

The following terms are presented to contribute to a better understanding of the concept Transport Poverty (Figure 1).

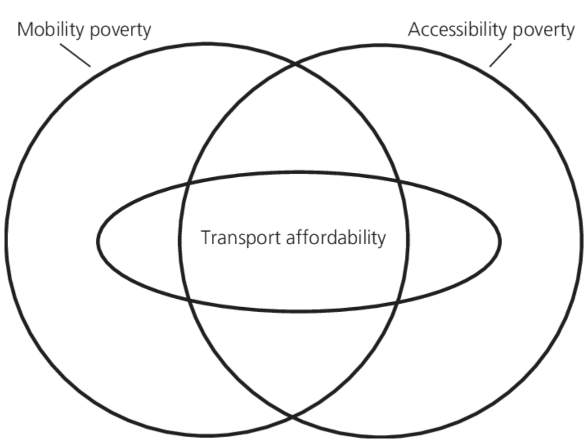

Figure 1. Transport poverty and related sub-concepts [3]

The definition of transport poverty, through ***transport affordability***, which identifies car ownership as a basic household necessity, is only relevant within the context of hypermobility in developed countries. One interpretation is that transport poverty occurs when a household is forced to spend more on travel than it can reasonably afford, with particular consideration given to the costs associated with owning and using a car [4].

While the concept of transport affordability relates to the lack of individual resources to afford transportation needs, ***mobility poverty*** relates to a systemic lack of transportation and the absence of transport alternatives. In this case, there is a proven correlation between low income and mobility poverty. Larger investments in infrastructure generally do not cater to the needs of the poorest, as investments in transportation, backed up by economic growth, "'tend to benefit the 'non-poor' most".

Accessibility poverty extends the concept of mobility poverty through additional considerations of whether people can easily reach their basic daily activities within a reasonable time and at reasonable costs. In developed countries, accessibility poverty has played a useful role in identifying social groups that lack the basic resources to be able to access key activities with the aim of improving their living conditions. If transportation is understood as a means to satisfy needs and rights, accessibility poverty acts to reproduce general conditions of poverty and is closely linked to social exclusion [3].

Transportation is considered an essential service, alongside water, energy, sanitation, financial services, and digital communication, to which everyone should have access, and thus, support is necessary for those without access [5].

One of the main barriers to better understanding the issue of transport poverty is the level of the available data required to research the problem in any meaningful and geographically specific way. Gathering such data is both time-consuming and costly, as it demands detailed analysis [6].

The population groups most exposed to the risk of transport poverty are individuals with low income, women, the elderly, persons with disabilities, and young people.

Individuals with low-income travel less, have low level of car ownership, walk more, and use public transportation more than those with higher incomes. Women face more barriers when accessing transportation, especially among groups with low income, leading to social exclusion. For many women, personal safety, due to fear of traveling alone, is a significant obstacle to using local transportation services.

The older population is considered one of the most vulnerable and largest groups without access to public services due to reliance on public transport. Older people with low incomes, who lack access to a car, face constraints and physical difficulties that limit their ability to access public transportation and travel longer distances.

Difficulties with accessibility, boarding, and moving by public transport, feeling unsafe, and walking long distances have become a huge barrier to transport accessibility, and thus transport poverty among individuals with disabilities.

Children and youth are greatly exposed to the risk of transport poverty, especially in low-income areas and family communities with low socio-economic status. Transport affordability gives young people a sense of community and independence. Access to safe and affordable transportation is also essential in providing employment opportunities for young people [7].

3. MEASURING THE EFFECTS OF LIMITED ECONOMIC AND PHYSICAL ACCESSIBILITY TO THE TRANSPORTATION SYSTEM

The phenomenon of transport poverty can be measured within any population group or area. Some of the indicators considered are those identified in the literature as useful for measuring various dimensions of transport poverty. Indicators are specific and depend on the characteristics of the transportation system, land use, and area characteristics.

Measuring transport affordability refers to actual transport expenditure as a share of income, where it is proposed that households spending more than 10% of their income on transportation be defined as "transport poor”. This approach neglects the concept of "suppressed transport demand" and the fact that, in developed countries, wealthier households spend more on transportation. When measuring the affordability of transportation services, it is important to consider other poverty indicators and consumption averages for similar households or areas, which entails combined housing and transportation costs.

Three variables commonly used to measure mobility are: *trip generation* - measuring the number of trips a person or household makes during a period of time; *travel distance* - besides measuring mobility, it can also be used as an implicit measure of accessibility; *travel duration* - which depends on network characteristics, the mode, etc.

Measuring accessibility include additional considerations about whether people can easily fulfil their basic daily activities within a reasonable time and at reasonable costs. It always considers the location of the "opportunities" that people want to access and the "separation" between people and those "opportunities”.

Various studies emphasize the need for comprehensive and sophisticated research on mobility, which takes into account various aspects of individual needs across a broad spatial spectrum where they live and perform their daily routines. Authors highlight the importance of considering geographical factors, socio-demographic characteristics, daily activities, physical and cognitive abilities, as well as environmental conditions. However, collecting such complex data poses a challenge, especially in developing countries [2].

There is no single initiative that can reverse transport poverty. Strategies that include data analytics, equity in planning, mobility as a service, ticketing and congestion charging need to be defined. Focusing on transport equity (based on race, income, elderly, and youth) is an important goal to reduce the effects of transport poverty and it should be a measurable outcome, with strategies to address transport equity in their communities [8].

4. ECONOMIC ASPECT OF ACCESSIBILITY IN TRANSPORTATION SYSTEMS IN RURAL AND URBAN AREAS

Many poor individuals in rural areas are isolated due to factors such as distance, terrain, unemployment, economic conditions, market, healthcare, and education. The lack of basic infrastructure (roads, bridges) and limited access to transportation services make it difficult for poor individuals to access markets and services.

Recent research has shown that investments in transportation systems tend to benefit the "non-poor" the most and that investments must be consciously designed to avoid further impoverishing poor people. In cases where investments in the transportation system have stimulated economic growth, the poor often had minimal benefits because they have not had the resources to take advantage of the opportunities afforded by better access. Good transportation infrastructure is a necessary condition for economic growth and poverty reduction, but investments in the transportation system alone cannot solve the problems of the poorest households [9].

There is ample evidence that building roads (and/or paths and pedestrian bridges) to connect rural communities to the road network provides numerous benefits and reduces the number of people in extreme poverty [10].

Interventions in urban areas largely address the issues of urban congestion and the rapid increase in motorization rates, benefiting primarily the middle-class population. Poor community can also benefit from these changes, although it is often the reverse case, especially with the construction of new roads, separation, and relocation. Urban growth and suburbanization lead to longer commutes and increased motorized travel, causing congestion and more complex travel patterns. Public transportation becomes increasingly challenging to maintain, resulting in greater dependence on cars and increased difficulties for those without access to a car.

Despite significant road construction, congestion worsens, and average traffic speeds decline. Congestion affects all participants in traffic, and poor individuals often have to walk or use low-quality transportation alternatives. Solutions for congestion, including high-capacity urban roadways, can be extremely expensive. While the construction of rural roads can directly benefit poor community members, interventions in urban transport (new roads, metro systems, bus rapid transit) are often designed to reduce urban congestion and may disproportionately benefit wealthier segments of the population compared to the poor if not properly designed [9].

Consideration should be given to the sources of transport-related income (such as congestion charges, fuel taxes, etc.) that could be used to invest in ensuring equality in the provision of the transportation system for all user categories.

5. WORLD AND EUROPEAN PRACTICE EXPERIENCES

China's economic growth has led to much higher incomes for its population but has also resulted in inequality among the population, which poses a significant barrier to economic, social, and environmentally sustainable development. A review of studies on transport poverty in Chinese cities has concluded that the most common causes of transport poverty include a lack of access to private cars, uneven access to transportation alternatives, inadequate public transport, and imbalances in urban structure. The main impacts of transport poverty include limited mobility and longer travel times, higher household travel expenses, reduced access to jobs and basic services, health, and environmental issues [11].

In Norway, in the region of Oslo, accessibility to private cars and public transport has been studied, as well as the difference in accessibility between these two modes of transportation. The difference was calculated as the public transport time competitiveness compared to a private car as a means of commuting to work. Public transport time competitiveness is an important factor in sustainable transport and the transition to low-emission mobility. However, absolute levels of accessibility are more important in interpreting social exclusion and transport poverty. It was concluded that wealthy areas have better public transport time competitiveness for commuting to work. It was noticed that families with children tend to reside in areas with low time competitiveness of public transport for job access.

When it comes to employment, low-income neighborhoods experience a lower level of public transport time competitiveness. This means that if the use of cars decreases due to increased costs, these neighborhoods will likely suffer from greater transportation poverty. This suggests that a shift towards low-emission mobility will require addressing various challenges and specificities [12].

Over the past decade, a significant increase in bus and rail ticket prices in Wales (United Kingdom) had the most significant impact on residents relying on public transport and those with low incomes. Although all households feel the effects of rising costs, households with low incomes are the most affected. Increasing transport costs already play a significant role in separating a larger portion of income to transportation needs [13]. Research shows that more than three million people in the north of England are at risk of social exclusion, prevented from participating in the opportunities and communities, as a result of poor transport services (mobility and connectivity). Citizens in the south of England can access up to seven times as many jobs by public transport [14].

6. CONCLUSION

The application of the Transport poverty concept would certainly improve the quality of existing practice in the urban mobility planning. It is crucial to gather the necessary data and establish a good quality database regarding the characteristics of the transportation system and the socio-economic characteristics of the population. It is important to investigate what level of transport service quality is available to different categories of residents. Existing travel pattern survey methods need to be supplemented with questions that provide insights into various aspects, including the percentage of income that an individual/household spends on transportation, ownership and use of private cars, the ratio of trips made by private cars versus public transportation, travel times, etc. Special attention should be given to the problems like: capability to collect real data on individual/household incomes and travel expenses, and more precise travel times using different modes.

The analysis should also incorporate changes in fuel prices, public transport ticket prices, parking costs, and potentially market prices for purchasing private cars. It is implied that questionnaires include inquiries about household income, motorization levels, possession of driver's licenses, as well as the proximity of the nearest public transportation line, the existence of public transport lines to locations of daily activities for individuals, any difficulties individuals may encounter in mobility and performing daily activities, and similar factors. Through the proposed detailed analysis, it is possible to assess the quality of service for different spatial areas and different categories of residents, and subsequently propose specific measures that could potentially contribute to reducing transport poverty.

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Andree Woodcock[1]
E-mail: A.Woodcock@coventry.ac.uk
Institute for Creative Cultures
Coventry University, UK.

HOW CAN AN UNDERSTANDING OF MOBILITIES OF CARE LEAD TO MORE HUMANE CITIES?

Keywords

Gender
Humane Cities
Mobilities of care

Abstract

This paper draws on a literature review of 27 international papers on ‘mobilities of care’. In this paper, the concept has been expanded to include the mobility of any person(s), of whatever age, who look after someone or perform caring tasks (e.g., elder relative, child, partner or friend). The approach and findings from these papers is of crucial importance to future transport planning and the design of ‘humane cites’, providing compelling evidence of the continued lack of transport provision to support such journeys, and the effects of the resultant transport poverty on the lives of the carers and the cared for.

The paper argues that the lens of ‘mobilities of care’ provides an opportunity to break away from technocentric approaches to the design of ‘smart humane cities’ to ones which are built around principles of caring for citizens and are truly humane.

1. INTRODUCTION

‘Care work can be defined as the unpaid labour performed by adults for children and other dependants, including labour related to the upkeep of the household’ [1]. The concept of ‘mobilities of care’ has been transformative in understanding and responding to the travel experiences and needs of (primarily) women and young children. It was developed as a counterpoint to mobility ‘for paid employment’ which was designed around the needs of the chief, usually male ‘breadwinner’. It can be used to include many activities previously described as ‘other’ or ‘recreational’ in transport surveys such as shopping, visiting, chauffeuring and escorting duties. Classifying journeys as ‘other’ trivializes their signifance, and leads to gender bias. Care related journeys are not only undertaken more by women, but actually form a substantial amount of everyday journeys. For example, [2] estimates that 32% of women’s daily mobility and 25% for men’s mobility is care related.

Cresswell [3] argues that researchers “ … have developed ways of telling us about the fact of movement, how often it happens, at what speeds, and where.” This type of analysis does still predominate, e.g. in surveys, traffic counts, collection of bigdata. But it provides little information on how transport contributes to a humane city, especially as data can be used to reduce certain services.He continues “Recently, they have also informed us about who moves and how identity might make a difference”. Qualitative approaches developed and favoured by feminist transport geographers and social scientists enable us to understand individual journeys and micromobilities. They provide insights into what travel involves, means and its role in human life. Yet such studies are undervalued.

In delivering against green mobility, technology roadmaps (e.g. [4]) a powerful technological push has been created for R&I to achieve zero fatalities, reduce carbon emissions and congestion, increase efficiency, and implement shared and autonomous transport systems. The role and investment in social science and human centred design in such projects is limited. Technology has become an end in itself, rather than an enabler of humane smart cities (which should encompass smart living, smart people, smart governance, smart mobility, smart environment, and smart economy and smart social inclusion). In delivering safer, regenerative, sustainable and fairer cities, local authority employees receive little support in overcoming the challenges in applying sometimes unproven technological solutions to improve transport, whilst at the same time keeping the city working, and making structural organizational changes to overcome silo mentalities and lack of trust [5].

Costa and Oliveira [6] amongst others, stress the need to address the right question in the design of ‘humane smart cities’ i.e, Who is at the centre of our research efforts; is it people or technology in all its guises (e.g transport, sensors, cameras)? Transport has transformed the design of cities, leading to spatially segregated areas (e.g.residential, employment commercial, entertainment, education) which necessitate travel. This has created many of the problems that urban dwellers are subjected to e.g. stress, pollution, congestion, accidents. R&I investment seeks to address these whilst at the same time supporting new forms of personal vehicles for ‘privileged users’. The EU funded TInnGO project (https://www.tinngo.eu) aimed to create a paradigm shift to enable gender sensitive smart transport solutions, in this, [7]’s media analysis of the automotive industry’s portrayal of smart cars showed a lack of representation of diversity (e.g. women, ethnicities, people with disabilities) or public transport. Inclusive transport, and the needs of real people are not featured prominently in future scenarios except in the most idealistic ways. Without a recognition of these needs how can a humane city be created?

Transport poverty has been largely ignored by the sector [8]. In the UK, SUSTRANS estimated that nearly ‘1.5 million people are at high risk of suffering from transport poverty’ [9]. In developing an interdisciplinary approach to creating a humane smart city, transport should play a key role in poverty reduction, by enabling affordable and fair access [10]. It should not create or perpetuate social excusion a lack of insight,empathy, poor design and safety or a failure to meet the needs of all potential users. Researchers have argued since the 1980s that transport systems fail to consider the needs of women in terms of the way in which their role as carers shapes their mobility, and their concerns over safety and security, lack of space and facilities.

Gender blind approaches should be replaced by gender sensitive ones [11]. Given the reluctance of key transport stakeholders to make changes, the key research question is how can existing qualtiative research on transport be used to create more humane smart cites and reduce (gender) transport poverty?

2. SELECTION OF PAPERS

A subset of papers from transport which addressed 'mobility of care' was selected to uncover emergent themes which could shape more humane cities. Searches were conducted on the TRID database and SCOPUS using key words transport/mobility, mobility of care, children, young people, adolescents, pregnancy, older people, disability, health and wellbeing. This resulted in over 170 papers. From the analysis of abstract, title and key words 10% of the papers were selected to ensure coverage across different disciplines, transport modes, data collection methods, geographic location, user and trip type, The resultant papers (listed from [12] onwards) provide a representative snapshot of current research. The papers demonstrate how quickly researchers from many disciplines have embraced the concept of 'mobility of care' and its usefulness in not just highlighting disparities in transport provision and gender related care, but also in furthering understanding of intergenerational relationships and the significance of transport in people lives. Here the emphasis is not simply on counting who uses what forms of transport and when, but on understanding how im/mobility shapes and gives meaning to peoples lives. Of special significance is the inspirational work by researchers in developing countries

Together the papers point to the difficulties shared by women across the world in time management where care duties have to be squeezed into busy schedules, are not shared equally between genders, or considered by transport planners. This significantly reduces the quality of life of female carers (who have to pay more for safer modes of transport, trip chain, and select where and when they can work) and those they care for. In the rush to provide technological solutions to move more people and goods, the sector has lost sight of the people and quality of life they are designing for. The following section provides of brief overview of some of the ways in which care - related journeys provide a lens through which we can study how cities and transport fall short of creating humane and caring cities.

3. OVERVIEW OF ISSUES RAISED

The concept of mobilities of care was first raised to highlight gender differences in mobility. Although figures vary with income, age, residential location, number of children [2, 25, 26, 28] and culture, in most countries, women make the most care related trips and those from lower income households rely more on public transport. Ravensbergen [2], noted that where integrated ticketing does not exist, women who trip chain to perform caring duties, not only undertake unpaid labour but face higher transport charges to do this.

Holistic considerations of the mobility of care were recurrent themes in research from developing counties and low-income neighbourhoods – meaning that one cannot simply look at transport on its own, but in relation to cultural practices and needs. Porter et al's comparative study of the mobility of care provided by women in low-income families in Abuja, Cape Town and Tunis during covid, showed how vulnerabilities of intergenerational caring duties and mobility become worse and more complex as women's burdens increased [23]. During lockdown women were the main carers and providers for multigenerational families – as carers their risks increased (through intimate care related contact with relatives), in travelling further to find work and searching for food. Covid restrictions meant that transport, employment and food were scarce and more expensive. This was exacerbated by patriarchal cultures that influenced where, when and how women could travel; transport deficiencies in low-income neighbourhoods – irregular, insufficient and costly public transport, poor infrastructure and a shortage street lighting. Even during covid women were subjected to pushing, stealing, verbal and sexual assault and were afraid to travel.

Women always plan their journeys to minimize risks even when they are performing caring duties or looking after their unborne child [20 and 31]. Minimising risk requires complex calculations, balancing time, cost and safety against quality of life. Plyushteva and Schwanen [22] used mobility biographies (at a micro level) to focus on intergenerational care in low-income households in Manila and London to explore intergenerational and close family and community ties effects on patterns of im/mobility, stressing the complexity of changes and how these are negotiated in time and place. Their study is one of few that address care in the community and local neighbourhood. Journeys which may be made on foot, in unlit and unsafe streets, and which are certainly never recorded in transport surveys.

Croucher et al's (2021) longitudinal, qualitative study is noteworthy because it addresses mobilities of care made by older carers [14]. It challenges our stereotype of ageing. With an ageing population and a drive to keep older people in the community, little attention has been paid to the mobilities of care of older people who become carers. For many, later life becomes a period in which attention is focused on the needs of others. Circles of care can include partners, grandchildren, life time friends and neighbours - some of whom may live with the carer, nearby, in a medical facility or many miles away. Journeys may be made to health care facilities, checking on welfare, shopping, and for leisure trips – taking someone out who may otherwise be alone and not get out the house. Such journeys are undertaken by older people who may be suffering from age related conditions themselves (e.g., cataracts, arthritis) and depend on private transport. With reductions in, or no, state provision for care in the community these trips become more frequent. They take an emotional, psychological, physical and financial toll on the care giver and take on a unique significance, for example when visiting a long-term partner in a hospice. Transport research focusses on the development of autonomous vehicles as a potential solution, but does not address how public transport could be improved.

Much research has naturally focused on parenthood [e.g.,15, 24, including chauffeuring of children e.g., 25, and 26] and motherhood [e.g., 12, 13, 15, 16,17, 27]. As well as looking at the gendered division of work in families, the papers deal with the role of transport in relation to characterizations of good parenting, accessibility, safety and promotion of sustainable travel behaviours in young people (cycling and walking).

In terms of the development of humane cities, they provide valuable insights into how mother/parenthood is experienced, develops and is enacted during journeys with children in the public domain, and the role of transport (and its users) and the urban environment in this. A new unit of attention is also raised, e.g. Boyer and Spinney 'mother and baby assemblage'. '*Parenting assemblages form between a wide range of human and non-human entities from grandparents, other parents, health visitors and paedetricians to night-lights, teddies, nappies, change mats, baby ibuprofen (et cetera).*' [29, p112] , this can include baby buggies, prams etc and the way other (actor)s interact/react to the assemblage. Carrying this forward an assemblage can also be related to any caring composition (e.g. [14]'s elderly carers and associated mobility aids). Currently the design of transport systems is still around the needs of fit, young commuters excluding the design for any one or thing that might be part of an assemblage – whether it is a pram, wheelchair or shopping bag – i.e., anything which takes up space or reduces the rate of flow. The lack of accessibility in the system shapes all transport decisions.

Grant-Smith et al (2020) discussed the lack of child friendly transport provision in terms of UN Declaration of the Rights of the Child, which argues that the right to safe and accessible transport is critical for 'just cities' for all citizens [16]. Children on public transport are not given sufficient space or consideration whether they are in buggies or travellers in their own right – often being regarded as little more than a piece of luggage. In a US study, [19] explored intersectional effects of low-income mothers travelling with disabled children on public transit. Participants described how their marginalization and exclusion shaped their lives with many experiencing barriers including affordability, safety, discrimination and accessibility. Women worried about their personal safety (sexual assault and harassment) at poorly lit stops which discouraged them from riding certain routes at particular times. Women with small children described the stress of having to collapse a stroller to get on and off the bus, finding it easier to walk. Latino women faced racism from bus drivers (e.g., not letting them sit down before they started the bus). When neighbourhoods were not served by a school bus, the high cost of public transit forced mothers to home school children or choose between health care or educational needs. They raised concerns about the safety of their children on the buses owing to poor bus driver behaviour. In Sweden, [18] explored the experience of mothers with disabled children who ewer forced to use private cars due to lack of viable alternatives. They experienced difficulties with the heavy and time-consuming activity of lifting their children, wheelchairs and other equipment in and out of the car, which meant that they made arrangements to travel without their child or ran errands durinng school time. Their mobility became centred around the needs of their child.

Very few studies have addressed maternal health, [20]'s intersectional review in the US highlighted the substantial barriers to public transit faced by pregnant women which were further exacerbated if they were also caregivers, were Black, Indigenous, People of Colour (BIPOC) and from lower income groups. Taking a 'whole journey perspective', pedestrian routes to transitm stops and stations were poorly maintained (lack of sidewalks, lighting, safe crossings), with little access to safe, clean public restrooms. Transport infrastructure was designed to accommodate pushchairs/strollers or those who may walk more slowly. When in vehicles, overcrowding and a lack of courtesy by fellow passengers to vacate seats added to their discomfort. This was further exacerbated if they were accompanied by children or were pregnant women of colour – in which case they experienced subjected inherent bias or outright hostility. In their analysis of Transport for London (TfL), [30] found expectant mothers suffered similar problems, with overcrowding and heat adding to their stress, fatigue and feelings of nausea. Commuting was so intolerable some took early maternity leave. To overcome the discourtesy faced by pregnant women, TfL introduced a 'baby on board 'badge scheme' designed to nudge passengers to give up their seats to pregnant women. This received mixed reviews – many passengers did not notice or ignored it, women felt that it drew unwanted attention to them and wearing it even resulted in verbal abuse.

4. CONCLUSIONS

The paper has described some of the insights arising from research conducted in by researches working on 'mobilities of care.' They point to specific ways in which transport falls short of the standards we would wish to see in humane cities of the future. It is critical that new research projects and transport engineers embrace draw on the findngs from transdsicplinary research and develop transport systems which are truly inclusive and facultate the creating of caring, sustainable and more humane cities.

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Arnela Mujić[1]
E-mail: arnela_mujic@hotmail.com
Edin Gadžo[2]
E-mail: edingadzo@outlook.com
Osman Lindov[3]
E-mail: osman.lindov@fsk.unsa.ba
[1]Rock n Log doo
Masarikova 17, Zenica, Bosnia and Herzegovina
[2]JP Autoceste FBiH d.o.o.
Mostar, Bosna i Hercegovina
[3] Faculty of Traffic and Communications University of Sarajevo
Zmaja od Bosne 8, Sarajevo, Bosna i Hercegovina

RESEARCH ON THE MODAL DISTRIBUTION OF URBAN MOBILITY USING SUMP INDICATORS AND THEIR APPLICATION TO CITIES

Keywords
Sustainable
Mobility
Indicators
Modal
distribution

Abstract

Sustainable Urban Mobility Plan (SUMP) is a document of traffic planning of urban areas aimed at the development of sustainable forms of transport to achieve a balance between the now dominant use of private cars versus other forms of transport. When making the plans themselves, an important role is played in the indicator identification process. Sustainable urban mobility indicators are used as a tool for cities and urban areas to identify their mobility system's strengths and weaknesses and focus on areas for improvement. The European Commission has developed its own set of practical and reliable indicators that enable a standardized assessment of system mobility to ensure harmonized data collection. This part of SUMP creation is the subject of analysis and research in this paper. In the cities, there is still no continuous political and institutional support for SUMP where such projects would be included in urban development plans. Also, there are numerous disparities between the way of applying a certain methodology when defining the way of data collection for SUMP indicators. This paper describes the method of data collection for processing basic and additional SUMP indicators. It presents the process of research modal distribution, which can be used to create new SUMPs that are needed by cities interested in this theme.

1. INTRODUCTION

Part of the Sustainable Urban Mobility Plans is, among other things, the implementation of the proposed measures, and it consists of monitoring and evaluating progress. These processes result in the progress of the entire SUMP planning procedure and provide insight into that progress and the impact of the implemented measures, reflecting their importance. For this reason, the process must be as objective and comprehensive as possible. The European Commission has published a set of urban mobility indicators that cities can use to monitor the implementation of SUMP. In this way, cities are enabled to assess the effect of their policy, and to make comparisons with the performance of other cities. The paper is divided into basic and non-basic indicators. The goal is to demonstrate their usefulness for evaluating effectiveness measures, for discovering the strengths and weaknesses of city systems and mobility and identifying areas for improvement through comprehensiveness indicators. In this way, a standardized evaluation of cities in the EU is carried out, and a comparison can be made for cities of similar size based on the collected data. Today's practice there are several world and EU methodology that suggest indicators of mobility, sustainability, or efficiency of the traffic system in cities, with the trend of achieving standardisation of indicators (benchmarking).

2. SET OF SUSTAINABLE URBAN MOBILITY INDICATORS (SUMI)

The European Commission has therefore developed a comprehensive rally of practical and reliable indicators supported by cities to assess its mobility system and just improvements stemming from new practices or mobility policies. As part of the CIVITAS impact and process evaluation framework, a set of indicators was developed to capture and evaluate the changes triggered by mobility-related measures in six main impact categories: society – governance; society – people; the transport system; energy; economy; environment.

Each indicator is defined, explained and comes with recommendations about data collection. These indicators are used already by many cities to keep transparent track of their mobility system and the links to other domains, to monitor their general mobility evolution and to evaluate the impact of mobility-related measures [1]. Indicators of sustainable urban mobility are useful tool for cities and urban areas to identify forces and weaknesses of the mobility system and focus on the areas for improvements. A standardised, methodically sound and practically feasible indicator set can enable public authorities to gain a better understanding of the current status of the city about sustainable urban mobility [2]. The set of SUMI consists of two groups of indicators: basic and non-basic [4]. Indicators 1 to 13 are defined as basic indicators, while indicators 15 to 19 are considered non-basic indicators.

The formulation of Sustainable Urban Mobility Indicators (SUMIs), capable of measuring and assessing potential solutions, is thus the key in addressing transport problems. SUMIs would prioritise people over cars establishing a new hierarchy where priority is given to sustainable transport modes such as walking, cycling and public transport [3]. A sustainable mobility system does not necessarily aim to completely “ban” cars, but it does seek to impose some barriers to their excessive usage. Simultaneously it should offer transport alternatives that will help people to cover their everyday mobility needs without having private cars as a mono-solution but as another (hopefully secondary) option [3]. As Modal Split, constitutes an important parameter for the calculation of several of the indicator above, is developed a spreadsheet to calculate the modal split, counting as a 14th core indicator (modal split is not an indicator but parameter for several indicators).

2.1. Indicator 1: Accessibility of public transport for the poorest groups

Definition: Proportion of the poorest household budget quartile required to own a public transport (PT) pass (unlimited monthly travel or equivalent) in an urban area of residence. Parameter: Rating = (Price of a monthly PT ticket * average household size) / income of the poorest 25% of urban residents [5].

2.2. Indicator 2: Accessibility of public transport for groups with reduced mobility

Definition: This indicator determines the availability of public transport services for people with reduced mobility. Such vulnerable groups include those with visual and hearing impairments and those with physical limitations, such as pregnant women, users of wheelchairs and mobility devices, the elderly, parents and caregivers who use buggies, and people with temporary injuries. Parameter: Proportion of total public transport services made accessible to individuals who would otherwise not be able to use them [5].

2.3. Indicator 3: Emissions of air pollutants

Definition: Pollutant emissions into the air of all modes of passenger and cargo transport (exhaust and non-exhaust for PM2.5) in the urban area [5].

2.4. Indicator 4: Noise disturbance

Definition: Disturbing the population with the noise generated by city traffic. Parameter: The percentage of the population disturbed by city traffic noise, based on the disturbance factor for data on the population's exposure to noise-by-noise range [5].

2.5. Indicator 5: Deaths on the road

Definition: Deaths on the roads from all traffic accidents in the urban area on an annual basis. Parameter: The number of deaths in the period of 30 days after a traffic accident as a result of the annual ones caused by urban transport per 100,000 inhabitants of an urban area [5].

2.6. Indicator 6: Access to mobility services

Definition: Share of the population with adequate access to mobility services (public transport). [5] Parameter: Percentage of population with adequate access to public transport (bus, tram, metro, train).

2.7. Indicator 7: Greenhouse gas emissions

Definition: Well-to-wheel greenhouse gas emissions of all types of passengers and freight transport in urban areas [5].

2.8. Indicator 8: Stoppages and delays

Definition: Road traffic and public transport delays during peak hours compared to off-peak travel (private road traffic) and optimal public transport travel time (public transport). Parameter: Weighted sum of delays on representative corridors for road private and public transport [5]. For road private transport, the sum of weighted averages for 10 representative car travel corridors as a ratio of peak travel time to off-peak travel time. For (road) public transport, the sum of weighted averages for 10 representative corridors for public transport journeys as a ratio of peak travel times to estimated optimal travel times.

2.9. Indicator 9: Energy efficiency

Definition: Total energy consumption in urban transport per passenger km and ton km (annual average for all modes) [5].

2.10. Indicator 10: Opportunity for active mobility

Definition: Infrastructure for active mobility, i.e., walking and cycling. Parameter: The length of roads and streets with sidewalks, bicycle paths, 30 km/h (20 mph) zones and pedestrian zones in relation to the total length of the city's road network (excluding highways) [5].

2.11. Indicator 11: Multimodal integration

Definition: An interchange is any place where a passenger can change from one mode of travel to another, with a minimal/reasonable amount of walking or waiting. The more modes available at the exchange, the higher the level of multimodal integration. Note: This indicator is called "Multimodal integration", not "Intermodal integration", because the term "Intermodality" refers to freight transport (mainly container transport). Parameter: An index between 0 and 1 that shows the average level of multimodal connectivity of distribution points within the urban transport network [5].

2.12. Indicator 12: Satisfaction with public transport

Definition: Perceived satisfaction with using public transport. Parameter: Average reported satisfaction with moving in the urban area by public transport [5].

2.13. Indicator 13: Active modes of traffic safety

Definition: Fatalities of users of active modes in traffic accidents in the city in relation to their exposure to traffic. Parameter: Number of deaths within 30 days after a traffic accident as a result of an event per year caused by active modes of transport, per billion journeys per year (exposure) [5].

2.14. Indicator 15: Quality of public spaces

Definition: Perceived satisfaction of public spaces. Parameter: The parameter is a successful result of survey responses on respondents' perception of satisfaction with green and non-green public areas [5].

2.15. Indicator 16: Urban functional diversity

Definition: Functional diversity refers to the mix of spatial functions in an area, creating proximity to interrelated activities. Parameter: Average (value 1) or not (value presence 0) of 10 spatial functions related to daily activities other than work in 1 km x 1 km grids [5].

2.16. Indicator 17: Travel time to work

Definition: Travel time to and from work or educational institution, using any type of mode [5].

2.17. Indicator 18: Use of space for mobility

Definition: Proportion of land use taken by all modes of urban transport, including direct and indirect use. Parameter: Square meters of direct and indirect use of space for mobility per capita [5].

2.18. Indicator 19: Safety

Definition: Perceived risk of crime and passenger safety in city traffic. Parameter: Reported perceptions of crime-related safety in the city's transport system (including freight and public transport, the public domain, cycle paths and roads for car traffic and other facilities such as car or bicycle parking) [5].

3. MODAL DISTRIBUTION OF URBAN MOBILITY AND APPLICATION TO CITIES

Problems in the implementation of SUMP often arise due to misunderstanding of the authorities and insufficient interest in starting the processes. A standardized, methodical and practically feasible set of indicators can also lead to the fact that the authorities better understand the current status of the city in terms of sustainable urban mobility and that they start implementing it more efficiently. A definition is given for each of the indicators, as well as their parameter. Clear instructions on how to obtain data for calculating these parameters have been given and this is helpful for large and small cities when it comes to the problem of data collection, which is usually reflected in the lack of human and financial resources. Definition modal split for passenger mobility: Modal division according to passenger kilometers travelled; Modal division according to vehicle kilometers travelled; Modal division according to the number of trips made; Modal division according to the number of vehicle kilometers travelled per trip. Definition modal split for cargo: Modal division according to kilometers travelled by goods vehicles; Modal division according to freight tons and kilometers travelled. Parameter: Modal breakdown by passenger kilometers travelled: the total number of passenger kilometers travelled for each mode of operation within an urban area compared to the total number of passenger kilometers travelled for all modes of travel within an urban area. Modal breakdown by vehicle kilometers travelled: the total number of vehicle kilometers travelled for each mode within an urban area compared to the total number of vehicle kilometers travelled for all modes within an urban area. Modal split by number of trips: the total number of trips for each mode within the urban area compared to the total number of trips for all modes in the urban area. Modal division by freight vehicle kilometers travelled: the total number of freight vehicle kilometers travelled for each mode of goods transport within the urban area compared to the total number of freight vehicle kilometers travelled for all types of freight vehicles within the urban area. Modal division according to vehicle tons travelled: the total number of ton kilometers of goods travelled for each type of goods transport within the urban area compared to the total number of ton kilometers travelled for all types of goods transported within the urban area [5].

4. CONCLUSION

The adoption of the Sustainable Urban Mobility Indicator - SUMI is a framework that helps cities overcome challenges related to more efficient planning of public policies, while at the same time encouraging the implementation of SUMP and smart mobility strategies. SUMI can serve as an important tool for identifying deficiencies sustainable urban mobility and areas where additional measures need to be taken and serves to assess progress towards set goals. One of the greatest advantages of such a standardized approach is that it enables cities to be compared with each other on the basis of databases, and that in this way examples of good practices can be more easily identified and that they can be applied to cities with similar characteristics. EU cities and urban areas and individual cities in Bosnia and

Herzegovina continue to develop sustainable urban mobility plans (SUMP), it is important that the process be standardized to be documented to ensure that achievements and implementation become useful and efficient for cities and its citizens. For the needs of measurement, the situation of mobility, efficiency or sustainability in all cities, so in Bosnia and Herzegovina cities need to be aware of the importance of the cities of collecting data process, and collected data standardize in the comprehensive database of indicators throughout the area of research while permanent monitoring EU development indicators in the segment of mobility. According to that, it is needed to ensure that cities are required to monitor systemic innovations mobility through establishing clear standards, guidelines and database to exchange EU standards, or the proposed SUMI with defined initialers, account and the way of collecting.

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Daniel Susekar[1]
E-mail: danielsusekar@gmail.com
Valentina Mirović[1]
E-mail: plast@uns.ac.rs
Jelena Mitrović Simić[1]
E-mail: mjelena@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, Novi Sad, Republic of Serbia

RESEARCH OF DEMANDS AND ATTITUDES OF CYCLIST IN ZRENJANIN

Keywords

Cycling
Infrastructure
Mobility
Cycling trips
Survey

Abstract

Within this research study a survey was conducted among the residents of the city of Zrenjanin and surrounding villages, whereby significant data on cycling traffic in the observed area were collected. The obtained data refer to the basic features of bicycle users and the features of cycling journeys, but also needs, attitudes and opinion on the current conditions of the cycling infrastructure and signalization, and cycling traffic conditions in Zrenjanin. The key advantages of bicycle use were identified from the point of view of their users, the difficulties they face when cycling and the recommendations for a more massive bicycle use as a transport means in Zrenjanin.

1. INTRODUCTION

Cycling traffic in urban areas represents a significant aspect of the contemporary urban planning. An increasing number of cities around the world recognize the importance of sustainable transport and encourages cycling as an environmentally friendly and healthy mode of transport [1]. Cycling traffic has numerous advantages, including the reduction of traffic jams, air pollution and noise, as well as the improvement of population physical health. In order to improve cycling traffic, it is important to continuously enhance the infrastructure, educate the population and support policies which are in favour of cycling. The implementation of the cycling infrastructure and the promotion of the bicycle as a transport means can contribute to the creation of a more sustainable and healthier urban environment [2]. For that reason, it is important to approach this problem from the aspect of strategic planning and create and adopt strategic documents which are used for planning cycling traffic in cities, such as Sustainable Urban Mobility Plan (SUMP) [3]. In strategic planning it is necessary to properly assess the current state of the traffic demand for cycling journeys, and to the greatest extent take into consideration the needs of the population who are the users of this mode of transport.

The results of the survey conducted among the cyclists in Zrenjanin will be shown in this paper. The surveyed respondents gave the data on the basic features of bicycle users and the features of cycling journeys, but also needs, attitudes and opinion on the current conditions of the cycling infrastructure and signalization, and cycling traffic conditions in Zrenjanin.

2. URBAN TRAFFIC IN ZRENJANIN

Zrenjanin is located in the central part of the Autonomous Province of Vojvodina and it is the economic, cultural, educational, healthcare and sports centre of Central Banat District, with around 160,000 residents of the district gravitating towards it. According to the last census from the year of 2022, there are 105,722 residents living in the wider city area, and within the very City of Zrenjanin there are 67,129 residents. There are 23 villages in the wider territory of the city of Zrenjanin [4] .

There is an extensive network of roads, which connect Zrenjanin with many towns and villages in the region, and it is one of significant railway and river junctions in Vojvodina. The traffic system in Zrenjanin in the previous period has recorded a constant decline in quality, which is partly the result of long-term exploitation with minimal maintenance, wrong investment and neglect of strategic plans for traffic development. The forecast of demographic and economic development implies that by the year of 2026, the motorization level in Zrenjanin will be one car per one family, and the population mobility will be three journeys per day, out of which 30% by walking and cycling, 30% by public transport means and 40% by passenger cars [5].

2.1 Cycling traffic

In Zrenjanin and its surrounding there are around 35 kilometres of cycling paths. In the previous period 6,661 m of cycling paths have been built on exit directions towards Novi Sad, Kikinda, Ečka and Klek. The construction of cycling lanes in the streets of Nikola Pašić, Beogradska, Banatska, Dositeja Obradovića and Bulevar Oslobođenja has been planned [5].

When it comes to the existing cycling infrastructure, due to the inadequate maintenance, it is noticeable that there is a lot of damage on paths, there is a lack of bicycle parking, there is restricted access to the entrance to certain institutions and similarly. Cycing infrastructure is still observed as a side issue, and, as a result, even newly built sections are insufficiently adapted to real needs. Therefore, on certain parts of the cycling network high curbs can be noticed, illogical beginnings and ends of the paths, unsafe sections, which consequently affect the fact that cyclists do not to use the dedicated infrastructure.

The most significant international cycling routes going through Zrenjanin are the route Zrenjanin – Temisoara and the route EuroVelo 11. The construction of the cycling path from Zrenjanin to Temisoara is a part of the crossborder project “Revitalization of the navigation structure of the canal Begej“, and the deadline for the realization of the project is 4 years. The path was built alongside the embankment and it will follow the canal of the river Begej. The total length of the path is 75 km, and the construction of the rest area at every four kilometres has been planned. In Serbia, the cycling path has been built from the village of Klek to the border with Romania. It has been planned to build a permanent cycling, pedestrian and ship border crossing by the end of 2023 [6]. Lately the path has been significantly damaged since it has not been used by cyclists only but by cars, and tractors as well, although there are traffic signs that it is only designated for cyclists. EuroVelo 11 route stretches from Norway, across Europe to Greece, in the length of around 6,000 km. EuroVelo 11 route enters Serbia from Hungary, and the places it goes through are Novi Kneževac, Čoka, nearby Ada, Novi Bečej, Zrenjanin, Pančevo, Kovin. After that it stretches towards Smederevo, all the way to Vranje, where it enters Macedonia. Zrenjanin has been marked on the map Eurovelo 11 route, which is made of 17 cycling routes in Europe. For that reason, at many points in the city and the surroundings it can be noticed that there is the road signalization which directs cycling tourists to this route [7].

3. RESEARCH METHODOLOGY

The survey was conducted online via a Google form during June 2022. There were 154 responses in total. The survey consisted of 16 questions and it included the residents of Zrenjanin and the surrounding villages. The introductory questions referred to the age, gender and the place of residence. The employment status of the respondents was recorded as well as the possession of the driving license. The following group of questions referred to bicycle use in sense of frequency, purpose, average journey length and the way of movement on the roadway. The survey participants were then offered to assess the state of the current cycling paths in Zrenjanin, the connectivity of the cycling network, as well as the state of the cycling signalization. The last three questions gave the possibility to the surveyed respondents to circle three priority answers out of more offered or to write down their specific observations in relation to the advantages of bicycle use, difficulties when cycling in the city and what is the thing which would contribute to a more massive use of bicycles in Zrenjanin. The form of the questionnaire is shown in the Figure 1.

1. Age (years) • younger than 14 • between 15 and 20 • between 21 and 30	• between 31 and 40 • between 41 and 50 • between 51 and 60 • over 61 years	**2. Gender** • male • female
3. In which part of the city do you live? ____________________		**4. If you are from a nearby village, write the name of the village.** ____________________
5. Are you employed? • Yes • No		**6. Do you possess a driving license?** • Yes • No
7. How often do you use a bicycle as a transport means? • Daily • A few days a week • A few days a month • I use it if I do not have any other transport means		**8. At which distances do you use a bicycle as a transport means?** • Between 0 and 1 km • Between 1 and 3 km • Between 3 and 5 km • Between 5 and 10 km • More than 10 km
9. What do you use the bicycle for? • Going to work / school • Doing daily activities • For recreation, sport		**10. When cycling, where do you usually cycle on?** • On the roadway, along the right edge of the road • On the pavement because I do not feel safe on the roadway • Only on the existing cycling paths • The combination of all aforementioned
11. How would you assess the existing cycling paths in Zrenjanin? • 1 (very bad) • 2 • 3 • 4 • 5 (great)		**12. Assess the connectivity of the cycling network in Zrenjanin?** • 1 (very bad) • 2 • 3 • 4 • 5 (great)
13. Assess with marks 1 to 5 how satisfied you are with the signalization (quality, information, the position of signs, how the signs were set, …) for the cyclists in Zrenjanin? • 1 (very bad) • 2 • 3 • 4 • 5 (great)		

14. What are the advantages of bicycles as a transport means (mark three answers which are of the highest priority)? • Healthy life habit • A faster transport mode in the city • There are no parking problems • A cheap transport means • Protection of the environment • Cycling is fun • A great means for recreation • Another advantage (please, write down)
15. Which are the biggest difficulties for cycling in the city of Zrenjanin (mark 3 answers of the highest priority)? • Disrespect by other traffic participants • Non-existence of cycling paths and cycling lanes • Parked vehicles on the existing cycling paths • Non-existence of proper cycling parking • It is stressful to cycle in the city • It is not safe to cycle in the city • Another difficulty (please, write down)
16. What would contribute to a more massive use of bicycles in the city of Zrenjanin (mark 3 answers which are of the highest priority)? • Popularization of cycling through different manifestations and media • Construction of cycling paths • Signalization /marking of cycling paths along the right edge of the roadway • A higher security of cyclists • A higher protection against bicycle theft • Another activity (please, write down)

Figure 1. The Form of the Survey Questionnaire

4. RESEARCH RESULTS

The age structure was divided into categories so that the first category (younger than 14) includes primary school children in Serbia, and the second group (aged between 15 and 20) includes children who attend secondary school in Serbia. Other categories were defined at every ten years. The lowest percentage of the surveyed was in the category “younger than 14“ (0.6%), while the most respondents were in the age group between 41 and 50 (22.1%) and those aged between 21 and 30 (20.8%). The sureveyed respondents were 43.5% male, that is, 56.5% female.

Out of 154 respondents, 90 live in the City of Zrenjanin, and most responses were from Bagljaš (22.2%) and Gradnulica (11.1%), while the fewest responses from Putnikovo (1.1%), Mičkej (1.1%) and Šumice (1.1%). The other 64 respondents are from nearby villages, and the most responses were given in Aradac, up to 70.3% of total responses. The following are Belo Blato 9.4% and Mihajlovo 6.3%. Aradac is around 4 km away from Zrenjanin and it has a built cycling path to the city. The path has been built recently, it is well equipped, it possesses cycling paths in both directons, it is lit, protected by guardrails, alongside the path there are benches for resting. This is one of the reasons why a lot of people use bicycles for going to the city. There were 62.3% of the employed, out of the total number, that is, 37.7% of the unemployed residents. Further, 65.6% of the respondents possesses a driving license and a vehicle.

The question “How often do you use the bicycle as a transport means?“ was responded by the highest number of the surveyed that it is done daily (53.9%), while 28.6% of the respondents said that they use the bicycle a few days a week. A certain percentage of the users rides their bike only when there is no alternative transport means (12.3 %), and occasionally, monthly, it is used by 5.2 % of the surveyed respondents.

When it comes to the average distance of bicycle use as a transport means, the responses can be used for determining the fact regarding the longest distance the residents are ready to use the bicycle for, as an alternative transport means in relation to the passenger car. When cycling, the most common distances are between 1 and 3km (31.2 %), then between 3 and 5 km (27.9%), which totally makes around two thirds of all the responses. The bicycle is least used for short distances (7.8 %), less than 1 km, since these journeys are commonly done on foot.

The purpose of the journey where bicycles are most commonly used is doing daily activities (59.1 %), then going to work /school (22.7 %) and recreation/sport (18.2%).

The respondents were offered the answers regading how they use bicycles, that is, whether it is on the roadway (along the right edge of the roadway), on the pavement (since they do not feel safe on the roadway), only on the existing cycling paths or they combine previously listed during their ride.The highest number of the respondents said they are forced to combine different ways of cycling (40.9 %), but that a large number of them use only the roadway (34.4 %). A smaller number of the respondents only ride on the existing cycling paths (18.8%), while the smallest number of the respondents ride on the pavements (5.8 %), because they do not feel safe on the roadway.

The respondents had the possibility to choose one mark from 1 (very bad) to 5 (great), and in that way express their opinion on the quality of the existing cycling paths, connectivity of the cycling network, and the state of the existing cycling signalization (Figure 2). The existing cycling paths were mostly assessed as good (35.1%), but the percentage of those who assessed the cycling paths as bad is not negligible (26%). Similar results were for the assessment of the cycling network connectivity. When it comes to the quality of the cycling signalization, most participants assessed the state as good - 3 (33.1%), but 25.3% of the respondents expressed their opinion that the cycling signalization is of good quality.

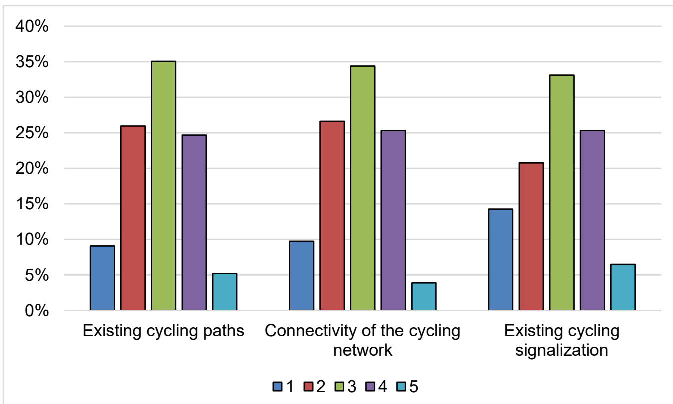

Figure 2. Assessment by the surveyed respondents

The last group of questions in the survey questionnaire meant that the respondents choose three answers out of more offered, but there was a possibility to write down an answer if they could not choose anything of the offered options. The first question referred to what the advantages of the bicycle as a transport means are (Figure 3).

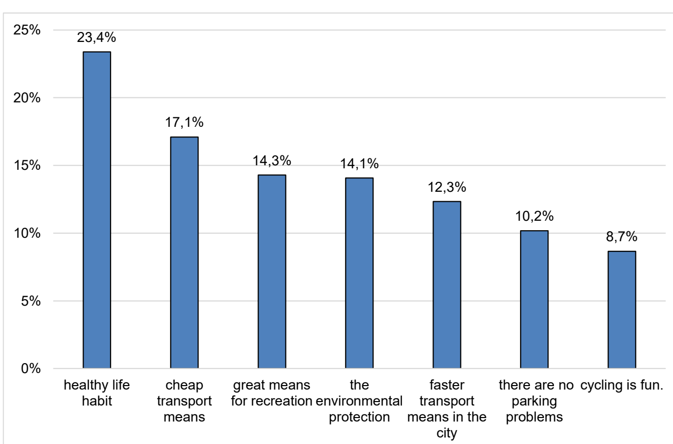

Figure 3: What are the advantages of the bicycle as a transport means?

The most frequent of all answers was that the bicycle is a healthy life habit (23.4 %), and then there are the answers that the advantage of the bicycle is that it is a cheap transport means (17.1 %), a great means for recreation (14.3 %), it is helpful in the protection of the environment (14.1 %), etc. As the most common combination of three answers there is a choice of the answer "healthy life habit", "protection of the environment" and "a great means for recreation", chosen by 10.4% of the respondents.

In the following question, the respondents had to choose three most important difficulties for cycling in Zrenjanin (Figure 4). The highest percentage of the answers referred to disrespect by other traffic participants (25.3 %), and then the answers related to the problems of non-existence of cycling paths and lanes (24%), parked vehicles on cycling paths (20.7 %), non-existence of appropriate bicycle parking (18.3 %),etc. No one of the respondents has chosen the answer that it is not safe to cycle in the city. Other answers (1.1 %) implied damaged cycling paths, pedestrians on the paths and weather conditions. As the most common combination of three answers there is the choice of answers "disrespect by other traffic participants" and "parked vehicles on the existing cycling paths" in combination with "non-existence of cycling paths/lanes" and "non-existence of appropriate bicycle parking" with 17.5% of answers for each combination.

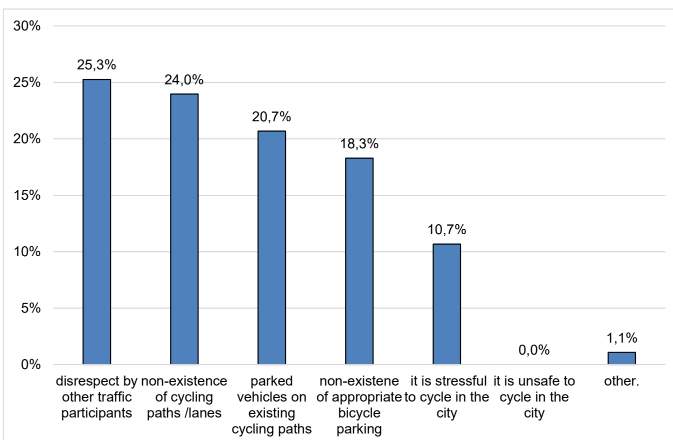

Figure 4. What are the biggest difficulties for cycling in the city of Zrenjanin?

At the end of the survey questionnaire, the respondents had to choose three answers where they were supposed to state what, in their opinion, could contribute to a more massive bicycle use in Zrenjanin (Figure 5). Most of the respondents (28.5%) think that the construction of cycling paths contributed to an increased bicycle usage, as a transport means. Greater cyclist safety (21.9 %), as well as the bicycles themselves (17.5 %) is also something what residents think could have a positive influence on a more massive bicycle use in the city. As the most common combination of three answers, there is a choice of previosly stated answers, whereby the combination was chosen by 20.1% of the respondents.

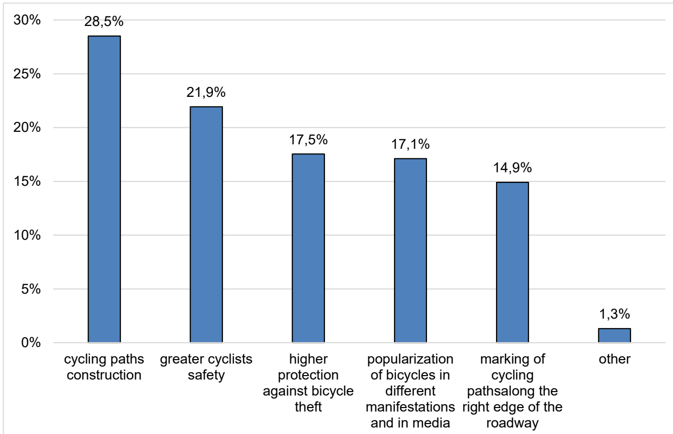

Figure 4. What would contribute to a more massive bicycle use in the city of Zrenjanin?

5. CONCLUSION

The city of Zrenjanin has expanded its cycling network in the previous years, and provided cofinancing for the purchase of bicycles to the interested residents. Additional investment into the cycling infrastructure has been planned in order to improve the existing conditions for cycling traffic. Cycling path Zrenjanin – Temisoara will affect the attractivity of the region and it will improve tourism in this part of Banat, but it will also enable cyclists to enjoy cycling in nature. Being on the cycling route EuroVelo11 is also very important for Zrenjanin.

The survey results imply that almost one quarter of cyclists are the residents aged between 40 and 50, women cycle more than men, and around two thirds of the surveyed respondents own a driving license and a car. Since the survey included the area of the city and the surrounding villages as well, most responses were from Bagljaš, and from villages, most responses were from Aradac, which is connected with the city by this cycling path. Two thirds of the respondents are employed, and most of the respondents said that they use the bicycle daily. According to the obtained results, the most common distances covered by bicycle are between 1 and 3 km. Due to the disconnection and lack of bicycle path, the respondents most often combine the way of movement (on the roadway, paths and pavement).

The existing cycling paths, cycling network connectivity and signalization are mostly assessed by the respondents with a middle mark (good), but the number of respondents who chose a bad mark is not negligible. It means that there is dissatisfaction of bicycle users and that it is necessary to improve the conditions for cycling traffic in Zrenjanin. A bicycle is usually a healthy life habit for most respondents. The biggest difficulty for them when cycling is disrespect by other traffic participants, and they also think that a construction of new cycling paths will contribute to an increased bicycle usage as a transport means. The City of Zrenjanin has a great potential to increase bicycle usage as one of urban transport modes, both because of the climate conditions and the terrain configuration, but for the size of the city itself.

ACKNOWLEDGMENT

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Milja Simeunović[1]
E-mail: mlekovic@uns.ac.rs
Zoran Papić[1]
E-mail: z.papic@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21102 Novi Sad

SATISFACTION OF BIKE SHARING SYSTEM USERS IN NOVI SAD

Keywords
Bike sharing
Bike docks
NS bike
Survey

Abstract
Cycling is a very important mode of sustainable transport. That is why it is very important to create conditions for its more frequent use. Survay has shown that the "NS bike" system is a very important part of the transport system in Novi Sad. Although residents are not completely satisfied with the system they rent bicycles for different reasons. Removing the shortcomings that users see as a problem would probably increase the number of "NS bike"users.

1. INTRODUCTION

In the wake of major climate changes, non-motorized modes of transportation are becoming increasingly popular. In addition to walking, cycling is the healthiest and most environmentally friendly form of travel. For these reasons, bicycle traffic in many cities of Europe represents one of the basic modes of transport in order to satisfy mobility. In the Netherlands, for example, there are about 18 million bicycles for about 17 million inhabitants [1]. In order to increase the use of bicycles, various strategies have been developed that favor this mode of transport, independently or in integration with public transport. Implementation of bike sharing systems in cities is one of such strategies.

Within this paper, the bike sharing system in the area of Novi Sad will be presented. In addition, the survey results of users of this system were given. The research showed user satisfaction with the system, but also highlighted certain deficiencies that need to be improved in the future.

2. THE ROLE OF BICYCLES IN SUSTAINABLE TRANSPORT

Traffic congestions, as well as increasing environmental pollution, are the everyday life of all cities, which has a direct impact on the quality and way of life and the environment. Reducing the use of motorized modes of transport is one of the attempts to solve the traffic congestions. Cycling is recognized as one of the most important mode of sustainable transport. Using a bicycle need significantly less non-renewable resources and requires a smaller area to move than motorized modes of transport. Bicycles do not make noise or pollute the environment. They are more economical than most other modes of transport, as they require an initial investment in the purchase of a bicycle and then seasonal maintenance and servicing. Cycling does not require the use of energy sources. All these advantages distinguish cycling as an important mode of sustainable transport. There are also various negative aspects of using bicycles, which relate to the impossibility of using bicycles in all weather conditions, the lack of infrastructure (parking spaces, bicycle paths, adequate traffic signaling), the limitation of loads that users can carry, the low level of safety in the event of a collision with motorized vehicles, etc. Therefore, it is necessary to create the most favorable conditions for using bicycles, in order to mitigate some of the existing negatives or avoid them completely.

2.1. Bike sharing systems

The implementation of a bike sharing system is one of the ways to increase the availability and use of bicycles in cities. These systems involve a bicycle rental at one location, free of charge or at an affordable cost of transportation, and then returning the bike to another location where it can be rented by the next user. Bike sharing systems are widely supported for use by the public to achieve sustainable mobility goals., The aim is to achieve a higher quality and attractiveness of urban transport compared to individual vehicles by using a public bicycle system. Generally, the application of the bike sharing system enables the possibility of choosing the most favorable transportation route, affordable transportation fees, preservation and protection of the environment, improvement of mobility and interconnection of spaces, etc.

3. "NS BIKE" SYSTEM

Novi Sad has long been a cycling city. In recent years, a new part of the cycling infrastructure has been renovated and partially built, resulting in over 80 kilometers of cycling paths in the city. Bicycle paths pass by the most important city locations, as well as the most important city roads. One of the three corridors of the Eurovelo 6 cycling route passes through Novi Sad. All this contributed to the fact that Novi Sad was declared the world champion in winter cycling in 2018. It was estimated that around 1400 inhabitants of Novi Sad used bicycles as a means of transport for work, school or other activities in that winter [2].

Following the example of European cities, bike sharing system ("NS bike") was developed in Novi Sad in 2011. The system has about 200 bicycles, which can be rented at 16 bike docks (Figure 1). All bike docks are equipped with video surveillance, in order to control activities related to the rental.

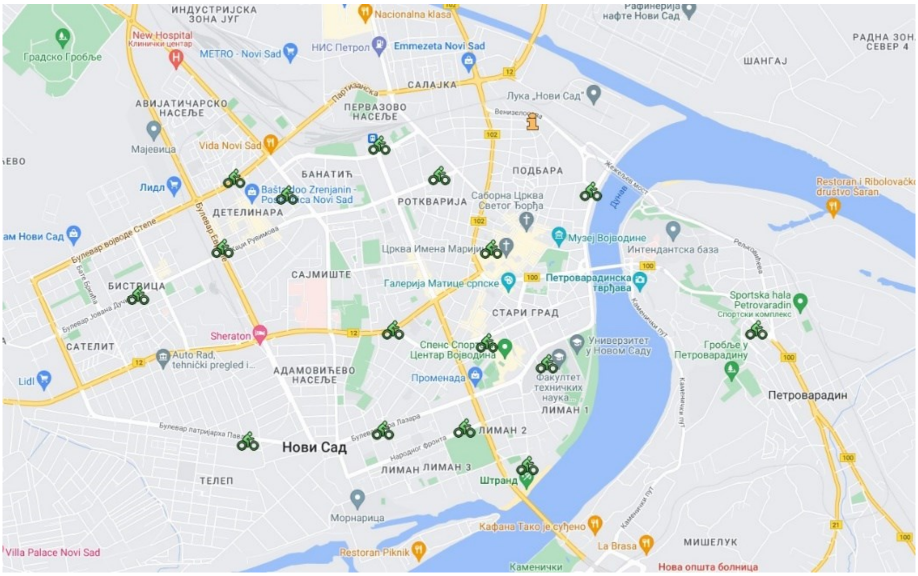


Figure 1. Positions of bike docks on the area of Novi Sad (source: [3])

Docking systems are automated, so bike rental is available 24 hours per day. The system operates in a certain seasonal period, mainly from April to November. All NS bike users must be registered. Registered persons receive a user card or a code with which they rent bicycles. The price of renting bicycles for each initial hour is 25 cents, that is, 1.45 EUR per day, while the seasonal subscription (cumulative two hours per day during the season) is 9.4 EUR.

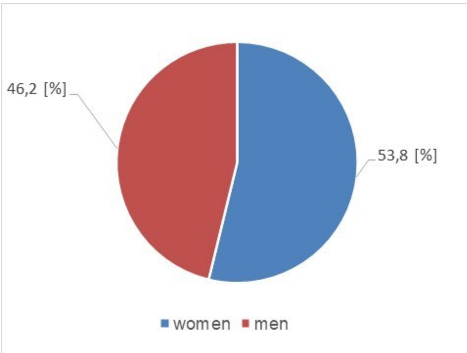
Through the existing android application, it is possible to check information in real time about the locations of bike docks, about currently available bikes, as well as the number of free places for bike rental.

3.1. Research and results

The survey of the "NS bike" system users was carried out in June, 2022, during a seven-day period, by direct interview. The research was conducted at selected bike docks on locations of high attraction. A total of 428 users were surveyed. Some results of survey are shown in the continuation of the paper.

Out of the total number of respondents, the majority of users are women (53.8%), while 46.2% of respondents are men.

The largest number of the "NS bike" system users is in the age group of 20 to 30 years (37.4 %) and 30 to 40 years (33.2 %). 16.6% of users are into the age category of 40 to 50 years, and 10.1% of surveyed users are over 50 years old. The youngest users, i.e. users under 20 years of age, participate in the age distribution with 2.7%.



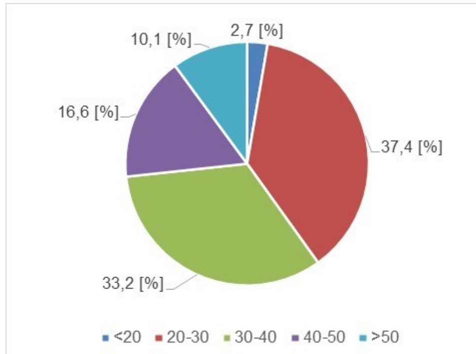


Figure 2, 3. Percentage of respondents per gender and age

When asked how often they rent a bicycle, most respondents answered 4-5 times a week (62.7%). The smallest number of respondents rent a bicycle 1 or less per week (2.8%), 2-3 times 28.6%, and 5.9% of users daily.

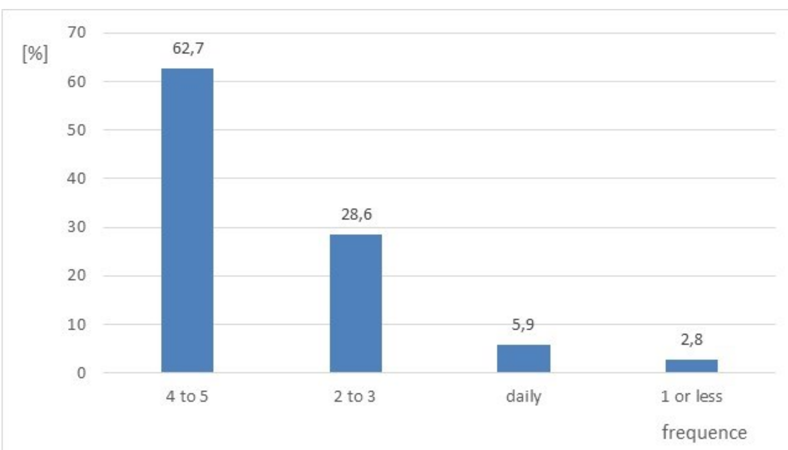


Figure 4. Frequence of bicycle use

Respondents were offered to rate the existing "NS bike" system with grades from 1 to 5. The largest number of respondents rated the system with a rating of 3 (46.1%), while the fewest respondents rated the system with a rating of 1. Figure 5 shows the percentage of users who are "NS bike" system rated 1, 2, 3, 4 or 5.

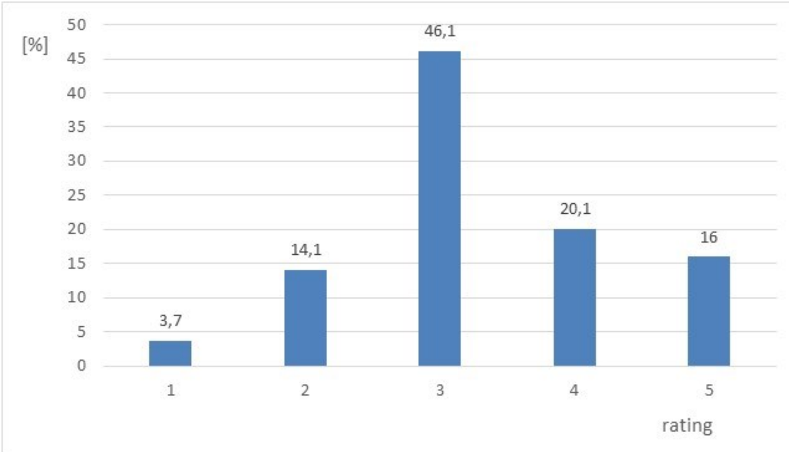


Figure 5. Rating "NS bike" system

In the next question, users of the “NS bike” system were offered options, which they should evaluate according to their own attitudes. Respondents were supposed to number the listed items in order of importance, which have an impact on their use of the “NS bike” system. The order of the offered answers is shown from the most important to the least important (Figure 6).

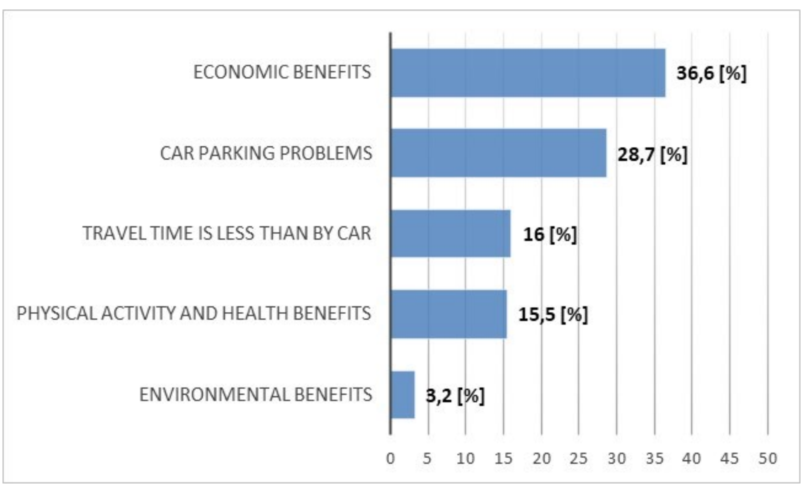


Figure 6. The most common reasons for using the "NS bike" system

The surveyed users mentioned the negative sides of the "NS bike" system also and many of them gave recommendations for improving this system. Users single out the small number of bike docks and the lack of bicycle paths in certain parts of the city as the biggest drawback. They also point out the insufficient number of bicycles in the system as a major drawback. In addition to these shortcomings, users believe that the operating season of the "NS bike" system should be extended. A younger user population suggests the introduction of electric bicycles, as well as electric scooters, as well.

4. CONCLUSION

The implementation of the "NS bike" system in the area of Novi Sad is one of the quality measures that leads to the improvement of the quality of life in the city. It has been shown that such a system is needed by the city, but its constant improvement also contributes to the long-term survival and functioning of the "NS bike" system. However, despite the investment in the "NS bike" system and the increase in the number of bike docks, the network of existing stations is still not sufficient for the metropolitan area of Novi Sad. The comments of surveyed of users the "NS bike" system about the lack of bike docks are completely justified, because in some parts of the city, these stations do not exist at all. In addition, the distance between the bike docks is far above 200-400 m for the central part of the city, which is usual for most implemented bike sharing systems.

The lack of cycling infrastructure is another of the shortcomings that the surveyed users singled out. Although in recent years the city has been investing in the expansion and improvement of bicycle lanes, there are a large number of city roads, where cyclists use the pavement with motorized traffic. This functioning of bicycle traffic contributes to the deterioration of the cyclists safety.

An important fact that was obtained from the survey is that the majority of users of the "NS bike" system use bicycles for economic reasons. The residents of Novi Sad still do not have a sufficiently developed awareness of the importance of using bicycles as a sustainable mode of transportation although the problem of environmental pollution has been promoted for many years. Therefore, it is necessary to work on the promotion of cycling as a mode of transport and highlighting all the benefits and advantages that arise from its use.

Certainly, the introduction of electric bicycles would contribute to the attractiveness of the "NS bike" system. It is reasonable to assume that electric bicycles would increase the number of users of all ages. The use of electric bicycles would be interesting both for the younger population and for the elderly, due to the reduced effort required to operate these bicycles. It is only necessary to analyze how the introduction of electric bicycles would affect the financial management of the "NS bike" system, since their use requires greater investment.

Long-term experience has shown that the "NS bike" system has proven to be an important part of the transport system of Novi Sad. Therefore, it is necessary to continue working on its improvement.

ACKNOWLEDGMENT

This research has been supported by the project „Development and application of modern methods and technologies in education and research in traffic and transportation“, founded by the Department of Traffic Engineering, Faculty of Technical Sciences in Novi Sad, University of Novi Sad, Republic of Serbia.

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NEW TECHNOLOGIES AND METHODS FOR FUTURE MOBILITY

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Tea Pavlica[1]
E-mail: tpavlica91@gmail.com
Nenad Ruskić[1]
E-mail: nruskic@uns.ac.rs
[1] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21102 Novi Sad, Serbia

COMPARATIVE ANALYSIS OF PEDERSTRIAN INFLUENCE ON ROUNDABOUTS BASED ON HCM 2010, HCM 2016 CALCULATIONS AND REAL-WORLD MEASUREMENTS

Keywords

Roundabouts
Pedestrian
Capacity
HCM 2010
HCM 2016

Abstract

Roundabouts are meant to intelligently control traffic flow at intersections without the use of stop signs or traffic lights. Roundabouts are gaining popularity due to the benefits of reducing accidents and enhancing efficiency. The capacity of a roundabout is the most important metric to consider while evaluating its performance. The presence of pedestrians utilizing the crosswalk at a roundabout approach reduces the approach's entry capacity. A roundabout's capacity is heavily reliant on pedestrians. In this paper, a comparative analysis of pedestrian influence on roundabouts capacity was performed using HCM 2010 and HCM 2016 calculations and real-world measurements.

1. INTRODUCTION

The LOS method, according to HCM 2010 [1] and HCM 2016 [2], is designed to translate complex road performance and experience factor into a single indicator that reflects the quality of service perceived by road users. The indicator is calculated using mathematical models based on various service measures and consists of a six-level evaluation system, with scores ranging from A (best conditions) to F (worst conditions). The LOS method is used by operational agencies to assess whether the performance of road facilities is satisfactory and also whether changes in the future would tend to be supported by the general public [3].

In the later versions of the HCM the LOS concept was extended to pedestrians, enabling the assessment of the quality of service provided on walkways, pedestrian crossings, and other types of pedestrian facilities, reflecting pedestrians' perceptions of the surroundings and of the traffic conditions. The relevant PLOS method, first introduced by Fruin [4] and refined thereafter, quantifies the performance based on complex factors that may influence the pedestrian movements and walking experience, and, just like VLOS, delivers a score ranging from A to F [5].
The capacity of a roundabout is heavily dependent on pedestrians, who can impede traffic anytime they enter a crosswalk. If there are a lot of pedestrians crossing, cars must stop to let them pass. They may even block the roundabout's center circle, which lowers its capacity and quality of service.
This paper gives a comparative analysis of pedestrian influence on roundabout capacity, performed using HCM 2010 and HCM 2016 calculations and real-world measurements. Using microsimulation software and drones to record roundabout footage, all assessments were performed.

2. DATA COLLECTION

Depending on the fluctuations in vehicle traffic and pedestrian volume, the performance of a road facility may vary on different days and at different times of the day. During times of low traffic flow, a roadway could function satisfactorily (LOS D or more), but during periods of high traffic volume, the quality of service might deteriorate to unacceptable levels (LOS E or F). It is obvious that the latter is a more serious situation because any design seeks to address these times of underperformance. The analyzed intersection is in the city of Nis, in the central zone. It is the intersection of Nemanjic Boulevard and Vojvode Misic Street (Figure1).

Figure 1. The appearance of the analyzed intersection

The intersection is about 1.2 km from the city center by air. The crossroads represent a more frequent crossroads in the city since they are located on location that connects attractive zones of the city. Every approach has a pedestrian crossing. At the crossroads, traffic in both directions is allowed to run in all direction. Lane widths at the zone junctions are 3.3 meters on each of the four approaches, but they are 4.6 meters in the circle-shaped center of the intersection.

3. COMPARATION

The previous counting determined the peak period of the day at the analyzed intersection, and that time was from 16:00 to 17:00 when the recording was carried out. The analyzed roundabout was filmed from the air with a drone. Figure 4 shows an analyzed intersection with traffic flow on each approach.

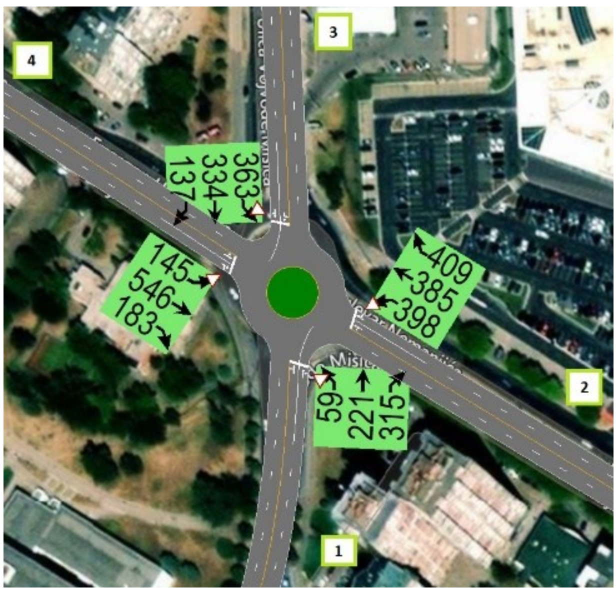

Figure 4. Analyzed intersection

Traffic and pedestrian counting were made for peak hour at all approaches. Results are given in the following tables. (Table 1, Table 2).

Table 1. Values of traffic flow at the roundabout

	Total number of vehicles on approaches by directions (15 min)							
	15min		15min		15min		15min	
	Ve	Vex	Ve	Vex	Ve	Vex	Ve	Vex
Approach 1	179	156	171	154	178	150	159	145
Approach 2	158	107	152	104	157	114	153	94
Approach 3	159	195	158	190	159	190	153	198
Approach 4	227	265	222	255	223	264	128	236

Table 2. Values of pedestrians at the roundabout

Number of pedestrians				
	15min	15min	15min	15min
Approach 1	85	72	83	89
Approach 2	97	89	85	103
Approach 3	109	112	102	116
Approach 4	127	131	124	125

Real-world measurements show the level of service H at the intersection without counting pedestrians and intersection capacity utilization of 129.7%.

HCM Unsignalized Intersection Capacity Analysis
3:

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Right Turn Channelized									MOYes			MOYes
Traffic Volume (veh/h)	145	546	183	398	385	409	59	221	315	363	334	137
Future Volume (veh/h)	145	546	183	398	385	409	59	221	315	363	334	137
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	158	593	199	433	418	445	64	240	342	395	363	149
Approach Volume (veh/h)		950			1296			304			758	
Crossing Volume (veh/h)		1191			462			1146			915	
High Capacity (veh/h)		532			962			552			667	
High v/c (veh/h)		1.79			1.35			0.55			1.14	
Low Capacity (veh/h)		405			780			422			521	
Low v/c (veh/h)		2.34			1.66			0.72			1.45	
Intersection Summary												
Maximum v/c High			1.79									
Maximum v/c Low			2.34									
Intersection Capacity Utilization			129.7%	ICU Level of Service					H			

The HCM methods are based on empirical and theoretical models that describe the relationships between traffic demand, capacity, speed, density, and level of service. [6]

3.1. HCM 2010 findings

In contrast to the real-world measurements, HCM 2010 considers the number of pedestrians when determining an intersection's capacity. After calculation, the level of service F is obtained on all approaches. Although there is an unfavorable level of service F in all approaches, HCM 2010 displays a significantly better level of service compared to the real-world measurements 2010 quantifies the impact of pedestrians on entry capacity through an adjustment factor f $_{ped.}$ [7]

$$c_e = f_{ped} * c_{e,cir} \tag{1}$$

Table 3. Pedestrian adjustment factor in HCM 2010

Case	f_{ped}	
If $q_c>881$	$f_{ped}=1$	(a)
Else if, $n_{ped}<101$	$f_{ped}=1-0.000137\,n_{ped}$	(b)
Else	$f_{ped}=\frac{1119.5-0.715q_c-0.644n_{ped}+0.00073q_c n_{ped}}{1068.6-0.654q_c}$	(c)

n_{ped}: number of pedestrians per hour (ped/h), q_c: circulating flow (pc/h)

Intersection	
Intersection Delay, s/veh	119.0
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	950	1296	646	907
Demand Flow Rate, veh/h	993	1335	664	936
Vehicles Circulating, veh/h	1226	476	1193	946
Vehicles Exiting, veh/h	504	1032	1026	865
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	665	782	564	757
Ped Cap Adj	0.787	0.706	0.834	0.729
Approach Delay, s/veh	208.9	126.0	59.4	57.2
Approach LOS	F	F	F	F

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	TR	LT	TR	LT	TR	R	LT	TR	R
Assumed Moves	LT	TR	LT	TR	LT	TR	R	L	TR	R
RT Channelized							Yield			Yield
Lane Util	0.470	0.530	0.470	0.530	0.470	0.530		0.514	0.486	
Critical Headway, s	4.293	4.113	4.293	4.113	4.293	4.113		4.293	4.113	
Entry Flow, veh/h	467	526	627	708	148	167	349	403	381	152
Cap Entry Lane, veh/h	451	479	791	810	462	490	403	556	583	683
Entry HV Adj Factor	0.957	0.958	0.972	0.970	0.967	0.966	0.980	0.980	0.952	0.980
Flow Entry, veh/h	447	504	609	687	143	161	342	395	363	149
Cap Entry, veh/h	339	361	542	555	372	395	329	397	404	488
V/C Ratio	1.317	1.395	1.123	1.239	0.384	0.409	1.039	0.995	0.897	0.306
Control Delay, s/veh	193.4	222.7	103.7	145.9	17.5	17.3	96.9	76.6	54.5	12.1
LOS	F	F	F	F	C	C	F	F	F	B
95th %tile Queue, veh	21	25	20	26	2	2	12	12	9	1

3.2. HCM 2016 findings

According to HCM 2016, pedestrian impedance for roundabouts which are analyzed using values of the counted number of vehicles per hour, is calculated using eq (2)

$$f_{ped}=\frac{1119.5-0.715v_{c,pce}-0.644n_{ped}+0.00073v_{c,pce}n_{ped}}{1068.6-0.654v_{c,pce}} \qquad (2)$$

The results obtained by the HCM 2016 methodology show the level of service F at the intersection. Compared to the HCM 2010 methodology, the intersection delay is 21.7% lower. HCM 2010 methodology at the NB approach shows an approach delay of 59.4 and a level of service of F on the other side. HCM 2016 methodology shows an approach delay of 34.8 and a level of service of D. This shows a significant difference, which is a 70% higher approach delay.

Intersection	
Intersection Delay, s/veh	93.2
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	950	1296	646	907
Demand Flow Rate, veh/h	993	1335	664	936
Vehicles Circulating, veh/h	1226	476	1193	946
Vehicles Exiting, veh/h	504	1032	1026	865
Ped Vol Crossing Leg, #/h	665	782	564	757
Ped Cap Adj	0.787	0.706	0.834	0.729
Approach Delay, s/veh	203.2	72.8	34.8	48.9
Approach LOS	F	F	D	E

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	TR	LT	TR	LT	TR	R	LT	TR	R
Assumed Moves	LT	TR	LT	TR	LT	TR	R	L	TR	R
RT Channelized							Yield			Yield
Lane Util	0.470	0.530	0.470	0.530	0.470	0.530		0.514	0.486	
Follow-Up Headway, s	2.667	2.535	2.667	2.535	2.667	2.535		2.667	2.535	
Critical Headway, s	4.645	4.328	4.645	4.328	4.645	4.328	349	4.645	4.328	152
Entry Flow, veh/h	467	526	627	708	148	167	482	403	381	825
Cap Entry Lane, veh/h	437	501	871	948	450	515	0.980	565	635	0.980
Entry HV Adj Factor	0.957	0.958	0.972	0.970	0.967	0.966	342	0.980	0.952	149
Flow Entry, veh/h	447	504	609	687	143	161	394	395	363	590
Cap Entry, veh/h	329	378	597	649	363	415	0.869	404	441	0.253
V/C Ratio	1.357	1.334	1.020	1.059	0.394	0.389	50.6	0.978	0.823	9.4
Control Delay, s/veh	211.0	196.3	68.2	76.8	18.2	16.0	F	71.7	40.3	A
LOS	F	F	F	F	C	C	9	F	E	1
95th %tile Queue, veh	22	24	16	19	2	2		12	8	

4. CONCLUSIONS

Roundabout capacity is significantly impacted by pedestrians since they are not subject to traffic lights or regulations. Specifically, in roundabouts, pedestrians have the right of way, and if possible, vehicles are required to stop for them to cross the street. HCM provides models and formulas for analyzing the capacity of pedestrian influence for entering roundabout lanes; however, the theoretical values obtained do not match the real values recorded on the field. This study compares the effects of pedestrians on roundabout capacity using observations from the real world and estimates from HCM 2010 and HCM 2016. All analyses were carried out using microsimulation software and drones to record roundabout visuals.

Values measured on-field indicate the level of service H, while the values obtained by the methodologies HCM 2010 and HCM 2016 show the level of service F. Entering the capacity adjustment factor for pedestrians into the HCM methodology results in better traffic conditions within the intersection because vehicles must stop to let pedestrians pass. The pedestrian impedance for roundabout, which is analyzed using values of the counted number of vehicles per hour by HCM 2016 methodology, shows considerable differences in approach delays compared to HCM 2010.

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Teodora Popović[1]
E-mail: tea07popovic@gmail.com
Biljana Ivanović[1]
E-mail: biljanai@ucg.ac.me
[1] University of Montenegro, Faculty of Civil Engineering
Podgorica, Montenegro

TURBO ROUNDABOUT – AN ALTERNATIVE TO CLASSIC TWO - LANE ROUNDABOUT AT THE INTERSECTION OF “JOSIPA BROZA STREET” AND “V PROLETERSKE BRIGADE STREET” IN PODGORICA

Keywords

Sustainable mobility
Environment
Safety
Turbo roundabouts

Abstract

The progressive increase of individual motorization, inadequately developed system of public transport, together with immense lack of interest in alternative types of transport that do not endanger the environment, make human life unpleasant. Moreover, it has already been sufficiently disrupted by the development of technology and negative impact of the modern way of life. Needless to say, Podgorica, as the capital of Montenegro, is not immune to the pressing problems of unsustainable mobility, either. Initiatives that can participate in resolving this global issue in cities can be defined through the appropriate choice of organization of interrupted traffic flows in urban areas. By implementing alternative, modern types of intersections that can face current challenges, it is possible to direct the present situation towards a new dimension of mobility. Namely, in addition to increased capacity, such solutions are distinguished by improved safety for all traffic participants. Safety at intersections is one of the valued factors for choosing a humane form of traffic, whether it is use of a bicycle or walking. Therefore, the subject of this article is the reconstruction of the existing two–lane roundabout with two entrances and exits, in Podgorica, at the intersection of “Josipa Broza Tita Street” and “V Proleterske brigade Street”, into a turbo roundabout.

1. INTRODUCTION

The main reason for the construction of two-lane roundabouts was the expected doubling of the capacity of single-lane roundabouts. After some time, the reality showed a contradiction in the calculation and design theories that supported the introduction and use of an additional lane in the roundabout [3]. Namely, the main advantage of single-lane roundabouts compared to standard intersections is the elimination of conflict points. In relation to the four-way intersection, 4 conflicting points of merging, diverging, as well as all crossing points were eliminated, reducing the total number of conflict points from 32 to 8.

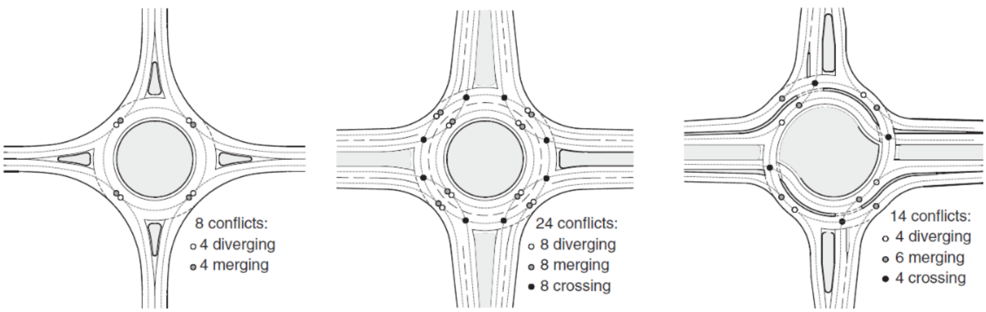

Figure 1. Number of conflicts on classic one-lane, two-lane and turbo roundabout [1]

In the case of a two-lane roundabout, the number of conflict points increases by 8 intersection points. The specific number of conflict points depends on the number of lanes at the entrances and exits. However, in practice it is not only possible to talk about these collision points, but potential sequences of conflict points which are also problematic because there are no specific positions and measures by which drivers are forced to stay or change lanes in the roundabout [3]. Two-lane roundabouts with two entrances and exits (24 conflict points) are particularly unsafe.

In this regard, it was proven that the additional lane in the roundabout increased the capacity by only about 30% [3]. These data show an insufficient improvement of capacity considering the significantly lower safety compared to single-lane roundabouts.

In addition, the impact on the environment is another aspect, which in urban areas such as Podgorica, should be on the list of priorities when selecting and designing appropriate intersections. This problem becomes much more important if we take into account the increase in the number of inhabitants and the disproportionate increase of individual motorization.

2. TURBO ROUNDABOUTS – AN ALTERNATIVE TO TWO-LANE ROUNDABOUTS

The negative effects of two-lane roundabouts can be compensated by an alternative intersection, known as a turbo roundabout, intersection with spiral driving flow. Physical barriers before entering, but also in the roundabout itself, clearly determine which lane the vehicle moves in from the moment it enters the roundabout, until it leaves it.

Professor L.G.H. Fortuijn first introduced turbo roundabouts in the late 90s. This alternative type of a roundabout has become popular throughout Europe and America in the last two decades. The first turbo roundabout was built in the Netherlands, where it was developed. In this country, the construction of classic two-lane roundabouts is prohibited.

Today, there are around 700 completed turbo roundabouts in the world, of which 414 are in the Netherlands. In the Balkans, Croatia leads the way, having built 9 and Bosnia and Herzegovina one intersection with a spiral road. Also, its construction has been completed in Serbia (Novi Sad, at the intersection of Car Lazar Boulevard and Fruškogorska Street). As for neighboring countries, Slovenia leads the way in their construction (17 turbo roundabouts).

The main role and reason for the creation of turbo roundabouts is the resolution of conflicts at the entrance and exit of the two-lane roundabout, as well as interweaving within the roundabout itself by physically separating the lanes. With this, the curb (delineator) is set as its most important element, which is why drivers must choose the appropriate lane before entering the intersection.

2.1. Bicycle traffic at turbo roundabouts

From the aspect of positive changes in Podgorica in order to approach a humane city, great attention should be paid to motivating the population to choose an alternative, bicycle traffic. The mentality of the Balkan people, including the Montenegrin people, is not inclined to accept changes, especially when it comes to the reduced use of the overwhelmingly predominant choice for overcoming distances in cities - the car. The topography in Podgorica favors the ability to quickly go from one end of the city to the other.

A bicycle would be a sufficient means of transport for the inhabitants of Podgorica. However, the benefits of using a bicycle must be communicated to future users. One of the effective measures can be the construction of efficient bicycle paths within the city traffic network. Problems occur in areas where traffic routes cross, at intersections. The most effective solution has already been implemented in developed European countries, such as highways exclusively for bicycle traffic, in which Denmark is leading the way. Of course, Podgorica, for several reasons, will probably not be up to that challenge in the near future. However, there are other, realistic measures, such as the construction of suitable intersections, the solution which would implement the safe possibility of using bicycles.

The issue of traffic safety is one of the important reasons for using bicycles as a means of transportation. A positive answer to this question can be given by the already mentioned turbo roundabout. In addition to the obvious benefits in terms of capacity, this type of intersection also provides safety, primarily for motor traffic. Safe and efficient cycling can be enabled by choosing the right design solution. The positive effects that can be achieved in this way promise an eventual decision to minimize the use of the biggest polluter of the environment in cities - cars.

Therefore, the two main advantages of turbo roundabouts are increased capacity and greater safety of motor vehicles, which is why it is suitable for implementation in urban areas. Precisely for this reason, in addition to the safety of motorized vehicles, the safety of other road users should also be taken into account.

In order to solve the problem of their safety, it is necessary to provide:

- speed control during dimensioning of the geometric shape of the intersection (the speed during the process must not exceed the value of 30-35 km/h (37-40 km/h);

- central island in the zone of pedestrian and bicycle crossings (preferable width of 2m (not less than 1.5m));

- detoured bicycle crossings (eventually) in order to reduce the speed of movement of cyclists in the intersection zone, provided that cyclists and drivers are constantly in visual contact;

- raised pedestrian crossings to calm traffic before entering the turbo roundabout, (reduction of traffic speed);

- pedestrian and bicycle traffic at different levels in relation to motor traffic if there is enough space for such a solution (overpass or underpass).

Campisi et al. [1] considered cycling mobility and safety at turbo roundabouts in two cases:

- segregation of motor and bicycle traffic (special paths for cyclists);

- integration of motor and bicycle traffic.

They concluded that in the case of higher flows, separated bicycle paths favor the safety of road users. However, if the traffic demand is lower, which can be the case in urban areas, even the integration of cyclists and drivers provides sufficient safety for all traffic participants.

3. COMPARISON OF THE CLASSIC TWO-LANE ROUNDABOUT AND THE NEWLY DESIGNED TURBO ROUNDABOUT AT THE INTERSECTION OF BOULEVARD V PROLETERSKA BRIGADA AND JOSIPA BROZA TITA STREET

Figure 2 shows the situational plan of the reconstruction project of the classical two-lane roundabout in question. The comparison of the safety of two types of roundabouts was performed based on defining the speed of passage and the number of conflict points, both between motorized vehicles and between motorized and non-motorized road users.

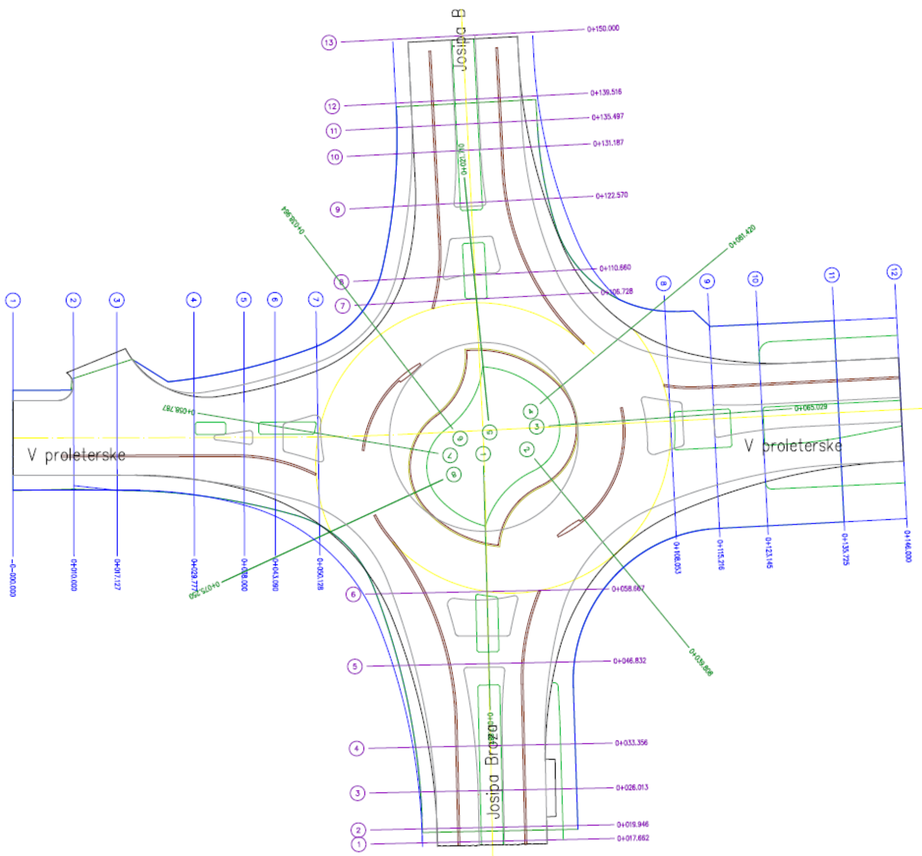

Figure 2. Situational plan of reconstruction of classic two-lane roundabout (grey lines) into turbo roundabout

3.1. Passing speed through the subject intersections

For the purposes of comparing driving speed, the method of drawing traffic lines [2] was used, whereby the speed is checked by the following equation:

$$v = 7.4 \cdot \sqrt{R} \tag{1}$$

Here, R is the radius of the traffic line, which depends on two elements: U (curvature - the length between the edge of the central island (or delineator) and the extension of the right edge of the roadway and L (the length between the beginning of the curve at the entrance and the end of the curve at the exit) [2]. The value of the radius of the traffic line is calculated as follows:

$$R = \frac{0.25 \cdot L^2 + 0.5 \cdot (U+2)^2}{U+2} \tag{2}$$

For the existing two-lane roundabout, 4 traffic lines can be drawn, and for the newly designed turbo roundabout, 12. The obtained values of the speed of traffic lines passing through the intersections are shown in the following tables:

Table 1. Passing speed on classic two-lane roundabout

Traffic line	v (km/h)
1	55
2	59.80
3	60
4	51.24

Table 2. Passing speed on turbo roundabout

Traffic line	v (km/h)
1	45.48
2	47.25
3	53.56
4	43.30
5	44.26
6	43.96
7	49
8	45
9	51.80
10	52
11	47.96
12	46.50

The passing speed through a classic two-lane roundabout range from 51 to 60 km/h. The speed at the turbo roundabout does not exceed the value of 54 km/h (three critical traffic lines). As the speed of passing through the turbo roundabout ranges from 43 to 54 km/h, it is a safer solution than the classic two-lane roundabout.

3.2. Number of conflict points at subject intersections

The number of conflict points between vehicles on a classic two-lane roundabout with two-lane entrances and exits is 24, and on a standard turbo roundabout, that number is 14.

The number of conflict points between vehicles and pedestrians and/or cyclists on a classic two-lane roundabout is 8. As this number depends on the number of lanes at the exits, the turbo roundabout has two fewer conflict points, because the exits on the minor road are single-lane.

Therefore, the criterion of conflict points gives an unquestionable advantage to the turbo roundabout in relation to the classic two-lane roundabout.

4. CONCLUSION

After comparing the speed of passing through the intersections, as well as the number of conflict points, the reconstruction of the classic two-lane roundabout at the location in question into a turbo roundabout is a completely justified solution. As the turbo roundabout has proven better aspects in terms of traffic safety, its construction would potentially cause traffic calming and help in making safer environment for cyclists. In this way, the use of cars could be reduced to an acceptable limit, and the capital of Montenegro would really step on the road to new, better mobility.

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Dragan Radovanović[1]
E-mail: draganr29@gmail.com
Elementary school "Vuk Karadžić"
Sočanica, Republic of Serbia

THE DIGITAL ERA REQUIRES DIGITAL BUSINESS

Keywords
IoT/IIoT4
Digitization
Applications
Costs
Development

Abstract

In the last few years, there has been a lot of talk about the digitization of Industry 4.0 (Smart Manufacturing), Logistics 4.0 and supply chains 4.0, their advantages and disadvantages and their technical elements and modularity of structures, which include: automatic identification technologies, RTLS (real-time location systems), CPS (Cyber-Physical Systems) and WSN (Wireless Sensor Networks), Blockchain Technology, Artificial Intelligence (Robots and Corobots), IoS (Internet Service), BD (Big Data) & DM (Data Mining) and other technologies that will represent a common language the future. In the paper, practical prerequisites for the application of new technologies, possible industrial domains, basic technical elements, types of services, costs of introducing IoT/IIoT4, business with non-digital partners and strategies for introducing IoT/IIoT4 will be pointed out. With the application of the mentioned technologies, complete digitization of logistics processes is expected from the creation of an idea about a product or service, engineering, continuous organization of production, development of process visibility on the E2E (End-to-End) network, process control to the provision of complete logistics services in supply chains.

1. INTRODUCTION

Modern business flows are characterized by the download, processing and categorization of a large number of digitized, structured, semi- or unstructured data and information, based on an "open source" platform, which change at high speed and are used in making strategies and planning the implementation of processes, in requirements and needs of users, proper risk assessment, real-time monitoring and service quality control. IoT/IIoT4 is a concept, which at first glance consists of ordinary "things", such as vehicles, machinery, temperature gauges in warehouses, accelerometers, vibration transmitters, etc. In logistics, M2M (Machine to Machine) mutual communication is enabled with its protocols without human communication. In addition to M2M and D2D, V2X, V2I, CAVs, V2V, V2P, V2D, V2G and others, new IT technologies are being built in the business of many companies with very different business services, the basis of which is business automation.

Several types of cloud services have been developed: SaaS with sub-variants DbaaS, PaaS, IaaS and DaaS. There are also LaaS logistics services based on integrated business models, through CDCs. A whole range of other applications is being developed, such as MsaaS, MbaaS, BaaS, DraaS, NaaS, MaaS and others. These applications make it easy for businesses from start-ups to large corporations to deploy, use and manage a cloud backend for their mobile, tablet and web applications, as well as to manage information technology as ITMaaS services.

In the implementation of the aforementioned technologies, a large number of technical elements are used, which include sensors and their networks, protocols, interfaces, gateways and routers, external utilities (eUtilities), integration platforms, etc. In logistics and supply chains (SC), WSANs (Wireless sensor and actuator networks), wireless sensor and actuator networks, which usually have at least one wireless communication module to communicate with the node, are significant. Protocols are generally written for a specific application and are implemented through so-called "network software". Integration platforms represent a combination of hardware and operating system software on which certain Web applications are installed. Today there are around 620 platforms in circulation, while in 2016 there were 450 of them. Several key platforms with the greatest potential for application in IoT/IIoT[4] and SC are AWS IoT, OpenMTC, IBM's Watson IoT Platform, and Microsoft's Azure IoT Hub. There are also other platforms (Temboo, supports M2M applications using MQTT, CoAP, HTTP protocols and codes of various languages Java, C/C++, and Python, which collect and store different types of real-time data, with management configuration from the cloud), ThingSpeak (platform with built-in Matlab for analysis, data processing and event planning), TheThings.iot, (supports code management in the cloud, enables the application of AI), Google Cloud IoT (a significant platform because it has a set of tools for managing connected devices in real time across all edge devices and/or in the cloud, and can run ML, meets all security requirements), and many others. It is a crucial strategic question to use a ready-made PaaS or build your new platform. It is considered that it is most convenient to get a ready-made platform.

2. CHANGES IN BUSINESS FLOWS

Industry 4.0 (in the literature: IIoT 4.0, IIoT4, IIoT4) implies a vision of future "Smart production". In parallel with the development of IIoT 4.0, logistics has been developing, which tends to become "Smart logistics", which implies "Smart service", the application of automatic transshipment, storage and sorting systems with new warehouse management software, intelligent containers, greater use of self-propelled vehicles, application of robots, drones, etc., which will fully support intelligent production. The development of SC started a little later due to the existence of numerous limitations: small supply sources (fragmented and scattered trade centres and manufacturers on networks), poor communication between SC participants, lack of knowledge of technologies and overall work processes, etc. In SC 4.0, the connection of IoT/IIoT[4], the use of robots, AI/ML, and Blockchain (BC) is required, and the application of predictive analytics with the ability to process large amounts of data from all SC processes and for all users, the use of sensors in vehicles, machines and devices in production, so such networks should be created everywhere, and automation should be applied as much as possible [1].

New technologies have a significant application in logistics processes, table 1. On the other hand, a large amount of BD data, cloud technology, cyber security, robots and drones, AI/ML, etc., may have applications but may also have limitations in application.

Table 1. Possibilities of applying new technologies through logistics processes [2]

TECHNOLOGY	LOGISTICS PROCESSES			
	Procurement	Storage	Transport	Delivery
IoT/IIoT	+/-	+	+	+/-
Blockchain	+/-	+	+	+
AI/ML	+/-	+/-	+	+
M2M and others.	+/-	+/-	+/-	+
RFID, OCR	+/-	+	+	+/-
Big Data (BD)	+/-	+/-	+	+
Virtualization	+	+	+	+
Cyber security	-	-	+	+/-
3D	+	+	+	+
Simulation	+	+	+	+
In the cloud	+	+	+/-	+/-
Robots and drones	+	+/-	+/-	+

According to [3], mobile data collection software is used: in WMS storage operations (67%), SC planning (SCP 33%) in shipping, receiving and preparation of documentation in all phases of LS, transport management (TMS 26%), in storage WES (23%), etc. The application in logistics and SC is particularly significant, for monitoring: vehicles, AGVs, and drones with the optimization of their driving routes, cargo under regulated temperature, storage conditions along SC and the quality of their delivery conditions, payments after completed transportation, intelligent purchases and receiving advice at the selling place following customer habits and preferences, control of cargo turnover in warehouses with automation of stock replenishment (Smart Product Management), sorting of cargo and materials in large warehouses, ports and terminals, detection of cargo emissions in closed warehouses, Fleet Tracking, control of roads for special cargo types (Hazmat, high-value cargo, perishable), collecting information from the CAN bus (Controller Area Network protocol) and sending real-time alarms for emergencies or providing advice to drivers while driving, etc.

3. REQUIREMENTS AND LIMITATIONS IN THE APPLICATION OF IOT/IIOT[4]

There are 10 basic limitations in the application of IoT/IoT[4], where 40% of respondents say that the problem is in data protection, i.e. data security risk, 40% see a problem in the protection of software, computers, databases, and other connected devices, 38% sees a problem in finances, 38% point to a lack of knowledge in the application of new technologies, 33% point to an inadequate IT infrastructure, 29% to a lack of standards, 28% believe that there is a lack of cooperation between software, platform and other equipment manufacturers, 27% doubt the expected effects of the application of this technology, 26% state that the integration flows of IoT/IoT[4] in production processes are unclear, and 24% of them believe that IoT/IoT[4] as a technology is not ripe for application [4].

When considering the application of AI/ML in SC, a significant problem is the lack of sufficient quality data to successfully apply some methods, which especially relates to data from complex (extended) SC. These data are often disaggregated and reside with the bearer of certain processes in the SC, it is difficult to store them, to ensure compliance with the priorities of the company and to prevent human bias in the use of AI/ML. Also, there is still not enough understanding of how it works and where to apply AI/ML because computers predict some solutions, but it is difficult to get an answer from the computer on how it came to such a conclusion. The application of BC technology has limitations in the application of IoT/IIoT[4] in logistics because there is a change in storage, ability to read and understand as well as sending data. According to [5], 64% of the society has people with certain abilities in IT, 59% would adopt the solutions of other societies but not be the first to introduce this technology, 39% express a lack of suitable business activity and technical conditions for the application of BC, with 33% the problem is technology, 33% believe that the problem is finances, 22% point to an unknown payback period of invested funds. Less than a quarter of respondents believe that the payback period is insufficiently short, which indicates that companies see BC as a valuable investment, but that financial constraints can make investing in BC difficult. This 59%, who want to adopt BC technology from other companies, see this as a significant problem because while many companies are cautiously waiting to see how BC technology is used within LS, the number of business partners who want to adopt this technology is usually limited in one BC and can remain without communication with their potential partners. There are other requirements, such as the security and reliability of this technology, lack of own certified staff or engagement of special PaaS service providers, lack of finance, lack of standards, etc.

The question arises whether non-digital partners can be partners in e-business at all. The simplest is to start with the development of standardized EDI/EDIFACT technology, which can be realized directly between users, through specific communication protocols (AS2, SFTP, FTPS) or specialized providers (EDI Network Services Provider) via VAN (Value-Added Network) networks. The next (second) step is to recognize the possibilities of business partners in terms of the scope of work and the types of transactions that need to be digitized, the state of their IT capabilities and staff training, their ability to access the portal or web form, with which partners to continue working without digitization, etc. In the following (third) step, one should choose which transactional documents should be digitized to automate processing and reduce manual operations in terms of simplifying digital collaboration with business partners. A special problem in interaction can be the incompatibility of devices, different manufacturers of sensors and devices.

4. IOT/IOT[4] INTRODUCTION COSTS

Investments are considered to be the main problem of digitalization development. However, the introduction of IoT/IoT[4] does not significantly increase the operating costs of any company, which is why companies continue to invest in new technologies to accelerate growth and productivity. The total amount of investment depends specifically on the structure of IoT/IIoT[4], concerning what societies want to monitor and process with their partners and they are different.

If a society has 100,000 devices, with an average data consumption of about 2Mb/day, then significant costs arise. Wireless certification costs start at $10,000 and up. The labor cost of programmers in the EU and USA is from $30/h to $35/h. Intelligent RFID technology is 1/10 (10%) of the cost of some alternative technology, with better accuracy. According to [6], the estimated cost of basic modules in 2035 will be as shown in Table 2.

Table 2. Presentation of the estimated costs of the IoT/IIoT[4] module

Type of module	Type of drive	Connection	Basic price without extra additions in $/pc.	
			2017	2035
Smart Tag	RF energy	NFC or RFID	0.40	0.15
Smart Sensor	The solar cell, battery	Bluetooth or LPWAN	4.00	1.15
Smart Camera	Electric power supply	WiFi, LTE or Ethernet	8.00	3.00
IoT Beacon	The solar cell, battery	Bluetooth, WiFi, Zigbee	3.00	1.00
IoT Receiver	The solar cell, battery	Bluetooth or LPWAN	3.00	1.00
IoT Gateway	Electric power supply	Bluetooth, WiFi, Internet	8.00	3.00

The complete implementation of IoT/IIoT[4], is estimated from $300,000 to $5 million, depending on the scope of monitoring and the amount of data required, analysis of technical conditions, prototypes and testing of software with automatic learning algorithms. Reduction of total costs is possible with the overall configuration and not with the configuration of individual sensors, devices and other equipment. For the further development of digitization, the EU requires and plans to finance the new digital program of Europe with over 9.2 billion euros, of which 3 billion euros will be directed to the digital connection of infrastructure in the period until 2027, because they believe that 69% of society does not have a basic understanding of their exposure to cyber risk, 60% of society has never assessed the potential financial loss and that more than 51% of European citizens are not sufficiently informed of the various attacks on their computers. The funds will be directed to the development of advanced technologies (BD/DM, robotics, AI/ML, BC technology, cyber security, development of high-performance computers, etc.) in the processes of industrial societies, logistics and transport (traffic), energy and utility companies, healthcare and other activities [7].

5. IOT/IOT^4 INTRODUCTION STRATEGY

Several preliminary steps should be taken to ensure a successful implementation of IoT/IoT^4: choose typical and priority processes for implementation and the choice of IoT/IoT4 final solution, because the processes and strategies of using the Internet can vary drastically between societies, especially in horizontal coordination. It is necessary to define the key KPIs that should be measured and examine possible medium-term strategies for the development of these technologies and data protection. According to [8], 10 basic strategic steps in the implementation of IoT/IoT^4 are proposed:

- define business goals and the expected outcome, with common measures, expected effects of implementation expressed using KPI,
- identify the necessary hardware and other physical devices to implement your solution,
- prepare and select sensor data for set metrics following the expected real-time outcome in or for long-term analysis,
- define device connectivity and data formats (CSV, XML, JSON) with connection protocols, and gateways, using Bluetooth Low Energy, Z-Wave, ZigBee, WiFi, Ethernet, Serial Port,
- ensure file protection, management and policy at every level of management, including the implementation of applicable regulations that define various guidelines for connecting to devices and accessing data,
- identify reference data sets generated by sensors and devices, needed to transform data into overview tables, summary values, trends,
- take into account the application of intelligent algorithms, AI/ML and predictive analytics for those cases that may become critical in the future or require expansion,
- monitor and analyze critical cases of processing in real time and how that data is generated,
- define long-term analytics, transformation, storage, processing and analysis of long-term data. Data separation for long-term archival and serial processing is an essential phase of IoT/IoT4 solution design,

- use the experience of business decision-makers who make decisions in business and operational managers who maintain the system in proper condition.

Smart logistics requires the introduction of an MES (Manufacturing execution system) information system with the control of a large number of sensors, process detailing, application of QA (Quality Assurance) as a system approach to control specific requirements at the data source, provide MRO (Maintenance, Repair and Operating supply), maintenance, repair and supply of all devices and vehicles, material and spare parts and everything else that is used in production processes.

6. CONCLUSION

Today, societies are faced with the transformation of their processes and change in mobility, the application of complex technologies IoT/IoT[4], AI/MI, BC, cloud services, etc., which are in different stages of their evolution with reached maturity levels for their applications. The introduction of new technologies requires the building of strong partnerships, the identification of common business goals, results and monitoring of KPIs, the selection of key processes, high protection of data and information, the establishment of a common analytics architecture, knowledge of existing standards, global initiatives, and "Know-how", etc. Logistics and the entire SC are affected by IoT/IIoT[4], enabling, and managing real-time data sources to be used efficiently. It makes the entire SC visible so that they can improve information on transparency, and complete integration of all members of the SC and others is achieved.

For this growth to continue, services should become more widely and easily accessible, and should also give more productivity to societies. Societies are especially looking for those services which can be managed and their quality improved. In the future, the rapid development of cellular networks and their 5G and 5G Recap technology modules with data transmission over radio waves using Fixed Wireless Access (FWA) networks, automated communication of Cellular Vehicle-to-Everything (C-V2X) platforms designed for V2V, V2I and V2N communications is expected and greater deployment of LPWA cellular modules with a significantly higher quality of 3GPP communications based on faster satellite communications. It is very important to choose a quality ASP (Application Service Provider) provider that has: the ability to adapt and manage existing and development of new "cloud", AI/ML, BC and other business applications, batch processing (Batch computing/processing) with strong PaaS.

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Jelica Komarica[1]
E-mail: j.komarica@sf.bg.ac.rs
Draženko Glavić[1]
E-mail: drazen@sf.bg.ac.rs
Miloš Nikolić[1]
E-mail: m.nikolic@sf.bg.ac.rs
Marina Milenković[1]
E-mail: marina.milenkovic@sf.bg.ac.rs
Ognjen Petar Todorović[2]
E-mail: ognjen.todorovic@beograd.gov.rs
[1]University of Belgrade, The Faculty of Transport and Traffic Engineering
Vojvode Stepe 305, 11000 Belgrade, Serbia
[2]City of Belgrade, Secretariat of Transport, Department of urban mobility
Twenty-seventh of March 43, 11120 Belgrade, Serbia

APPLICATION OF NEURAL NETWORKS IN ASSESSING THE IMPACT OF MICROMOBILITY ON ENVIRONMENTAL POLLUTION

Keywords

Road traffic
Environmental pollution
Micromobility vehicles
Neural networks

Abstract

Constant increase of passenger cars usage in urban area has numerous negative social and economic effects. More and more often, road traffic is the leading source of negative impacts on the environment. In order to solve the problems of environmental pollution caused by road traffic, without imposing mobility restrictions, alternatives to vehicles with combustion engines are often proposed. The results of numerous studies indicate that micromobility vehicles can have a significant impact on reducing environmental pollution, if, in addition to emissions of pollutants and noise, the source of electricity and the process of their production are taken into account. Bearing in mind the above, the aim of this paper is to analyze the influence of micromobility vehicles on environmental pollution, as well as to analyze the acceptability of the use of this type of mobility by the public. In addition to the descriptive statistical analysis, the methods of artificial neural networks and Naive Bayes were applied in order to evaluate the impact of micromobility vehicles on environmental pollution. The obtained results indicate that in addition to the fact that micromobility vehicles can have a significant impact on environmental pollution, they can also contribute to changing modal shift. A comprehensive analysis can be a useful basis for decision-making when defining strategies for reducing environmental pollution.

1. INTRODUCTION

The increased use of internal combustion passenger cars and their growing number contribute to dependence on fossil fuels and exhaust gas emissions [1,2]. The majority of greenhouse gas emissions from transportation are carbon dioxide (CO_2) emissions that result from the combustion of petroleum-based fuels, such as gasoline and diesel fuel, in internal combustion engines [3].

For decades, various strategies have been proposed to reduce the emission of polluting substances, among which are the redistribution of surface uses, the promotion of more energy-efficient and environmentally sustainable vehicles [4]. In this regard, the use of electric microvehicles is often proposed as one of the possible solutions for reducing environmental pollution, taking into account their characteristics and the possibility of solving the first and last kilometer problem [5,6].

Microvehicles, such as e-scooters, e-bikes, and e-mopeds, do not emit or have limited direct CO_2 emissions into the air, making them sustainable and more environmentally friendly than other forms of transport. Namely, zero emissions of pollutants from vehicle exhaust pipes, such as carbon dioxide, can be achieved by using electricity from renewable sources [7,8]. Also, as an important impact on the environment, the production process of microvehicles can be highlighted, including the material from which both the vehicle and its battery are made. In this regard, many conducted studies indicate that the production process can contribute to a much greater extent to environmental pollution (over 50% of the total emissions), especially in the case of the use of materials such as extracted raw materials (steel, aluminum, etc.) [9]. However, this is not the case if recycled materials are used for the production of vehicles and batteries, which can reduce the negative impact on the environment.

In addition to the above, the use of microvehicles, which has experienced expansion in the past few years, has replaced movements that were previously realized by some other type [10]. Bearing in mind that in most cases walking is the type of movement that is most replaced by the use of microvehicles, it is evident that pollutant emissions will increase in that case. For this reason, during the implementation of such a transport subsystem, it is necessary to motivate as many users as possible to replace the movement with a passenger car, for some of the types of microvehicles with electric drive. Bearing in mind the above, the goal of this paper is to analyze the impact on the acceptability of the use of this form of mobility by the residents of Belgrade. The paper will present the analysis of the data obtained from the research, as well as the accuracy and precision of the machine learning model in predicting the acceptability of microvehicles. The obtained results of the artificial neural networks (Multilayer Perceptron) and Naive Bayes models can represent a useful basis for decision-making when defining strategies for reducing environmental pollution.

2. APPLIED METHODOLOGY

2.1. Data Description

Data on users' attitudes were collected through an online survey in the period from April 2023 to May 2023. The questionnaire combined questions about revealed preferences, related to existing habits in daily movement and attitudes about environmental pollution by road vehicles. In addition, we asked about the stated preference, to analyze the attitude of the respondents on the acceptability of using microvehicles from an ecological aspect. The survey was sent to residents and users of the territory of Belgrade, 20 km from the roundabout on Square Slavija. After incomplete questionnaires with illogical answers were removed from the total sample, the valid sample used in the further analysis consisted of 302 respondents.

Survey data were analyzed using IBM SPSS 22 and Weka software. In this paper, using IBM SPSS 22 software, data analysis was performed using the standard method of descriptive statistics. The specialized software tool Weka (Waikato Environment for Knowledge Analysis) was used to predict the output data and evaluate the most influential factors on the acceptability of the use of microvehicles. For this work, after entering the collected data from the survey, the Multilayer Perceptron and Naive Bayes algorithms were used for training.

2.2. Model development

Weka software was used to develop the two models. Based on the set of data collected from the questionnaire, the development of the Multilayer Perceptron (MLP) and Naive Bayesian (NB) models are approached. The MLP algorithm consists of a perceptron that computes a single output (y) from multiple inputs (x_i), creating a linear combination based on their input weights (w_i). Adding noise (b) affects the increase of the weighted sum of the input, which is shown by formula (1).

$$y = f\left(\sum_{i=1}^{n} x_i w_i + b\right) \tag{1}$$

On the other hand, the Naive Bayes model represents a simple probabilistic classification model that relies on Bayes' theorem. In this regard, the model implies that the attributes are conditionally independent of each other and that each attribute contributes equally to the final decision. Taking into account the above, the output value of the algorithm v_{NB} is obtained by formula (2), where V represents the final set of input values, and its individual members are marked with v_j. Based on the definition, it is possible to calculate the product of individual attributes $P\left(a_i \middle| v_j\right)$.

$$v_{NB} = argmax_{v_j \epsilon V} P(v_j) \prod_i P\left(a_i \middle| v_j\right) \tag{2}$$

In this regard, in this paper, supervised (MLP) and unsupervised (NB) machine learning was applied to the available data set, with the aim of obtaining a prediction of the target variable, i.e., acceptance of the use of microvehicles from an environmental point of view. The datasets within the MLP and NB models are randomly divided into two subsets, for training and testing. The training dataset made up 70%, while the testing set made up the remaining 30% of the data, in the case of both models. The parameters related to the learning speed are assumed values and amount to "Learning Rate = 0.3" and "momentum = 0.2". Data are normalized based on its properties and classes. Also, when it comes to the number of epochs intended for training and the training process, it is 500, as assumed in the Weka software.

During the development of the model, 27 attributes were defined, which are considered to be important in terms of assessing the respondents' attitudes when accepting the use of microvehicles. The first 5 attributes refer to the sociodemographic characteristics of the respondents, then the next 16 refer to the characteristics of movement, while the last group of attributes includes reasons that influence the attitude of the respondents towards not using microvehicles. All attributes represented artificial neurons within the input layer of the MLP model, as well as the input attributes of the NB model. Also, the output layer of the MLP model, which was related to the question of the acceptability of the use of microvehicles, consisted of two neurons, which represented the answers "Yes" and "No", while the hidden layers were automatically defined by the Weka software. On the other hand, within the NB model, the mentioned answers represented classes during the process of classifying the output values of the algorithm. After the learning or training process is performed, the resulting data can be predicted within a data set in which there is no output data. Namely, in the data set for testing (30%), instead of the output data ("Yes" and "No"), the sign "?" was defined, with the aim of predicting the acceptability of the use of microvehicles.

3. RESULTS

3.1. Sample characteristics

The study included 302 participants. Of the total number of participants, 51.99% were men, and 48.01% were women. When it comes to the age category, the most represented category was respondents aged 18 to 25 (49.3%). They are followed by those aged 46-55 (15.6%) and those aged 26-35 (14.6%). Of the total number of respondents who believe that measures should be taken to reduce environmental pollution (257), 10.5% use one of the offered types of microvehicles (electric bicycle (17), electric scooter (12), and electric moped (1). The remaining 89.5% do not use these vehicles for their movement and they were considered in further analysis to predict acceptability. Of the 89.5% of respondents, 72.8% would change their attitude and accept the use of microvehicles, while the other 16,7% would not. Respondents who would agree to use microvehicles from an environmental point of view, most often move by motorized means and on foot. Observing daily movements with the purpose of going to work and for other purposes, respondents mostly use passenger cars (26.6% and 30.3% respectively), public transport (34.0% and 29.2% respectively) and walking (30.5% and 32.8% respectively). By replacing passenger cars with some types of microvehicles, it would significantly affect both the reduction of environmental pollution and the problem of traffic congestion.

3.2. Experimental results

Before displaying the results, the Weka software indicates the time required to build and test the model on the training data. In this regard, the MLP model requires more time, i.e. 14.12s for the creation and 0.02s for testing the model, compared to the NB model (0.00s and 0.01s respectively).

By comparing the performance of the algorithms regarding the accuracy of classification of instances during data training, it can be seen that the MLP algorithm gives better results (98.76%) compared to the NB algorithm (88.2%) (Table 1). Comparing other statistical parameters, it can be concluded that the values of the Kappa statistic indicate that the MLP algorithm has an almost perfect agreement with the existing data. The error results (MAE, RAE, and RRSE) indicate that the MLP algorithm has better prediction accuracy results compared to the NB algorithm. Nevertheless, the NB algorithm shows relatively good prediction accuracy results, especially in terms of the RMSE error, in which it is the only one better than the MLP algorithm.

Table 1. Statistical analysis of classification algorithm models

Statistical parameter	Classification algorithm	
	Multilayer Perceptron	Naïve Bayes
Correctly Classified Instances	98.76 %	88.199%
Incorrectly Classified Instances	1.24 %	11.80%
Kappa statistic (KS)	0.954	0.512
Mean absolute error (MAE)	0.015	0.1596
Root mean squared error (RMSE)	0.112	0.301
Relative absolute error (RAE)	5.34%	56.62%
Root relative squared error (RRSE)	29.86%	80.68%

In addition to the above, as another type of model performance analysis, the accuracy of the classification of output values is checked. The obtained values in Table 2 indicate that the values of the MLP algorithm are close to "perfect" class prediction. While the parameter values of the NB algorithm lie on the borderline between very poor and perfect prediction. As the ROC Area value is one of the most important for defining the quality of the classification algorithm, it is required that its value be as close as possible to 1. In this regard, the MLP and NB models have very good ROC Area values (0.94 and 0.91 respectively), which indicates the significant quality of their classification.

Table 2. Classification parameters of MLP and NB models

Alg.	TP	FP	Precision	Recall	F1	MCC	ROC	PRC	Class
MLP	1.00	0.07	0.99	1.00	0.99	0.96	0.94	0.97	Yes
NB	0.96	0.52	0.90	0.96	0.93	0.52	0.91	0.98	No
MLP	0.93	0.00	1.00	0.93	0.96	0.96	0.94	0.94	Yes
NB	0.48	0.04	0.72	0.48	0.58	0.52	0.91	0.64	No
MLP	0.99	0.06	0.99	0.99	0.99	0.96	0.94	0.97	**Weigh. Avg.**
NB	0.88	0.44	0.87	0.88	0.87	0.53	0.91	0.92	

In addition to the above, a confusion matrix is used as another way of checking the performance of the algorithms regarding their classification of instances into the "Yes" and "No" classes. Table 3 presents a 2x2 confusion matrix, the dimension of which depends on the number of responses. The gray fields indicate the correctly classified answers of the respondents, while the white fields indicate the incorrect ones.

Table 3. Confusion matrices of MLP and NB algorithms

		Multilayer Perceptron		Naïve Bayes	
		Existing values			
Sample	**Estimated values**	Yes	No	Yes	No
Training data	Yes	134	0	129	5
	No	2	25	14	13

The obtained results indicate that both models have a greater number of correctly classified values, so it can be concluded that they are properly trained and therefore function correctly. Also, it is evident that the MLP model performs a more accurate classification compared to the NB.

After the analysis of the results obtained after the training of the data, the analysis of the prediction of the data concerning the acceptability of the use of the microvehicle is approached. The prediction result from both algorithms indicates that they almost equally accurately predicted and classified "Yes" and "No" responses for the observed cases. Namely, out of 69 instances, the MLP algorithm correctly predicted the values for 51 instances, while the NB algorithm correctly predicted the values for 50 instances.

At the very end, within the framework of the MLP algorithm, an analysis of the weight coefficients of the model can be performed. During the training of the network itself, the weights of the branches are constantly recalculated, so that at the end of the training process, the weights of the branches converge to certain values. In this regard, the acceptability was significantly influenced by the respondents for whom a significant reason for not using a microvehicle (No) is safety (0,49), then also those who never move on foot for other purposes (entertainment/recreation/shopping)

(0,48). On the other hand, respondents aged 46-55 (-0,62), as well as those who walk every day with the aim of going to work (-0,46), had the least impact on output values.

4. CONCLUSION

The increasing use of vehicles with an internal combustion engine, results in increasing environmental pollution, with the emission of polluting particles and noise. In this regard, the use of microvehicles is often proposed as one of the possible solutions for reducing environmental pollution. Having that in mind, the focus of this paper was on the analysis and prediction of the acceptability of the use of microvehicles in order to reduce environmental pollution. The research results indicate that the residents of Belgrade have a positive attitude towards the use of these vehicles, which was successfully predicted by the MLP and NB model developed in this paper. It is important to point out that the MLP model has higher sensitivity, specificity and prediction accuracy than the NB model. In addition, using the MLP model it was possible to determine which attributes have the most influence on the acceptability of microvehicles, such as movement characteristics and reasons for not using them.

Future research directions should be aimed at increasing the number of research participants, with the application of both proposed models, in order to help decision makers when implementing a system of one of the types of microvehicles from an ecological aspect.

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Milica Miličić[1]
E-mail: mmilica@uns.ac.rs
Pavle Pitka[1]
E-mail: pitka@uns.ac.rs
Tatjana Kovačević[1]
E-mail: savkovic.t@uns.ac.rs
Milica Majstorović[1]
E-mail: milicamajstorovic@uns.ac.rs
Andrijana Jović[1]
E-mail: andrijana.jovic@uns.ac.rs
[1] Faculty of Technical Sciences in Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad

INTERNET OF THINGS (IOT) APPLICATION IN TRANSPORTATION

Keywords
Internet of things
Road transport
Logistics
Public transport

Abstract

Internet of things (IoT) enables the interconnection of the objects that surround us. The implementation of IoT-based technologies has led to great opportunities in technological progress for various aspects of people's lives. Solutions based on the IoT technologies application in the transport sector, which represents one of the most important prerequisites for the overall development of society, are particularly significant. The paper presents application of IoT technologies in the transport sector with the aim of introducing the reading public to current technologies that are applied to improve the transport sector. The application of smart sensors, collection and messaging tools in the transport environment are used like strategic means to improve transportation management. IoT technologies make it possible to avoid crowds, find parking spaces faster and reduce travel times. Also, the demands of users in the logistics chain are increasing, so accordingly, the application of IoT in smart cargo transportation, delivery and storage should respond to the rapid changes in customer expectations. There is a great impact of the IoT environment on the public transport system, so new frameworks of the intelligent public transport system are being developed accordingly.

1. INTRODUCTION

According to (Pretz, 2013), the Internet of things (IoT) is a network in which things are wirelessly connected through smart sensors. The IoT will increase internet ubiquity by integrating every object for interaction across embedded system, leading to highly distributed network of connected devices. In the next few years, the IoT technologies growth will be large and it is expected that over $125*10^9$ IoT devices will be connected [1]. Thanks to rapid progress in basic technologies, the IoT opens up enormous opportunities for a large number of new applications that promise to improve the quality of life [2].

Internet of things technology is different from traditional information technology because it includes a large number of digital devices with their complicated hardware and software components, but scientists believe that IoT makes our world smarter and more connected, which leads to drastic changes in lifestyle, way of working and learning [3]. IoT technologies have a great impact in various domains, including healthcare [4], education [5], transportation [6], smart cities [7], engineering [8], agriculture etc [9]. Due to the significant potential in innovation and benefits for the population, IoT technologies are assumed to be the key pillars of the fourth industrial revolution.

The very approach to solving problems in various areas, including transport, was greatly influenced by current technical achievements. Intelligent transportation systems help a lot to improve the transport process. In that area, there are certain IoT-based solutions in terms of data collection, processing and data transmission in the transport environment. In this way, some problems that are present every day in the transport sector should be improved, concerning traffic safety and congestion [10]. IoT technologies can also be used in the existing infrastructure to design and improve an efficient system of public passenger transportation [11]. In addition, IoT has great promising opportunities in solving certain complexities in the field of supply chains (long delivery times, interruptions in the raw materials supply, high operating costs, etc) [6].

The paper presents the IoT technologies application in the transport sector, analyzing the logistics areas, transport of goods and transport of passengers.

2. INTERNET OF THINGS (IOT) APPLICATION IN TRANSPORT SECTOR

In our daily life, we face many problems related to the transportation system. There are many challenges that need to be acted upon in various ways, and one of them is the application of Intelligent Transportation Systems in order to improve them, such as: managing traffic congestion, improving traffic safety, providing the data accessing in the transport environment, environmental protection, provision of financial resources, etc [12]. Adopting cutting-edge digital technologies such as IoT smart transportation, fleet management and more can provide a range of opportunities and productivity gains [13].

2.1. Internet of Things (IoT) in Road Transportation

In modern cars, as much as 30% of the total costs go to electronic components. This trend will be further enhanced when cars become capable of communicating and autonomously gathering information about their surroundings. For example, if there is a traffic jam, the cars at the beginning of the queue can inform the cars at the end of the queue if there is an accident, or they can notify about the congestion itself. The cars can help the driver keep a safe distance from the car in front, and can prevent dangerous actions like speeding if the weather conditions are unsafe or overtaking if the oncoming car is going too fast. Cars can enable autopilot driving on highways reducing the risk of driver fatigue as well as reducing the number of traffic accidents [14]. Furthermore, automotive industries have been established where there is a plan to use the new features of the Android platform to accelerate the adoption of the Internet of Vehicle (IoV) paradigm [15]. The IoT industry improves the functionality of ordinary cars. Smart cars integrated with IoT technology offer the same functionality as any regular car, in addition to improvising the features of a traditional car. Smart cars have sensors that register changes in the environment and provide real-time information about roads and traffic, thermostats to automatically adjust the temperature, child lock features and more. Figure 1. shows the transmission of vehicle information in real time [16].

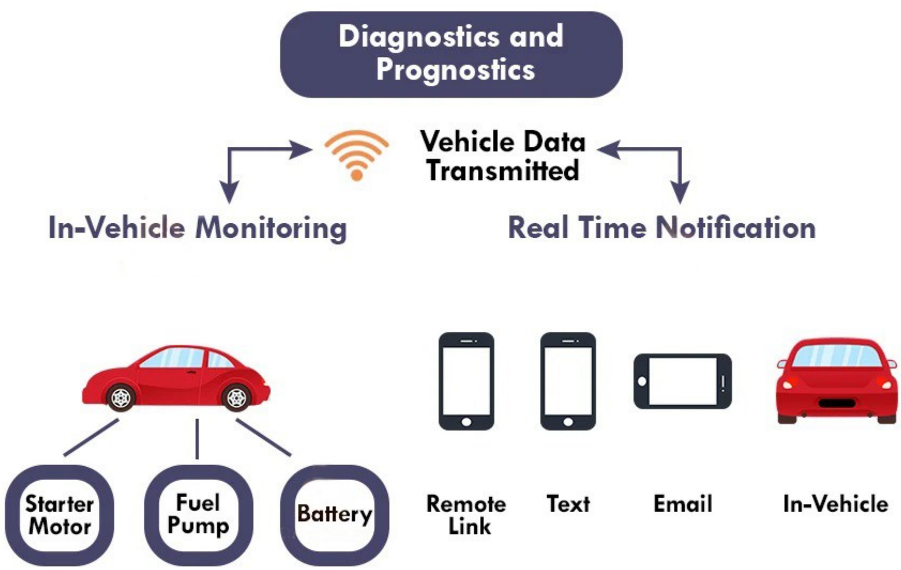

Figure 1. Vehicle information transmission in real time [16]

Shao (2019) [17] states that modern technology in road freight transport can provide accurate real-time information, tracking of goods as well as execution of routing plans using IoT technology. In addition, it was discovered that IoT can be used to monitor environmental conditions such as humidity, gas concentration, and temperature, which ultimately helps in eliminating dangerous and unwanted situations and possible accidents.

2.2. Internet of Things (IoT) in Public Transportation

Within the framework of new information technologies, it is necessary to provide methods and advanced theories of management, which will be introduced and applied in public transport to overcome certain difficulties [18]. Many uncontrollable events or variations, such as extreme weather, fluctuating passenger flow, vehicle breakdowns, can cause dynamic changes in traffic conditions. Likewise, difficulties in controlling and managing system processes lead to failure in implementing established scheduling plans and resource allocation plans.

Kiriazis presented an IoT application related to public transport control that aims to use different resources such as environmental and traffic [19]. Zhang and Chen proposed an IoT-based on congestion index system in public transport, and their system can be used to evaluate the vehicle congestion status based on a wireless sensor network node [20]. Zheng introduced a developed intelligent public transport system with some application of IoT technology [21]. Du and Chen presented the design of a public transportation emergency management system, which uses IoT technologies to monitor traffic and critical transportation infrastructure on road networks and uses a geographic information system (GIS) to facilitate emergency operations [22]. Puiu presented an application for a public transport system that provides route recommendation and incident notifications to the user by real-time data processing [23].

2.3. Internet of Things (IoT) in Logistics

Modern logistics is based on information and communication technologies that support the implementation of business processes and enable the connection of users in supply chains. Technologies in this field have led to the existence of smart containers, pallets, packaging, forklifts, infrastructure, ports, terminals and other significant elements. The systems that are widely used in logistics are: RFID (Radio frequency identification), GPS (Global Positioning System) and WSN (Wireless Sensor Network). In addition, advanced technologies such as 4G and 5G networks are also used. According to [24], various parameters must be frequently monitored in logistics activities, which requires a large number of sensors.

The most significant effects of the IoT concept in the field of logistics are [25]: a) Real-time tracking of transport and transshipment vehicles, logistics units, goods and people; b) Resource performance measurement and planning according to the current state; c) Analysis of all data and information in order to analyze the current situation and identify opportunities for new business promotions. Automating business processes by eliminating manual work while improving quality and reducing costs; d) Optimization of people, systems and resources and their coordination and integration.

3. CONCLUSION

The field of transport in the coming years is waiting for big changes. An increasing number of electric vehicles and vehicles powered by alternative fuel will be in use. The application of IoT technologies has found application in this area in the sphere of smart cars [26], infrastructure [27], autonomous vehicles [28], security [29], smart parking [30].

With the help of IoT technologies, certain negative external effects produced by traffic, such as congestion or traffic accidents, can be detected. The use of intelligent transportation systems, i.e. by collecting certain data in real time, accurate traffic estimations can be made. In addition, in freight transportation, the application of IoT technologies enables cost management, reduction of CO2 emissions, avoidance of congestion by using alternative routes, etc.

The current application of IoT technologies in the public passenger transportation system leads to a better service that the system provides to its passengers. Providing data for each bus line in real time that IoT technologies provide is of significant benefit to decision makers in this area as well as to passengers.

High speeds, low latency, greater coverage, lower power consumption and real-time execution of actions are essential factors for IoT implementations success. IoT is becoming the key to the future development of logistics because a major challenge for logistics is the visibility of the supply chain. Without good monitoring, condition or location information, goods will be lost.

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Drago Ezgeta[1]
E-mail: drago.ezgeta@tel.net.ba
Mustafa Mehanović[1]
E-mail: mustafa.mehanovic@fsk.unsa.ba
[1] Faculty of Traffic and Communications, University of Sarajevo
Zmaja od Bosne 8, Sarajevo 71000

THE IMPACT OF DIGITIZATION OF MOBILITY SERVICES AND THE USER'S DIGITAL ENVIRONMENT ON SUSTAINABLE MOBILITY

Keywords

Digitalization
Sustainable mobility
Mobility-as-a-service

Abstract

Digitization of mobility services in urban areas made it possible to increase the efficiency of existing public transport services and create a new approach to mobility-as-a-service (shared ride, vehicle sharing, on-demand service, etc.). This gives users new opportunities to access information, plan trips and pay for transportation services. On the other hand, it creates new challenges for users who do not have access to digital technologies or do not have the necessary knowledge and skills to use them. For the development of sustainable urban mobility, it is necessary to ensure the availability of public transport services to all categories of users and provide intuitive interfaces for easier access and use of digitized mobility services. Digitization in the field of mobility must be implemented as part of the broader concept of developing the digital environment of a smart city. Digital technologies support changes in user access to mobility services by encouraging a new approach to mobility-as-a-service that includes service sharing and vehicle sharing with less use of personal vehicles. The overall concept of mobility-as-a-service supports sustainable mobility in the urban area. When implementing the digitization process in the field of mobility, the willingness and limitations of users to accept and use new digital mobility services must be taken into account.

1. INTRODUCTION

The development of modern cities is accompanied by the wide application of information and communication technologies in the field of transport, which leads to digitization in the field of mobility. The development of intelligent transport systems has enabled new approaches to solving mobility problems in urban areas. This led to changes in the transport infrastructure, means of transport, the way of providing transport services, the way of using the public transport system and changes in the demands of users in the field of mobility. ITS services in the field of urban mobility have contributed to increasing the efficiency and quality of public transport services in urban areas through better information for users and better management of the fleet of public transport vehicles. This opened up new possibilities and ways of providing public transport services supported by information and communication technologies. The development of the concept of smart mobility and the concept of a smart city has changed the users' view of mobility services by offering them new services that require new knowledge and skills to access and use information and communication technologies. Digitization in the field of mobility should be viewed not only as a process of transforming analog information into digital, but also the willingness and ability of users to use digitized mobility services [1]. Sustainable mobility in urban areas requires reducing the dependence of transport system users on cars, which have a negative impact on the congestion of the road network, have a negative impact on the environment and reduce the level of mobility services in urban areas. Sustainable mobility is a concept that supports the sustainable development of society that contributes to the social, economic and environmental sustainability of society as a whole. The basic goals of sustainable mobility are [2]:

- make it possible to meet the mobility needs of all members of society by ensuring access to mobility services in a way that will protect the safety and health of people and reduce harmful effects on the environment
- ensuring the possibility of choosing mobility services on a market basis
- reduction of emissions, reduction of noise and rational use of land surfaces

Sustainable mobility requires more rational use of the available transport infrastructure and the optimization of transport processes, which can be achieved through the application of modern information and communication systems and the development of intelligent transport systems.

2. MOBILITY-AS-A-SERVICE IN THE FUNCTION OF SUSTAINABLE MOBILITY

The development of intelligent transport systems has enabled a new perspective on mobility and a new concept of mobility-as-a-service (MaaS). This change enables the development of new transport services in the urban area that are aimed at achieving sustainable mobility. Users view transportation services through the means of achieving their efficient movement without relying on transportation by personal vehicle.

Mobility-as-a-service can be viewed from two aspects:

- from the aspect of the private sector, MaaS offers new business opportunities and new services on the market
- from the aspect of the public sector, MaaS offers opportunities for sustainable mobility in urban areas

Mobility-as-a-service enables the development of mobility systems to be directed towards the goals of sustainable mobility while ensuring better accessibility to mobility services for all social strata, regardless of their information skills and economic status. Mobility-as-a-service is not only related to road transport but also includes multimodal transport services with different levels of integration shown in Table 1. The level of MaaS integration ranges from level 0 which includes MaaS without integration to level 4 which includes MaaS services with a high level of integration that enables the achievement of social goals of sustainable mobility.

Table 1. Mobility-as-a-Service MaaS Integration Levels [3]

MaaS integration levels	Ways to integrate MaaS service
Integration level 0	without integration (individual disconnected MaaS services)
Integration level 1	Information integration (multimodal travel planner)
Integration level 2	Integration of reservation and payment of services (reservation and payment of individual trips)
Integration level 3	Integration of service offerings (packages, subscriptions, contracts)
Integration level 4	Integration of social goals (policies, incentives, etc.)

At different levels of integration of MaaS services, different tools are used to encourage this new view of mobility in order to ensure the sustainable development of the transport system in urban areas. The integration of MaaS should result in the integration of the services of different modes of transport into one service adapted to the demands and needs of users.

The development of MaaS services requires a change of view on mobility, which includes [5]:

- consideration of user requests
- integration of mobility services (transportation, information, payment, reservation)
- adaptation of mobility services to user requirements through the development of transport services at the user's request

Accordingly, MaaS integrates conventional and new transportation services into new integrated customer services that include the concept of vehicle sharing and shared transportation services. A mobility-as-a-service system consists of a transportation service that includes the means and infrastructure to perform transportation and digital MaaS support platforms that enable access to information, reservations, and payment for services via smartphones and tablets.

The development of the mobility-as-a-service concept shown in Figure 1 depends on the following factors:

- technological development that should enable the interoperability of data collection and sharing
- social development that should ensure the acceptance of MaaS by users who will accept the economy of sharing vehicles and sharing services while reducing dependence on the personal car to enable sustainable mobility
- the development of the mobility services market, which will result in new types of services and new service operators in the field of mobility
- management of MaaS development by competent authorities that need to create a regulatory and technological framework for the transformation of the existing approach to mobility towards sustainable mobility that includes the concept of mobility-as-a-service

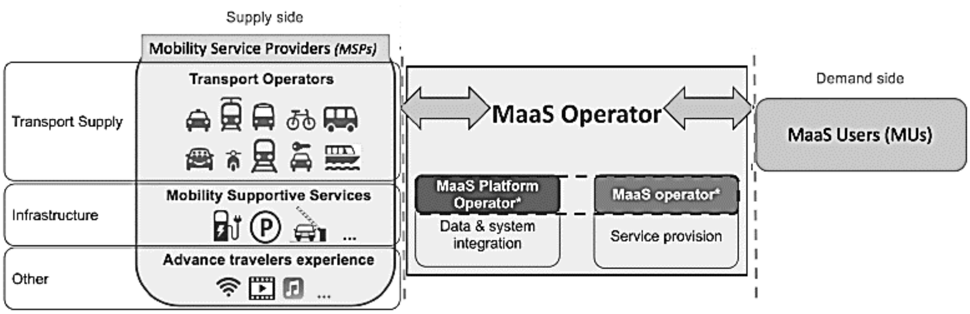

Figure 1. Concept Mobility-as-a-Service (MaaS) [5]

The concept of mobility-as-a-service includes different mobility options with the use of multimodal transport services, the use of different communication technologies and digital platforms for data exchange, which requires the standardization of services and data flows.

3. IMPACT OF DIGITIZATION ON MOBILITY SERVICES

Digitization of transport provides users with new opportunities in planning trips, accessing information, organizing trips and paying for services. Digital technologies present new challenges to users and operators of mobility services in a digital environment. Digitization has taken a central role in users' access to mobility services, which requires users to have the appropriate digital equipment and digital skills to take advantage of the possibilities of digital technologies. Digital technologies provide access to a wide range of information, greater flexibility during travel and meeting individual requirements. Users who do not own digital equipment and the necessary digital skills to use it have limitations in accessing mobility services in the digital environment, which leads to digital inequality in the field of mobility. Solving the problem of digital inequality in the field of mobility is a complex problem. The problem of digitization in the field of mobility is not only related to having a smartphone. It is related to the way people perceive digital technologies, access to the Internet, how much users trust digital technologies (personal data protection), the type of digital mobility services users want. Limitations of access to digital technologies and lack of digital skills can affect the use of digital services in the field of mobility. Digital technologies are an important part of the sociotechnical system and represent new challenges for meeting the needs of mobility services for vulnerable groups (elderly, visually impaired, children, etc.) [6].

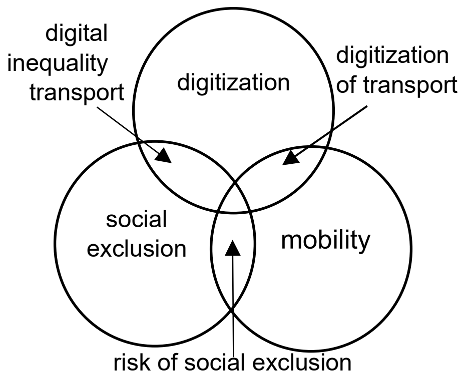

Figure 2. The impact of digitization on social exclusion in the mobility system

Social groups that have access to digital technologies and have digital skills expand their mobility options in a smart city, while groups that have some limitations in the use of digital technologies may have limitations in accessing and using mobility services in a digital environment. Digital technologies support changes in user access to mobility services by encouraging a mobility-as-a-service approach, supporting a shared vehicle and service approach. Carrying out the digitization process in the field of mobility through the transformation of analog information into digital ones must take into account the capabilities of users and their willingness to accept and use new services. Digitization should enable mobility services to be available to everyone. Therefore, digital transformation must include the partial retention of conventional technologies and their use alongside digital technologies due to the different user structure.

Planners, operators and users of mobility services see digitization as an opportunity to improve the planning and management of infrastructure, fleet of vehicles, a higher level of service that enables sustainable mobility.

The positive effects of digitization in the field of mobility are [7]:

- development of new services in the field of mobility
- changes in access to mobility services, information, travel planning and service payment methods
- the use of digital tools that provide support to travelers during their journey
- the integration of planning, booking and payment of mobility services through digital platforms support the development of mobility-as-a-service

Digitization of vehicle and infrastructure management enables real-time management of mobility services, which increases the level of service and user satisfaction.
Digital technologies can influence the improvement of passenger satisfaction, which is reflected in better communication, better information and safety during travel. Digitization has a significant contribution to the development of the sustainable mobility scenario. Sustainable mobility should provide easily accessible mobility services to all groups of society, which would reduce the need to own private cars in urban areas.

4. VULNERABLE GROUPS OF THE TRANSPORT DIGITIZATION

The limitations of certain social groups in accessing digital technologies and the lack of digital skills affect the limitations of their access and use of mobility services in the digital environment. This can lead to social inequality in access to mobility services of social groups that differ according to age (elderly, minors), income level, education level, etc. Elderly people have a harder time following the development of digital technologies and harder to acquire digital skills due to the weakening of their psychophysical abilities. Although younger people acquire digital skills more easily, children may have limitations in owning and accessing digital technologies due to not having a smartphone, credit card, etc.

Table 2. Types of digital skills [8]

Skill group	Skill type	Skill description
Skill related to the medium	Operational skills	Using digital technology in basic ways, such as knowing which buttons to use and how to open a file
	Formal skills	Handling formal media structures, such as understanding how browsers work
Content related skills	Information skills	Searching, finding, selecting and critically evaluating information
	Communication skills	Transfer of data to other people
	Content creation skills	Creating and generating new content and turning it into a product or service
	Strategic skills	Orienting, acting and deciding on information in order to achieve a specific goal and realize benefits

People with lower incomes and less education are considered vulnerable because the transition from off-line to on-line shopping public transport tickets can be a problem. People with communication disorders (auditory, visual and cognitive) may have limitations in the use of digital technologies in the field of mobility.

In addition to access to digital technologies, social groups differ according to the skills of using digital technologies shown in table 2. Information skills and knowledge are needed to search for information, select it and evaluate its quality and reliability of information sources. The negative effects of digitization in the field of mobility can be mitigated by designing digital mobility services in an inclusive, user-centered way. Digital technologies should support users in accessing information and making decisions related to mobility in an understandable and intuitive way adapted to their needs [9]. Supporting vulnerable social groups in the use of digital technologies in the field of mobility will contribute to sustainable mobility in the urban area.

5. CONCLUSION

Sustainable mobility as part of the broader concept of sustainable development requires a digital transformation of the mobility area that will enable more efficient use of the existing infrastructure, changes in the characteristics of means of transport in terms of their greater efficiency and environmental acceptability, and changes in the user's perception of mobility services and the way they are planned, organized and paid for. The wide application of information and communication technologies and the development of intelligent transport systems will increase the efficiency of transport operations and enable sustainable mobility. Digital technologies support changes in user access to mobility services by encouraging a new approach to mobility as a service, supporting a shared vehicle and service approach. When implementing the digitization process in the field of mobility, the willingness of users to accept and use new digital mobility services must be taken into account. Support for vulnerable social groups in the use of digital technologies in the field of mobility will contribute to sustainable mobility in the urban area.

Therefore, in the process of digitizing mobility services, it is necessary to harmonize technological changes and user requirements while respecting social, technical, organizational and human limitations in order to provide equal access to sustainable mobility services to all social groups. Digitization in the field of mobility must be carried out as part of the entire process of smart city development, while enabling access to digital technologies for all layers of society, especially vulnerable groups.

Digitalization of transport will influence the development and way of providing mobility services, creating a new digital environment for users. Mobility as a Service (MaaS) integrates conventional and new transportation services into new integrated customer services that include the concept of vehicle sharing and shared transportation services that will contribute to reducing the need to own private cars in urban areas as an important goal of sustainable mobility.

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Luka Strezoski[1]
E-mail: lukastrezoski@uns.ac.rs
[1] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovica 6, Novi Sad

INTEGRATION OF MASS AMOUNTS OF ELECTRIC VEHICLES INTO ELECTRICAL POWER SYSTEMS

Keywords

Electric vehicles
Electrified transportation
Power systems

Abstract

Electric vehicles (EVs) are widely considered as future of transportation. As most of the greenhouse emissions today come from gas-fueled vehicles, electrifying transportation is one of the most promising solutions for combating the wide-spread pollution of modern cities. However, integration of mass amounts of EVs, with their accompanying charging infrastructure, may cause serious issues to electrical power systems. As emerging super chargers for EVs consume huge amounts of electrical power (in a range of 300-400 kilowatts), their stochastic integration in large amounts would cause voltage violations, feeder overloads, harmonic distortions, etc., causing destabilization of power systems which would consequently cause blocking the further rollout of EVs. This paper summarizes the main challenges that integration of large amounts of EVs causes to electric power systems, and offers this author’s viewpoint on how to overcome these challenges and enable safe electrification of a transportation sector.

1. INTRODUCTION

Electric vehicles (EVs) are widely recognized as the future of transportation. Over the past decade, EV technology has rapidly advanced, addressing key barriers such as charging time, battery capacity, and range, which previously deterred potential buyers [1-4]. Additionally, the price of EVs has significantly decreased in recent years, although it remains higher than that of traditional vehicles [5]. Given that conventional gas-fueled vehicles are significant contributors to air pollution, there are numerous government initiatives worldwide aimed at deploying and gradually electrifying the transportation sector to combat greenhouse gas emissions [1-5].

However, the advantages enjoyed by EV drivers, such as fast charging and larger battery capacities, present significant challenges to the safety and reliability of electrical power systems, particularly distribution grids [6-8]. Traditional distribution grids were originally designed as passive networks solely responsible for distributing electricity from supply substations to end customers [9-10]. For decades, these grids were managed using simple, paper-based processes, assuming one-way power flow. However, the rapid increase in distributed energy resources (DERs), particularly EVs with their dynamic and stochastic charging patterns, has transformed traditional distribution networks into complex and dynamically changing systems [10]. Such systems cannot be effectively managed using conventional tools and processes. Consequently, while the widespread deployment of EVs is crucial, their stochastic integration can give rise to critical challenges in electric power systems, hindering their further expansion.

The deployment of high-power EV chargers, reaching up to several hundred kilowatts, in a stochastic manner can lead to safety and reliability issues within power systems [11]. Areas with high EV charger penetration may experience significant peak loads, voltage fluctuations, and frequent overloading of legacy feeders originally designed to accommodate gradual load increases. Traditional planning procedures for passive distribution grids are inadequate for effectively integrating EVs and their associated charging infrastructure. Due to the dynamic nature of EV charging, a tightly integrated approach is necessary, combining electrical power system planning tools with real-time management capabilities to ensure the proper integration of EVs without violating technical constraints [11].

This article, based on the comprehensive research presented in [1], as well as in other available reference, aims to present the state-of-the-art in the integration of EVs into electrical power systems, focusing on the challenges faced in power system planning and operation.

Several studies have explored the effects of integrating varying shares of EVs into power systems, detecting challenges such as peak load rise, voltage fluctuations, and feeder overloads [12]. Computational scheduling methods for integrating plug-in EVs into power systems have been extensively reviewed, highlighting promising solutions in the literature [13]. Integration of EVs and their management through the internet of energy (IoE) has been investigated, emphasizing the need for intelligent software tools to successfully integrate and manage emerging distribution grids [14]. Methodologies for optimizing power system demand by intelligently using EV charging have been proposed, acknowledging the challenges associated with fast charging [15]. The benefits of using EVs as demand response resources have been analyzed, although challenges related to EV availability and feeder capacity were not thoroughly investigated [16]. Integration challenges and potential solutions for electric buses and taxis have been reviewed, primarily focusing on peak load rise as a major challenge [17]. The impacts of EV charging on power systems, both positive and negative, have been comprehensively reviewed, stressing the need for intelligent control and optimization tools to transform challenges into benefits [11]. Optimization models for the integration of EVs and charging stations in power systems have been explored, highlighting the necessity of digitized control centers with software tools to efficiently integrate and manage EV fleets alongside other system components [18]. A conceptual framework for EV integration, considering grid operation and electricity markets, has been proposed, emphasizing the requirement for a centralized EV charging control strategy [19]. Technical challenges to power system operation resulting from EV integration have been examined, reiterating the importance of centralized intelligent charging for operational benefits and flexibility resources [20]. Finally, V2G technology has been analyzed, focusing on optimization techniques and stakeholder coordination to enhance electrical grid operation [21].

Based on the available literature, the main aim of this paper is to summarize the main challenges that integration of large amounts of EVs causes to electric power systems. Additionally, this paper offers this author’s viewpoint on how to overcome these challenges and enable safe electrification of a transportation sector.

The rest of the paper is organized as follows. In Section 2, planning challenges due to mass amounts of EVs are summarized. Section 3 summarizes operational challenges that power system operators face as a consequence of high penetration of EVs. Section 4 gives this author’s viewpoint on how we can overcome the aforementioned challenges. Section 5 concludes the paper.

2. PLANNING CHALLENGES

The process of traditional distribution grid planning was characterized by its linear and straightforward nature [1, 22, 23]. Distribution utilities' planning departments would analyze the existing system conditions, utilize traditional load forecasting methods to project future load growth, and perform analyses to identify system needs, reinforcements, and replacements [22, 23]. Based on these evaluations, utilities would determine the most suitable solution, such as upgrading substations or lines, and develop an investment plan accordingly. This approach worked reasonably well for several decades, as the rate of load growth was relatively modest. However, the landscape has undergone a radical transformation with the proliferation of EVs and the accompanying charging infrastructure. The introduction of level 3 chargers, primarily used in commercial charging stations, capable of delivering up to 400 kW of power each [1, 11, 22], means that a single charging station comprising multiple level 3 chargers can reach power capacities in the range of several megawatts [1]. Consequently, integrating multiple charging stations into a distribution substation's area or a feeder is no longer a simple task. Employing traditional planning procedures would necessitate substantial investments to modify or reinforce numerous components of the grid.

For example, consider California's recent state regulation mandating that 35% of new car models sold in 2026 be zero-emission, with the goal of reaching 100% by 2035 [22]. Meeting the power demands of these vehicles while ensuring sufficient electricity supply for other customers would require the state to triple its current electric power production and comprehensively strengthen all the affected grid elements [22]. However, the challenges extend beyond financial investments. Even if utilities were to accept such an investment plan, the entire process of obtaining various permits and executing a labor-intensive project would span several years if traditional planning procedures were followed. Consequently, the widespread adoption of EVs would be postponed for years, if not decades, severely compromising the progress of electrifying and decarbonizing the transportation sector.

Therefore, there is an urgent need for new and advanced planning tools that can facilitate the integration of large numbers of EVs at a faster pace, without compromising the safety and reliability of the electrical distribution grid.

3. OPERATIONAL CHALLENGES

The integration of a large number of EVs into electrical distribution grids poses several operational challenges. One of the main challenges is the increase in peak load demand. Studies have shown that even low penetrations of EVs, if charged randomly, can lead to a peak load demand increase of nearly 60% [1, 11]. This surge in demand requires significant infrastructure investments. However, with controlled charging and centralized management of distributed energy resources (DERs) and aggregated EV flexibility, faster integration of higher quantities of EVs becomes viable [11].

Another challenge is congestions and overloads in the distribution grid. The increased load caused by EV charging can overload transformers, feeders, and cables. Even with low EV penetrations, overloading of transformers can reach up to 50% in a distribution grid [1, 11]. Unmanaged usage of level 3 charging stations would result in congestions, overloading, and destabilization of the grid. Therefore, careful planning and coordination with other flexible resources are necessary to avoid such issues.

Voltage stability is also a concern when integrating EVs into the grid. Studies indicate that even with less than 30% EV penetration, voltage issues can arise in distribution grids [1, 11]. Voltage imbalances can occur due to the installation of single-phase chargers at customers' homes. Additionally, the use of vehicle-to-grid (V2G) technology can lead to voltage rises beyond the allowed limits. Comprehensive grid management solutions are needed to ensure voltage stability [1].

Power losses are another significant challenge. The increased load from EV charging results in higher currents flowing through transformers, lines, and cables, leading to significant power losses. Studies have shown that even with less than 50% EV penetration, uncontrolled charging can cause unacceptable power losses [1, 11]. Managed charging through intelligent software solutions can effectively mitigate power losses [1].

4. POTENTIAL SOLUTIONS

Addressing the discussed challenges requires the implementation of advanced grid management solutions such as Distributed Energy Resource Management Systems (DERMS) [24-27]. These systems enable the intelligent management of EV charging, coordination with other DERs, and optimization of grid resources. By adopting such solutions, distribution system operators can integrate EVs more efficiently and ensure the reliable and sustainable operation of distribution grids [1].

A Utility DERMS, also known as a "Grid DERMS," is a centralized software solution designed for distribution grid operators, grid engineers, and network planners to assist them in the management of distribution grids with a high penetration of Distributed Energy Resources (DERs) and EVs. This solution is grid-aware and relies on an accurate network model and real-time state estimation to provide continuous awareness of the grid's operating conditions. A typical Utility DERMS comprises planning, real-time, and lookahead modules, each equipped with sophisticated functionalities. These modules enable utilities to plan new DER and EV integrations, conduct what-if analysis, and implement non-wires alternatives. Additionally, they facilitate real-time control, optimization, and protection of dynamic distribution grids. A Utility DERMS offers a comprehensive toolkit for utilities, encompassing the entire process from planning the integration of new DERs or EV charging stations to incorporating these devices into the distribution grid's ecosystem and utilizing them as flexible resources for control and optimization purposes.

Thus, DERMS enables advanced management solutions, such as active network management (ANM) and non-wires alternatives (NWAs), which offer alternative approaches to planning and utilizing grid resources. These methods leverage the flexibility provided by aggregated DERs and EVs to defer capital investments and enable a more expedited integration process [1]. By using DERMS software, distribution system operators (DSOs) and planning departments can gain access to a comprehensive set of ANM and NWA tools, empowering them to intelligently plan and integrate mass amounts of EVs without the immediate need for extensive capital expenditures and the associated time-consuming procedures.

It is essential to recognize, however, that as the number of Electric Vehicles (EVs) increases, the existing grid infrastructure may need hardware upgrades to enhance its capacity and effectively support the complete transition to electric transportation. However, the implementation of a DERMS offers a promising solution for Distribution System Operators (DSOs) to navigate this transitional phase and prepare for a future where EVs constitute a significant portion of the vehicle fleet. By intelligently managing the evolving distribution grid, DSOs can bridge the gap between the present and an inevitable future with high EV penetration, without the need to delay the further deployment of EVs until the grid is fully reinforced.

By leveraging a DERMS, DSOs gain the ability to optimize grid operations and effectively balance the growing demand from EVs with the available grid resources. This approach ensures reliable and efficient power distribution while maintaining system stability. It empowers DSOs to proactively manage the integration of EVs into the grid, making the most efficient use of existing infrastructure and avoiding unnecessary delays in the adoption of EVs. With a DERMS in place, DSOs can navigate the challenges of high EV penetration and pave the way for a sustainable and electrified transportation future.

5. CONCLUSIONS

In this paper, main challenges that power systems are facing due to the integration of mass amounts of EVs are presented and discussed. These challenges range from planning issues, where the traditional planning procedures are not applicable for proper planning of the required expansions to accommodate mass amounts of EVs, to operational challenges, faced by grid operators. Main operational challenges are peak load rise, congestions due to stochastic charging of EVs, voltage fluctuations, increased power losses, and potential destabilization of power systems, due to unmanaged charging. All of these issues need to be properly addressed in order for power systems to be prepared to host even partially electrified transportation.

In the second part of the paper, this authors' view on how to address these challenges is presented. This includes deploying emerging software solutions, called DERMS, training the utility personnel to use these novel software solutions, as well as grid expansions in the most critical and congested areas.

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Osman Lindov[1]
E-mail: osman.lindov@fsk.unsa.ba
Aleksandra Petrović[2]
E-mail: aleksandra.petrovic@pr.ac.rs
Nebojša Arsić[2]
E-mail: nebojsa.arsic@pr.ac.rs
[1] Faculty of Traffic and Communications University of Sarajevo
Zmaja od Bosne 8, Sarajevo, Bosnia and Herzegovina
[2] University of Pristina in Kosovska Mitrovica
Knjaza Miloša 7, Kosovska Mitrovica

SUSTAINABLE URBAN E-MOBILITY TO TOWARDS INCLUSIVE CITIES

Keywords
Innovative
E-mobility
Sustainable
Cities
Education

Abstract

Mobility is experienced differently by different groups of people, and their specific needs should be considered by applying a participative approach and involving users and actors concerned. Furthermore, an integrated and holistic approach should be applied, allowing people to be aware of the interdependencies of actions taken in one area on others (environmental, economic, social and governance).

A lot of cities and urban settlements in the last decade have contributed to safe and safer cities, especially pedestrians, users of public transport, cyclists and other public activities, with the design of space and new streets, and especially by the redesign of space and existing streets. The approach to space, urban mobility is changing, planners and urban planners are emerging with new ideas, who, together with the technical professions of traffic and construction engineers, are launching new forms of design that help safe, safe, humane urban living. In this paper will be given guidelines for accelerating transformational change towards sustainable urban mobility through innovative and integrated electric mobility solutions.

The paper will also analyze the segment of engineering education in e-mobility and innovative solutions in e-mobility.

1. INTRODUCTION

During the last decade, many governments have announced new climate change mitigation commitments that include national or regional commitments to reduce their carbon emissions in the 2025-2035 timeframe. The underlying government planning efforts and national actions do tend to be linked with a major transformation in the transport sector toward advanced efficiency technology with a shift to lower-carbon energy sources. Many governments have announced that their original goals will not be met for a variety of reasons, amongst which one of the most important is the lack of skilled and trained personnel with a sufficient level of knowledge in this area. In the last decade, many cities and urban settlements have contributed to sustainable, safe and safer cities, especially pedestrians, users of public transport, cyclists and other public activities, through the design of space and new streets. The approach to space and urban mobility is changing, planners and urban planners are emerging with new ideas, together with the technical professions of traffic and construction engineers, are launching new forms of design that help safe, safe, humane urban living. It is necessary to increasingly form safe mobility zones in urban areas and urban planning system space and area for E mobility. It is necessary to share knowledge and skills across mobility and in particular the increasing supply of E-mobility means in the area of innovation, policies, technologies and investments.

2. MOBILITY

Mobility is defined as the potential for movement and the ability to get from one place to another using one or more modes of transport to meet daily needs. Mobility directly results from social activities such as living, working, relaxing and production, trade and consumption (for goods) [1]. Mobility is experienced differently by different groups of people, and their specific needs should be considered by applying a participative approach and involving users and actors concerned. Furthermore, an integrated and holistic approach should be applied, allowing people to be aware of the interdependencies of actions taken in one area on others (environmental, economic, social and governance).

2.1. E-Mobility

E-mobility represents the concept of using electric powertrain technologies, in-vehicle information and communication technologies and related infrastructure to enable electric propulsion of vehicles and fleets. E-mobility is the principle of using electric drive for a wide range of transport and transport. E-mobility is the concept of using electric powertrain technologies, information, and communication technologies in all means of transport and transport related to infrastructure that enables smooth and independent movement, which includes E scooters, E bicycles, E scooters, E cars, E buses, E trucks, E SUV vehicles, E ships and E aircraft. A common characteristic of all E means of transport and transport is that they are fully or partially powered by electricity, that they have means of storing energy and that they get their energy mainly from electricity (network) through charging stations.

E mobility, and in general low-carbon mobility, is one of the main targets of the European Union's policies dedicated to a green transition. EU policies are promotion of sustainable mobility, and E-mobility in particular. The European Union has long identified E mobility, in the wider context of sustainable mobility, as one of the priorities for the decarbonization of transport in all Member States. E-mobility has been considered as a key transition to overcome the fossil fuel dependency of the EU's transport systems. In accordance with the undertaken initiatives and strategies, the process of E-mobility based on renewable energy sources and the replacement of dirty technologies in the transport system is progressing in the EU countries. E-mobility is an important strategic vector of action to achieving the set goals for zero carbon dioxide emissions. It can be efficiently achieved by gradually employing electric vehicles that will use renewable and clean energy sources.

3. LAND USE TO SUPPORT URBAN E MOBILITY

A lot of cities and urban settlements in the last decade have contributed to safe and safer cities, especially pedestrians, users of public transport, cyclists and other public activities, with the design of space and new streets, and especially by the redesign of space and existing streets. Strategic for support urban mobility and towards inclusive cities It should be carried out through the following activities:

- Create liveable urban spaces.
- Close the knowledge gap.
- Deploy and scale green, safe, and inclusive mobility solutions for people and goods.
- Accelerate market opportunities.
- Promote effective policies and behavioural change.

Adopting the UN Sustainability Goals in particular sustainable cities and communities' development of transport and mobility will be systematically and permanently focused on the development of mobility in the EU, and to stand out in this area as a driver of the process of sustainable transformation towards a low-carbon economy and creating a comfortable living environment focused on citizens and their real needs. Also, when planning space, it is necessary to be guided by integrated space planning in the context of sustainable urban mobility, i.e. that space planning must be oriented from the space for motor vehicles towards the space for human pedestrians and cyclists and citizens who use public transport in their activities in movement and mobility [2, 3].

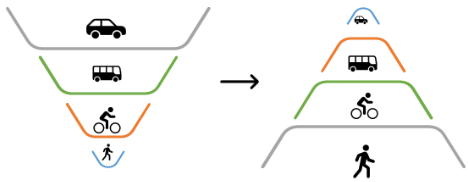

Figure 1. Integrated spatial and urban mobility planning [4]

The aim of the integrated and innovative action to advance sustainable urban mobility is to strengthen European territorial cooperation, focusing on modern urban challenges, through the use of innovative methods and tools, in order to establish integrated action plans that support sustainable mobility [4]. Today, the needs of urban mobility are:

- addressing the challenges of air pollution and urban noise pollution,
- redesigning the mobility model,
- the establishment of new infrastructure that supports innovative mobility,
- continuous restructuring of the public sector in the part of sustainable development of urban environments,
- Cooperation of all city actors to adopt new mobility practices.

3.1 Mobility Hub Concept in Urban Areas

Mobility Hub represent a new concept that offers the potential to 'trigger' change by establishing a visible and very different concept of mobility. Understanding the common process and common solutions adopted by cities would undoubtedly be good to know, capture, codify, and 'package'. Cities must transform their mobile infrastructure and services and the habits society has for moving in and around their cities. Packaging seeks to bring together three things that are not usually addressed commonly in cities: 1. a deep understanding of social wants and needs (the world of community managers); 2. what technical approaches could solve these problems (the engineering world) and 3. what business model and financing options can be used to support implementation (finance). It seeks to encompass functionally common, interoperable, component-based solutions for these needs. Because it is functionally common (as opposed to physically similar), it bypasses the typical concern with 'one-size-fits-all' solutions that cities often impose on the industry. This enables cities to adapt functionally common proven solutions to their unique context. The Mobility Hub concept is based on lessons learned from the example of the City of Milan, as one of the leading cities within Sharing Cities [5], with more than 40 Mobility Hub at different stages of the life cycle process.

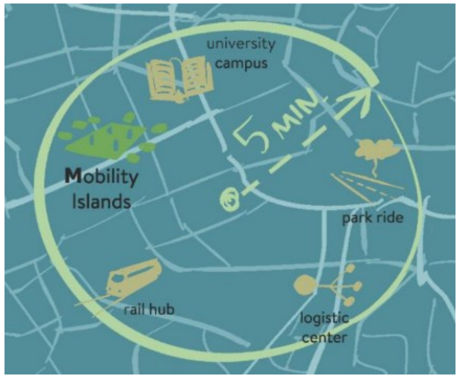

Figure 2. Mobility Hub as a 5-minute city [6]

Figure 3. Mobility Hub (Island) Sarajevo (Skenderija) [6]

4. GOVERNANCE OF SMART AND SUSTAINABLE MOBILITY IN URBAN AND SUBURBAN AREAS

The approach to space, urban mobility is changing, planners and urban planners are emerging with new ideas, who, together with the technical professions of traffic and construction engineers, are launching new forms of design that help safe, safe, humane urban living. The new EU Transport Strategy (Sustainable & Smart Mobility Strategy) [7] is fundamental and will, if successful, change the European transport sector completely with impacts on many other aspects of life such as the economy, environment, and health. The objectives new EU Transport Strategy are (Figure 1):

- ✓ Sustainable mobility.
- ✓ Smart mobility.
- ✓ Resilient mobility.

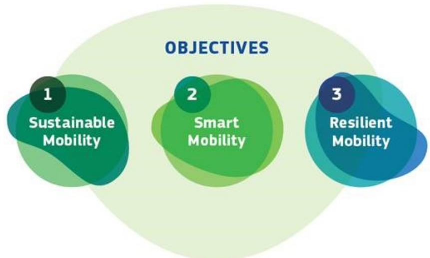

Figure 4. Objectives the New Transport Strategy EU, (2020)

Main topics on the new transport strategy are:
- ✓ Electric mobility,
- ✓ Digitalization,
- ✓ aviation,
- ✓ Sustainable Urban Mobility Plan,
- ✓ Automated driving,
- ✓ Road safety, and
- ✓ Infrastructure.

5. ENGINEERING EDUCATION IN E-MOBILITY

The introduction of new technologies in middle–developed countries (like Western Balkan countries) is still in the development stage, with the very poor economic, technical and educational environment for their application. The education system is not sufficiently developed and adapted to new challenges and is extremely incompatible in terms of supporting the achievement of the green transition goals in the field of E mobility. It is necessary in engineering education to acquire adequate competencies and skills in the field of E-mobility and develop adequate laboratories and practical classes for E mobility. Currently, there are no other available national sources of funding that could significantly increase the developmental level of the WB HEIs (Higher Education Institutions) [8]. Most common education gaps in the everyday use of electric vehicles can be considered from the technical, social, economic, ecological, legal and safety aspects.

- Social Issues: lack of or insufficient knowledge or an inadequate level of education about so-called new mobility culture, that is on benefits of electric vehicles in urban transport system; limited awareness of the privileges of using electric vehicles; lack of proper promotion of the electric vehicles uses.
- Legal Issues: lack or insufficient knowledge about the use of vehicles in electric sharing systems and technical or legal issues related to this.
- Economic Issues: lack of or insufficient knowledge related to the real costs of driving the electric vehicle; lack or insufficient knowledge related to appropriate tax reliefs or other discounts and applicable low-carbon mobility programs.
- Environmental Issues: lack of or insufficient knowledge related to the possibilities of improving the quality of life and the impact on sustainable development due to the

application of EM in practice; limited awareness of the carbon footprint and clean transport zones.
- Safety Issues: lack or insufficient knowledge related to the safety of using electric vehicles, i.e., issues of connecting the vehicle to the charger; concerns about the possibility of electric shock.
It is necessary for engineering education to improve and develop the existing curricula in the field of E mobility, especially in the part Ecological and sustainable design of road traffic, Electro Mobility and Hybrid Technology, Organization and exploitation of Electrical Vehicles, Intelligent Technologies for the Internet of Vehicle, Energy Storage Systems for Electric Vehicles, Electric Vehicle Systems Architecture and Standardization Needs. The aim of the improved study programs is to include different disciplines such as environmental sciences, sustainable transport, and electrical and traffic and transport engineering [8].

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Valentina Ivanović[1]
E-mail: Valentina.Ivanovic@fsk.unsa.ba
Osman Lindov[1]
E-mail: olindov@gmail.com
Nikola Ivanović[3]
E-mail: arhikon.studio@gmail.com
Branka Spasojević[4]
E-mail: brankaspasojevic09@gmail.com
[1] Faculty of Traffic and Communications, University of Sarajevo
Zmaja od Bosne 8, Sarajevo
[3] "Arhikon" Ltd. Design and consulting studio
Srpskih ratnika 47, Pale
[4] Public Institution "Tourist Organization City of East Sarajevo"
Stjepana Lučića bb. Pale

E-MOBILITY CONCEPT IMPLEMENTATION IN THE FUNCTION OF SUSTAINABLE TOURISM DEVELOPMENT MANAGING

Keywords

E-mobility
Traffic
Sustainable development
Tourism

Abstract

Planning as sustainable mobility function requires new approaches and new planning concepts that encourage the transition to cleaner and more sustainable transport modes such as walking, cycling, public transport, new patterns of car use and ownership, and the adoption and use of new technologies as indispensable support for sustainable mobility development. This approach aims to satisfy the mobility needs with a healthier environment and a better quality of life, since healthy and ecologically clean environments are becoming more attractive, both for the local population and for tourists, which can be especially important for those local communities with special tourist potential and developed tourist offer. Given the fact that electric mobility contributes significantly to the climate change mitigation through the reduction of pollutant emissions using different types of electric vehicles, it is necessary to consider the possibility of using e-mobility in order to strengthen the offer of tourist destinations while simultaneously protecting these areas from excessive noise, pollution, usurpation and deterioration of the quality and

appearance of tourist areas. Considering that the city of East Sarajevo, as one of the tourist attractive local communities in terms of the diversity of the tourist offer with a scattered concentration of tourist destinations on predominantly hilly terrain, this paper will present the concept of introducing a bike-sharing system, an electric bus and an eco-taxi vehicle in the function of tourists' transportation system with supporting infrastructure development plan, all based on tourist demand data analysis.

1. INTRODUCTION

In recent years, society is increasingly concerned about the environment and its pollution. State authorities strive to encourage society for accepting and using sustainable modes of transportation through their active commitment and action, both through the legislation creation and through the financing system. Consequently, a lot of people are accepting sustainable ways of mobility, whether it is due to personal attitudes and beliefs, or achieving certain savings or due to media pressure.

Tourism, as one of the non-productive branches of the economy, significantly affects the environment quality, due to mobility as the main actuator of tourism, and also because of the natural potential's degradation and area disruption. It is estimated that tourism on a global level contributes to the total world emissions of greenhouse gases with about 5%, of which about 40% belongs to aviation, 30% to automobile traffic and 20% to tourist accommodation.

2. SUSTAINABLE MOBILITY MANAGEMENT IN TOURISM

The precondition for sustainable tourism development is transport infrastructure development, so there must be a well-designed transport policy that meets current and future transport demand with the application of sustainable modes and transport technologies. In this sense, we should strive towards the strengthening and development of sustainable mobility, because a sustainable transport system in tourism means sustainable tourism at the same time.

"A tourist place is considered to be one that meets the following basic conditions [1]:

- attractive (natural beauty, healing springs, cultural and historical monuments, various cultural, entertainment and sports events, etc.),
- communicative (possibility of access, traffic connections, etc.),
- receptive (accommodation facilities and accompanying facilities required for the provision of various services – trade, craft, PTT services, etc., as well as parks, swimming pools, promenades)."

It is concluded that a certain place could not be categorized as tourist, regardless of its tourist potential, without adequate traffic communication.

2.1. E-mobility system planning in the function of tourists' transportation

Electromobility (e-mobility) is a new mobility concept in urban areas that represents one of the most efficient and environmentally friendly transportation modes, which aims to achieve a sustainable balance between people, electric vehicles and the environment. This type of vehicle includes electric buses, electric taxis, electric bicycles, mopeds and electric scooters [2]. E-mobility has a positive effect on the greenhouse gas emissions reduction, as studies show that the reduction of CO_2 is from 11% up to 100% if the electricity for charging the vehicle is produced from renewable sources [3].

In order to minimize the harmful mobility impact in tourism on the environment, it is important to develop strategies to bring more people to their vacation spots in an environmentally friendly way, by establishing an adequate passenger transportation system to/from accommodation facilities, taking into account the comfort of passengers, their luggage and the spatial distribution of accommodation capacities. The biggest problem in traffic planning is the seasonal traffic capacities use and the uneven distribution of tourist flows, so it is necessary to find an adequate way of deploying and introducing sustainable e-mobility systems that can serve all categories of tourists in high tourist demand periods, depending on the electric way of transport type, distance and type of terrain where transportation is carried out.

For a detailed planning e-mobility process in tourism, input parameters related to tourist flows are necessary, such as number of tourists on an annual, semi-annual (seasonal) and daily level, the age and gender tourists' structure, the number of tourists visiting certain tourist attractions, data on existing road infrastructure and public transport, parking spaces, etc.

2.2. Model of implementation of the e-mobility system in the tourist offer of the City of East Sarajevo

Due to the great tourist potential in the city of East Sarajevo area, tourism represents a strategic economic branch. The most important tourist facilities that are available to tourists in this area for tours are mountains for winter and summer tourism (skiing, children's winter sports, mountaineering, mountaineering, recreation, adrenaline sports, paragliding, gondola rides), cycling, speleological facilities, picnic areas, waterfalls, lakes, sources of rivers, etc. The most frequently visited tourist destinations are Jahorina (Dvorišta), Trebević (Brus, Tvrdimići) and Romanija Mountain, Ravna Planina, The Orlovača Cave and the Miljacka Spring.

The proposed concept of implementing the e-mobility system is based on the assessment of tourist demand in the winter and summer seasons and the most visited City destinations data. This concept in terms of available transport capacities can satisfy the needs of sustainable mobility in a trial period of exploitation, where it is necessary to provide the expanding capacities and supporting infrastructure possibility in accordance with the tourist needs determined on the functionally designed and developed system basis of monitoring and data recording. In connection with this, it would be necessary to predict the possibility of introducing the following measures as soon as possible:

- Restriction of entry into the tourist destination area without prior notice;
- Adoption of regulations that will regulate the practice of submitting data on the number and structure of tourists who rent accommodation;
- Increased inspection supervision regarding the rental of accommodation facilities;
- Establishing quality cooperation between the Tourist Organization, authorities, inspection authorities, restaurants and transport companies in order to data exchange;
- Establishing of e-reservation system and purchase of transport tickets.

According to the data of the Statistical Office of the Republic of Srpska on tourist arrivals and overnight stays by municipalities and cities in 2021, about 82% of arrivals and about 91% of overnight stays were realized in the area of the municipality of Pale out of the total realized in the city of East Sarajevo area [1], [3]. According to the data on the number of ski passes sold in the winter tourist season on a daily basis, which is about 20,000, it can be concluded that there is a great need for mobility on a daily basis. Tourist flows are served by traditional ways of transport (passenger cars and buses powered by internal combustion engines). Hereof the need to start the process of implementing the sustainable e-mobility concept as soon as possible.

The proposed E-mobility model of the tourist transport system in the city of East Sarajevo includes the following:

- Bike-sharing system of electric bicycles with accompanying infrastructure;
- Electric buses with accompanying infrastructure;
- Eco-taxi service for transporting tourists within and between tourist centers.

The most optimal solution for the positioning of the e-mobility main center is the location "Famos" next to the main (transit) road in Pale, where is planned the departure station of the gondola to Jahorina. Within the facility of this e-mobility center would be the main e-bus departure point, a space intended for electric bicycles based on the bike-sharing system principle, and a place for eco-taxi vehicles, all with accompanying charging infrastructure connected to solar panels (e-charging stations with 22kW power with a charging time of a completely empty bus battery in about 8.5h and at least two up to 150kW power with a charging time of about 2.5h) and adequate parking space. There is also planned a space for providing tourist information and services, as well as buying train tickets and renting bicycles.

For the e-bike-sharing system functioning purpose, it is also necessary to install rental equipment in Jahorina and Trebević. In order to serve tourists with electric buses, it is planned to introduce at least three departures (morning, midday, evening) from Pale on the routes Pale-Dvorišta-Jahorina, Pale-Sumbulovac (The Orlovača Cave)-Romanija, Pale-Trebević (Brus)-Tvrdimići, which will be served by two electric buses. For the e-buses function, it is necessary to install one arranged stand in Dvorište along the main road, one stand in Trebević (Brus) with an e-charging station and one arranged stand in Romanija. When planning the installation of equipment, the locations of existing e-charging stations should be taken into account. All existing bus stands can be used for the passengers entry and exit, with the fact that they need to be arranged and adapted for tourists (tourist maps with all important information about transportation) and, if possible, equipped with wi-fi internet. For eco-taxi transport services, in addition to the main stand in Pale, it is necessary to install stands in Jahorina and Trebević (Brus) with e-charging stations. There is a possibility that the number of places intended for eco-taxi vehicles can be increased for already existing taxi stands by decision of the City, without endangering private taxi carriers.

Figure 1. E-mobility center Pale [5]

The proposed e-mobility model was suggested on the situation in terms of different distances between tourist attractions and accommodation facilities, the possibility of overcoming different distances on extremely hilly terrain, the diverse structure of tourists in terms of age and ability, the possibility of communication with remote places and monitoring current needs and tourist movements. However, in order to more precisely determine the required number and capacity of vehicles, their schedule depending on the period of the day and season, and to create a timetable for electric buses, it is necessary to carry out more detailed analyses.

Prerequisites for the e-mobility system implementation:

- Create a sustainable urban mobility plan for the City of East Sarajevo with precisely defined measures and activities with strict monitoring and evaluation process;
- Approach changes in regulatory plans in order to systematically solve traffic infrastructure problems in accordance with the sustainable urban mobility plan and regulations;

- Establish an electronic system for quality monitoring of tourist flows (by introducing mandatory prior announcements of visits to each tourist destination);
- Access to rehabilitation of existing and construction of new traffic areas;
- Application of traffic policy instruments regarding to more expensive parking fees or payment for the accommodation facilities access roads use or tourist centers for passenger vehicles with internal combustion engines, depending on the possibility of legal regulation of such measures;
- Logistics problems solving system, i.e. supply of accommodation and other catering facilities in terms of time service time and type of vehicle for logistics;
- Informing public about new sustainable transportation modes;
- Creation of accurate maps of tourist centers in digital (with navigation) and printed format, with all essential data and information;
- Solving the problem of digitization and public access to wi-fi internet in tourist areas, especially in rural areas, in order to facilitate the sustainable transport use;
- Establishing cooperation with sustainable mobility companies and the electric vehicles sale/rental companies with the aim of obtaining possible subsidies;
- Establishing cooperation with an electricity supply company in order to conclude special contracts on subsidies for vehicle charging;
- Formation of the ownership structure at the level of the City over the e-mobility system;
- Establishing cooperation with transport companies;
- Adoption of regulations on taxi transport in terms of subsidies provision for e-vehicles;
- Defining an appropriate and non-discriminatory tariff policy for transport services by sustainable mobility forms, with the provision of introducing privileges/rewards for using e-mobility instead of traditional transport forms.

3. THE SIGNIFICANCE OF E-MOBILITY SYSTEM IMPLEMENTATION IN TOURISM

In modern globalization, we are faced with rapid economic growth as well as its negative environment impact. If we take into account the fact that both traffic and tourism are a segment of the economic system of a country, it can be concluded what consequences their synergy has on the environment. However, in recent years, interest in ecologically clean and sustainable modes of transport has expanded, thus creating the basis for the sustainable tourism development.

The benefits of sustainable mobility and sustainable tourism can be felt most by those local communities that have significant tourism potential and have developed tourist offer, one of which is the city of East Sarajevo. The advantages of the e-mobility system implementation in the function of sustainable tourism development of the City of East Sarajevo are:

- Environmentally friendly ways of transporting without harmful gases emissions;
- Easier fleet maintenance due to efficient vehicle operation;
- Possibility of cheaper charging and cheaper self-driving;
- Significant noise reduction in tourist centers;

- The sustainable transport using possibility for the needs of the local population;
- Relieving the traffic network and preserving its quality;
- Reducing the need for additional parking facilities;
- Preservation of areas, as well as the natural beauty of tourist destinations;
- Preservation of the life quality of the population in rural areas;
- Possibility of contribution to tourism by the rural areas population;
- Easier and more financially acceptable communication with extremely rural areas;
- The possibility of planning transport capacities depending on tourist demand.

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Danijela Senić[1]
E-mail: senic.danijela@uns.ac.rs
Valentina Mirović[1]
E-mail: plast@uns.ac.rs
Jelena Mitrović Simić[1]
E-mail: mjelena@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21000 Novi Sad

MICROMOBILITY – USERS' NEEDS AND ATTITUDES

Keywords

Micromobility
Bicycle
Survey
Charging stations
Cyclotourism

Abstract

Micromobility has appeared as a traffic term with the electrification of typical transport means for short relations, such as an ordinary bicycle and a scooter. The paper contains basic information on advantages and disadvantages of micromobility. The paper shows the results of a research study which was conducted as an online survey of micromobility users. The aim of the research study was the overview of the current state regarding the possession of micromobility devices, that is, obtaining information from the respondents related to their plans of micromobility devices purchase in the following two years. Apart from this, the emphasis was on the opinions of the current and future users on the selection of the locations for setting up the micromobility charging stations and on the acceptable time for their recharging.

1. INTRODUCTION

Cycling has become a general phenomenon recently although the bicycle itself has been used since the nineteenth century in Europe. With the introduction of electrification in transport means, new types of vehicles have been created, that is, micromobility devices. A new term also appeared, micromobility.

With micromobility devices a series of new advantages appeared, but downsides, as well, that is, problems. Cycling in a classic sense is directly related with minimum three fields: traffic, medicine and ecology. With micromobility there is a tendency to keep the mentioned fields as primary ones, that is, to reduce traffic congestion in cities with the use of micrmobility, to preserve the health of the population, to pollute the environment as little as possible, that is, to enable recharging of micromobility devices on the charger which uses renewable energy resources.

Further in the paper, there is information related to the basic characteristics and categories of micromobility devices, as well as the data and results of the research study conducted this year.

2. BASIC CHARACTERISTICS AND CATEGORIES OF MICROMOBILITY

In the previous period, due to the non-existence of accurate and clear divisions, demands and definitions of micromobility devices according to the current Law on Traffic Safety on Roads [1] and Regulation on the Classification of Motor Vehicles and Trailers and Technical Requirements for Vehicles in Road Traffic [2] cities faced significant problems regarding micromobility traffic. Those problems were primarily related to the surfaces designated for their motion, space sharing with other transport means and with pedestrians, safety of micromobility users, and minimal requirements for micromobility devices recharging which should be fulfilled by the cities. The aforementioned problems and doubts should be solved with a change and amendents to the current legislation and adopting new regulations in this field, which is currently being done.

Micromobility represents a set of micromobility devices which can be grouped in the following way: pedelec (maximum continuous rated power is 250 W), lightweight e-bicycle (1,000 W), heavyweight e-bicycle (4,000 W), e-scooter (600 W) and other vehicles of micromobility (500 W), which include hoverboard, segway, e-skateboard and e-roller [3]. Micromobillity devices are currently using batteries such as: SLA (Sealed Lead Acid battery), NiMH (Nickel Metal Hydride battery) and Li-ion (Lithium-ion).

According to Legal Framework and Guildelines for Implementation in the Republic of Serbia a group of experts has determined 11 constructive-technical characteristics which are the miminum to be met by micromobility vehicles. They are: maximum design speed, maximum continuous rated power, maximum vehicle width, maximum vehicle length, minimal wheels dimensions, braking system, minimal clearance, the possession of a device for sound signals and warnings, the possession of a vehicle lighting system, walking mode and the possession of a steering wheel. In some countries, such as Italy, Austria and the United Kingdom, there is legislation in force covering micromobility. In accordance with foreign legal regulations, best practice experiences, and recommendations, Legal Framework and Guildelines for Implementation in the Republic of Serbia has been given requirements for the use of micromobility vehicles. The requirements have been grouped into: approval of the type before the use, vehicle registration, periodical testing, driving license, users training, knowledge of traffic regulations, insurance, wearing a protective helmet, wearing high-visibility clothing in low-visibility conditions, minimal age of the user, as well as the speed limit [3].

The advantages of electric bicycles for individuals are: travelling a longer distance with the same energy consumption, and even less in relation to classic bicycles.

On the basis of the research study conducted by German Federal Environmental Agency, it can be concluded that classic bicycles are faster than cars within the range of 5 km, while an e-bicycle is faster than a car within the range of 10 km to 20 km. When using e-bicycles and other micromobiles, natural obstacles (ascent) and weather conditions (headwind or crosswind) are not a challenge, as is the case with a traditional classic bicycle. New micromobility vehicles offer a mobility chance to a group of population which has not been able to use the conventional bicycle due to different health issues.

Micromobility vehicles can be integrated into the combined passenger transport, that is, they can be used at initial and final kilometres of their journeys.

Currently the biggest disadvantages of micromobility are the price of these transport devices in relation to the classic bicycle, lower subventions in relation to electric cars, and the fact that national and European strategies have not been defined properly [4].

Nowadays micromobility is mentioned when talking about smart cities, which successfully manage their resources (first of all, renewable energy sources) in order to improve life quality of their residents.

3. RESEARCH METHODOLOGY AND RESULTS

For the needs of this paper an online survey was conducted and its respondents were micromobility users. The online questionnaire was available in the period between 10.8.2023 and 27.8.2023, when 161 questionnaires were completed. The respondents were mostly the members of different cycling associations / clubs, such as: 'Novosadska Biciklistička Inicijativa' (Cycling Initiative of Novi Sad), association of cyclists 'Drumski vozači' (Road Riders), group 'Bicikliramo' (We Are Cycling), 'Tour de Délvidék' and a group of students from the Faculty of Technical Sciences in Novi Sad. If we consider the spatial scope of the analysis, it can be said that most of the responses were from the territory of the Autonomous Province of Vojvodina, that is, from Novi Sad and the surrounding settlements which gravitate towards the city.

According to gender structure, 54.66% of the respondents are male, while the remaining 45.34% are female. Regarding employment, more than a half of the respondents are employed (55.28%), then there is a group of students with 37.27 %. The third place with 6.21% is the category of the unemployed. The last group is made of the retired, with 1.24%. The respondents belong to the following age groups: no respondent was younger than 18, those aged between 19 and 26 make 46.50%, aged between 27 and 35 make 15.92%, aged between 36 and 50 27.39%, aged between 51 dand 65 make 9.55% and those aged over 65 make 0.64%.

Figure 1 shows the current state of micromobility use. Based on the answers of the respondents, it can be concluded that 90.91% of the surveyed are still using the classic bicycle. In the category of micromobility devices, e-scooters participate with 5.11%, after which there is a group of light e-bicycles with 2.27%. In the third place there is the category of pedelec with 1.14%, while in the last position there are heavy e-bicycles with 0.57%. There were no users of hoverboard, segway and e-skateboard among the respondents. It is extremely important to study the users' plans for further analyses and the possibilities of planning for their own benefit. Out of all respondents, 56.40% is not planning the purchase of a micromobility device in the following two years. Most of the respondents would invest into a classic bicycle, with 19.77%, while 9.88% would like to buy a light e-bicycle, e-scooter 6.40%, pedelec 4.07%, heavy e-bicycle 2.33%, while hoverboard and e-skateboard – less than 1%. The above mentioned results have been shown in Figure 2.

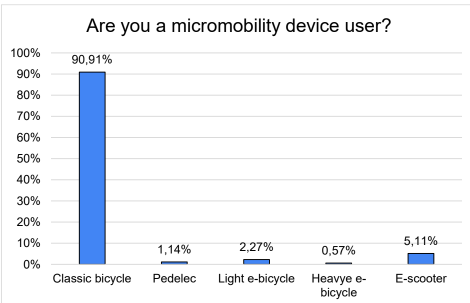

Figure 1. Current micromobility users

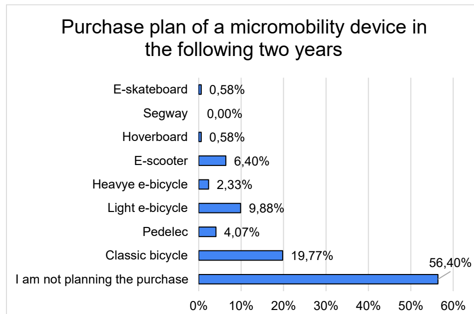

Figure 2. Potential micromobile users

Currently 80% users recharges their transport devices at home, while only 20% has a chance to recharge their micromobility devices while they are at work (Figure 3).

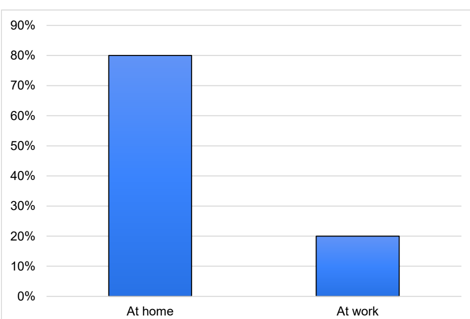

Figure 3. Current charging location

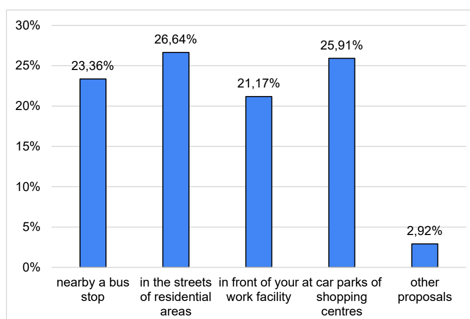

Figure 4. Preferred sites for future charging stations

The respondents were asked in the survey where they would put micromobility chargers if they could affect the location determination. The result was the following: 26.64% of the respondents voted for placing the charging stations in the streets of residential areas, 25.91% would choose the ones at the car parks of shopping centres, 23.36% of the respondents suggest having a charging station nearby bus stops and 21.17% think that they should be in front of the facilities where they work. The remaining 2.92% have another proposal (Figure 4).

Figure 5 shows the percentage amount of the acceptable time of charging of e-scooters and e-bicycles. According to the received responses, it can be concluded that a significant percentage, more precisely 75.46% of the respondents think that the accpetable micromobility charging time is less than 4h. Then, in the secoond position,19.33%, there is a group of respondents who think that the acceptable charging time is between 5 and 6h. For a significantly less percentage, that is, 2.97% of the respondents think that the appropriate charging time is between 7 and 9h, and the remaining 2.23% would accept their micromobility device charging time longer than 9h. It is important to determine the acceptable distance of the charging stations in the street network. In Figure 6 it can be noticed that 16.87% of the respondents want that there is a charging station at every kilometre, 56.25% think that the most adequate distance is between 2 and 4 km, 21.88% of the respondents are in favour of the distance between 5 and 7 km and the remaining 5% are in favour of the distance which is over 7 km.

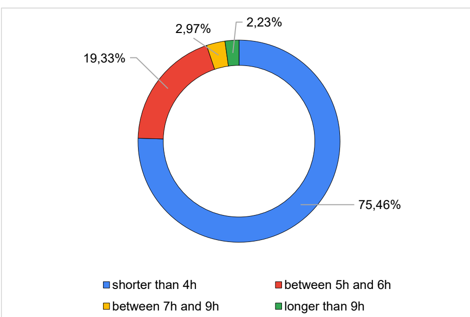

Figure 5. Acceptable micromobility charging time

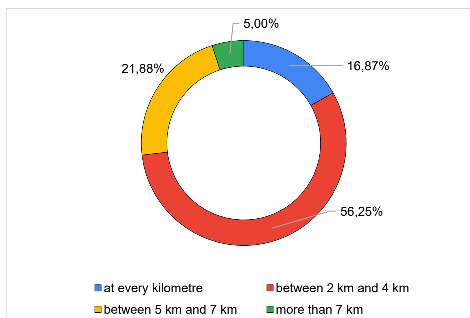

Figure 6. Acceptable distance between charging station

During the analysis an emphasis was on the separation of the classic bicycle from the micromobilitydevice. Out of the total number of classic bicycle users, 58.50% are not cyclotourists, while 13.61% are currently cyclotourists. The remaining 27.89% would choose cyclotourism if there were charging stations for micromobility devices on cycling routes (Figure 7). When it comes to the analysis of micromobility and cyclotourism (Figure 8) it should be emphasised that 57.14% of the users do not use their own micromobility devices for the purposes of cyclotourism. Among the micromobility respondents 28.57% are simultaneously cyclotourists, while only 14.29% would be cyclotourists if there were charging stations along the routes.

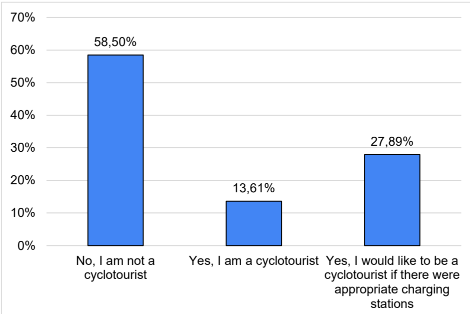

Figure 7. Cyclotourists (classic bicycle)

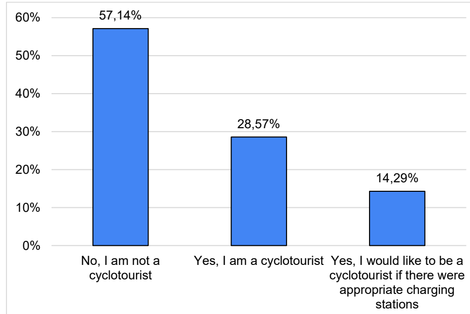

Figure 8. Cyclotourists (micromobility)

4. CONCLUSION

After the analysis of the data obtained in the online survey, it can be concluded that currently over 90% of the respondents use a classic bicycle and only 9.09% are the users or owner of some type of a micromobility devices. Regarding plans for the purchase of a micromobility device in the following two years, out of the total number of the surveyed respondents, 56.40% do not plan a purchase of new transport means, 19.77% want to buy a classic bicycle and 23.83% have a short-term plan of a micromobility device purchase. It should be emphasised that without any campaigns, advertisement or education, more than 20% want to be the user of a micromobility device. This percentage can be significantly increased if certain measures are taken to stimulate the use of this transport mode. Based on the obtained responses of the current micromobility users, 80% recharg their transport means at home and only 20% at work. This distribution implies that currently the number of micromobility charging stations is insufficient. In future the emphasis should be placed on the environment protection, which is only possible if the charging stations are the ones which generate electricity from renewable energy sources. The first step is to enable subsidization of these charging stations which are first ot be installed in front of public institutions, in front of work facilities, nearby bus stops, at car parks of shopping centres and in the streets of residential areas. Apart from this, it is necessary to determine precise locations of charging stations at the city and community level.

According to the obtained data, most respondents, that is, 75.46% think that the acceptable charging time is shorter than 4h. The acceptable distance between the charging stations is from 2km to 4km for 56.25% of the respondents, that is, 21.88% of the respondents say that it is acceptable if they are between 5km and 7km. It is necessary to emphasise that proper functioning and use of micromobility is possible if cities have their own maps within applications showing the precise locations of the stations. When considering cyclotourism, classic bicycle users mostly are not cyclotourists, but 27.89% would become cyclotourists if in the future there are charging stations. Micromobility users mostly are not cyclotourists, although 28.57%

of the respondents are, that is, additional 14.29% of the respondents would be if there are charging stations at certain locations.

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Marko Slavulj[1]
E-mail: mslavulj@fpz.unizg.hr
Hrvoje Prskalo[2]
E-mail: h_prskalo@yahoo.com
Hrvoje Pavlek[3]
E-mail: hrvoje.pavlek@yahoo.com
Luka Vidan[1]
E-mail: lukavidan1998@gmail.com
[1] University of Zagreb Faculty of Transport and Traffic Sciences
Vukelićeva street 4, City of Zagreb
[2] City of Berlin
Stefan-Heym-Platz 1, 10367 Berlin
[3] Zagreb Holding Ltd, Zagreb parking Subsidiary
Šubićeva street 40, 10000 City of Zagreb

GOOD PRACTICE EXAMPLES OF MOBILITY AS A SERVICE IN GERMAN CITIES

Keywords

Mobility as a Service
Sustainable mobility
Mobile application
Shared mobility

Abstract

Mobility as a service (MaaS) is a new way of offering sustainable mobility in cities centered on the person, i.e. the user, who chooses the way to travel to the destination according to individual preferences via a mobile application. All the necessary actions such as: planning, choosing the mobility method and paying for the trip, as well as providing all the relevant information about the trip in real time, are in the user's hands, using the application on their smartphone. By purchasing a mobility service as needed or as a monthly tariff, buying, owning and caring for your own car becomes unnecessary, which has a positive effect on city traffic and urbanism. This could become an effective way of sustainable urban mobility, which does not create traffic, but is aimed at achieving mobility through public transport and ride-sharing services or vehicles, mainly electric, which has a positive impact on the climate. Powerful and available information and communication technology and access to MaaS business models are essential prerequisites for general acceptance and increased use of the service. Objective of the research in this paper is to show the services, application and advantages of different MaaS mobile applications in 5 German cities and highlight their special features. The purpose of the paper is to show the increase in the use of sustainable modes of mobility in cities through examples of the use of MaaS mobile applications. Finally, the paper presents conclusions and suggestions for further development and improvement of mobile applications to strengthen the MaaS service.

1. INTRODUCTION

At the core of the Mobility as a Service (MaaS) concept lies the user and their mobility needs, aiming to provide optimal mobility services without the necessity of car ownership or other means of transportation, in a sustainable manner. Rather than purchasing a car, users can access suitable mobility services through a mobile application (alternatively via computer) tailored to their individual preferences, facilitated by digitalization. Private cars are typically used for only one hour per day on average, remaining idle for 23 hours, incurring associated costs, and simultaneously occupying already limited public spaces, which is not sustainable. The "Mobility as a Service" (MaaS) concept is made available to users through a digital platform (mobile application) that offers easy access to existing mobility options such as public transport and sharing services.

The second variant of "Mobility as a Service" includes subscription-based models, where users can choose from different mobility packages, similar to mobile phone plans. For pre-booked routes, credits are deducted from the respective package based on the transportation mode used. An example of this offering is the multimodal mobility service provided by UbiGo in Stockholm. The service includes unlimited usage of public transport and packages for carsharing, rent-a-car, taxi, and bike sharing. Ordering and payment are facilitated through a smartphone application, and the bill can be shared within a household. During the test phase in Gothenburg, participants' car usage was reduced by half. At the same time, satisfaction with their mobility increased from 19% to 51%.

Passenger transportation accounts for almost two-thirds of emissions. Mobility as a Service can help change mobility-related behaviors. An important prerequisite for the successful acceptance of "Mobility as a Service" by the population is a dense public transport network with frequent connections, sharing services, and the availability of on-demand options through the mobility-as-a-service platform. Rural regions require more flexible mobility solutions, such as on-call shared taxis. These demand-responsive offerings must be integrated into the offerings of transportation associations [1].

2. GERMAN MARKET

A significant step towards Mobility as a Service has been achieved in Germany with the introduction of e-scooters. Today, brands like Voi, Bird, or Lime are a common sight in the urban landscape of many European cities. It is estimated that there are around 50,000 shared e-scooters in Germany, with approximately 15,000 of them in Berlin alone. The total sales of the shared e-scooter segment in Germany amounted to 72 million euros in 2019, and by 2022, it has more than doubled, reaching 176 million euros. The number of users has also increased from 4.4 million in 2019 to nearly 10 million currently. However, according to projections, the trend is expected to stabilize soon and reach around 200 million euros by 2025. Uber already has concrete plans in the area of self-driving cars, while other providers like Bolt are making their way into the German market, catering to the low-cost segment.

3. AUTONOMOUS MOBILITY AS A SERVICE – FUTURE OF URBAN TRANSPORT

Promising further development in MaaS technology involves the integration of autonomous transportation. Numerous attempts are already being made worldwide in this direction. In Germany, the first autonomous bus was put into operation in 2017 and continues to operate smoothly on its routes in several cities. Companies like Amazon and Postmates are also investing in this field and aiming to provide autonomous delivery services. Postmates even received conditional approval to test its delivery robot called Serve, allowing them to conduct tests in San Francisco for 180 days. Amazon announced that its delivery robots called Scout are now operating in Irvine, California. MaaS is less widespread in the United States compared to Europe, likely because Europe has more international cities in a smaller area. However, being ahead of the American market in this emerging sector is a rather unusual phenomenon [2].

4. EXAMPLES OF MAAS IN GERMAN CITIES

4.1. Stuttgart

Mobility Stuttgart is a multimodal mobility platform that integrates public and private mobility services from the city of Stuttgart and surrounding areas into a single mobile application. Currently, 13 cities and municipalities participate in the Mobility Hub, which offers a base for mobility services, providing services like Park&Ride spots and rental of shared vehicles (carsharing, e-scooters). From public transportation to ridesharing and vehicle-sharing services, the application offers door-to-door trip planning, reservation, and payment for services, as well as Park&Ride services with a display of available parking spaces. The ultimate goal is to reduce or eliminate the use of private cars. The application helps users choose the fastest routes and considers personal travel preferences, such as mode of transportation. Real-time travel information, including disruptions, delays, and alternative routes, is provided, along with push notifications for transfers and audio navigation. The app also offers ticket purchase suggestions based on the selected travel route. [3]

On-Demand-Service Stuttgart

Stuttgarter Straßenbahnen (SSB) offers on-demand mobility service through their SSB-Flex app, utilizing mini-buses that are more efficient compared to traditional taxis. This service allows for ridesharing, which means transporting multiple passengers within the same time frame or on similar routes, making it a cost-effective and environmentally friendly option. SSB-Flex complements public transportation where it may not be extensively developed, especially in the outskirts of the city [4].

4.2. Hamburg

The easiest way to meet mobility needs sustainably in the city of Hamburg is by using the unique mobile platform through the "switch" application, which consolidates all relevant mobility services. Currently, Hamburg boasts over 1,500 sharing vehicles. Through ride-pooling, where passengers with similar routes are grouped together, service providers aim to reduce costs and offer prices up to 40 % lower than local taxis, depending on the time and route. On-demand mobility is achieved by ordering taxis through the app and sharing the ride with other passengers, thus reducing costs for all travelers. Citizens and visitors can currently rent one of 2,600 bicycles from 220 stations. The service is being expanded to 350 stations and 4,500 bicycles. What makes this offer particularly attractive is that the first half-hour of bicycle use is free of charge [6].

In order to shorten commutes, reduce traffic, and save time, Hamburg has set the ambitious goal of creating a "15-minute city," where all essential needs of the population can be met within a maximum of 15 minutes of travel time. The aim is to design a city where residents can easily access amenities such as schools, workplaces, shops, parks, and other services within a short distance from their homes, promoting convenience, sustainability, and a higher quality of life [7].

4.3. Mobil-flat, Augsburg 2018 – today

The municipal utility company, Stadtwerke Augsburg, manages the public transportation system in the city of Augsburg, Germany. In addition to trams and buses, Stadtwerke Augsburg also operates the city's only carsharing system (both free-floating and station-based) and a bike-sharing system. This multimodal service portfolio allows Stadtwerke Augsburg to position itself as both a public transportation operator and a mobility service intermediary [8].

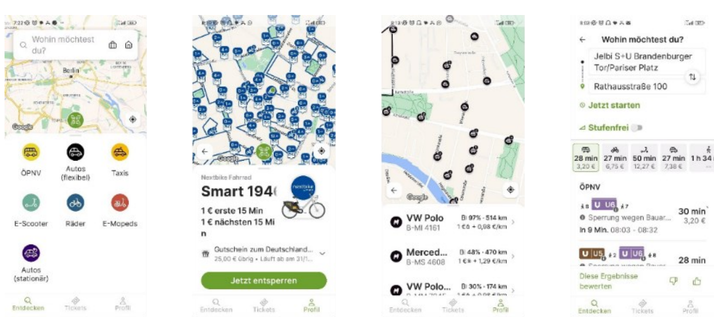
Following its long-term multimodal mobility strategy, Stadtwerke Augsburg launched a MaaS project called "Mobil-Flat" in October 2017. Around 50 residents of Augsburg were invited to subscribe to a mobility package for a one-year trial. While the overall goal of MaaS journeys for Stadtwerke Augsburg is customer retention, the objective of this initial trial was to learn about travel behaviour under the influence of the package [9].

The tested package included a monthly budget of 30 hours for carsharing (any vehicle, unlimited distance), an unlimited number of 30-minute bike-sharing trips, and a citywide public transportation pass. The price of the package was 75 euros, which, in comparison to the minimum price of 110.5 euros for individual services (52.5 euros for public transportation ticket, 48 euros for carsharing without additional charge per kilometre, and 10 euros for bike-sharing), offered cost savings.

Participants were asked to keep a simple mobility diary throughout the program to enable research and package development. Leveraging the analysis of trial reservation data, Stadtwerke Augsburg improved its subscription packages and launched the first two commercial multimodal subscription packages in Germany on November 1st, 2019. The first package ('swa Mobil-Flat S') was a slightly smaller version of the trial package, offering 15 hours of carsharing (half of the trial version) and the same budgets for public transportation and bike-sharing, at a price of 79 euros per month. The second package ('swa Mobil-Flat M') essentially continued the trial package at a price of 109 euros per month (after an initial discounted price of 79 euros per month for the first 6 months). The initial acceptance of these packages was promising, with around 150 applications received in the first 2 weeks [10].

4.4. Berlin

The mobile application "Jelbi" offers all mobility services in Berlin in one single app, with over 40,000 vehicles from all partners and the Berlin Public Transportation Company (JGP), so to speak, "all in one place." No need to install other additional apps to access mobility throughout Berlin and its suburban areas. After selecting the desired location, multiple transportation options are provided, with a focus on sustainability and healthy mobility choices. All types of tickets are available in digital form after purchase. The majority of sharing vehicles are electric, contributing to eco-friendly transportation. Increasingly, ride-sharing services are being offered, where passengers benefit from shared routes with multiple travellers, resulting in lower costs per ride. The app clearly compares different offers based on duration and price, allowing each user to easily book the most suitable option depending on the occasion, weather conditions, cost, or availability. Mobility hubs are strategically located near major JGP transit hubs, train stations, or areas with high foot traffic, both in the city centre and the outskirts. These hubs facilitate seamless transfers between public transportation and sharing options, as they provide a comprehensive range of urban mobility services in one place. Jelbi stations also offer additional amenities, such as internet access, package stations, and electric vehicle charging points, enhancing the overall user experience [11].



a) b) c) d)

Figure 1 a) Choices for modes of transport b) Price display for individual modes of mobility c) Displaying the location of bicycles for rent and prices near your location d) Locations and prices for carsharing vehicles

Figure 1 a) is the home screen of the Berlin mobile app Jelbi, where the destination is entered while simultaneously selecting the preferred mode of sustainable mobility. Figure 1 b) shows the point of departure, the destination with the highlighted price of the modes of transport offered and the duration of the trip. Figure 1 c) shows the location of rental bikes near your current location, the number of bikes available and the rental price. Figure 1 d) shows the location of electric car rentals near your current location, along with the type and registration number of the vehicle for faster finding, the battery condition, the maximum number of kilometres that can be travelled with the current battery condition, and the rental price, i.e., per kilometre travelled.

The micro-mobility sharing sector, including e-scooters, bicycles, and e-mopeds, has nearly 65,000 vehicles available, with e-scooters being the most prevalent, totaling 48,000 vehicles. Additionally, there are around 7,300 carsharing vehicles, consisting of 7,000 free-floating vehicles and 300 vehicles available at rental stations. Currently, Berlin has 1.98 carsharing vehicles per 1,000 residents, making it the third-largest city in Germany in terms of carsharing availability [12].

5. CONCLUSION

Mobility as a Service is really about users and mobility, as the mobility platform is available through a free app to the vast majority of the population via their own smartphones. It is the availability, the practicality of handling and the application adapted to the individual needs of the user that guarantee an increase in interest and the realization of a sustainable way of multimodal mobility through the MaaS service. The most widespread vehicle in the carsharing service is the e-scooter, with around 50,000 vehicles in Germany, of which 15,000 vehicles are in Berlin. Common to all applications in the mentioned cities are basic functions such as: planning, reservation, payment for driving services, travel information in real time, as well as the offer of public and private transportation services.

A very important service, which not all cities have, but Berlin, Hamburg and Stuttgart, is on-demand mobility, which strengthens mobility in the outskirts of cities with weaker coverage by public transport and sharing services. Berlin has a large number of Jelbi mobility hubs near the station and larger passenger transfer points, where sharing vehicles (bicycle, e-scooter, e-moped, e-car) can be booked in advance and continue the journey in a sustainable way. Jelbi offers a monthly ticket through the application and a €25 start package for mobility services with the aim of attracting new users.

Only the city of Augsburg currently offers in Germany through its application "swa Mobil-Flat" the possibility of monthly or annual subscription of a certain package for the use of MaaS services. This offer is practical, because the costs of all multimodal mobility services are calculated automatically in the form of deducting the monthly amount of the selected tariff option. The user should only choose the mode of mobility, i.e., the means of transport, with which he wants to make trips and should not deal with paying for each trip.

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9th INTERNATIONAL CONFERENCE
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Filip Dobrić[1]
E-mail: filipdobric@yahoo.com
Miljana Djukić[1]
E-mail: miljadot@gmail.com
Mladen Dobrić[2]
E-mail: dobric_mladen@yahoo.com
Milan Simeunović[1]
E-mail: milansim@uns.ac.rs
[1] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad
[2] Faculty of Economics and Engineering Management (UBAINS)
Cvećarska 2, 21000 Novi Sad

UNINTERRUPTED PASSENGER TRANSPORT – E-SCOOTER TRANSPORTATION TRAILERS

Keywords

E-scooter
Bus trail
Mobility
Transport

Abstract

Recent years brought the rise in electric scooters (e-scooters) use that has transformed urban transportation and general mobility. These compact and eco-friendly vehicles provide an efficient means of commuting within cities. Challenge lies in integrating e-scooters into existing public transportation systems. Bus trailers offer a promising solution, enabling convenient and sustainable e-scooter transportation.

1. INTRODUCTION

In recent years, the rise of electric scooters (e-scooters) has transformed urban transportation. These compact and eco-friendly vehicles provide an efficient means of commuting within cities. However, the challenge lies in seamlessly integrating e-scooters into existing public transportation systems. Bus trailers offer a promising solution, enabling convenient and sustainable e-scooter transportation.

E-scooters by capacity characteristics cover in most cases only short travel distances, on the door-to-door principle. By incorporating bus trailers dedicated to e-scooter transportation, public buses can bridge the gap between major transit hubs and final destinations. Passengers disembarking from a bus can quickly access an e-scooter from the trailer, thus becoming drivers of their scooters, allowing for an uninterrupted and efficient transition.

In densely populated urban areas, time and space optimization is crucial. Bus trailers for e-scooters maximize the utilization of limited transportation infrastructure. Rather than allocating separate parking areas or docking stations for e-scooters, which can be space-consuming and costly, bus trailers offer a flexible and compact solution. It acts as an intermodal bridge for uninterrupted urban mobility.

Figure 1. E-scooter driving

Figure 2. Bus train on road [5]

One of the primary objectives of incorporating e-scooters into public transportation is to alleviate traffic congestion and reduce carbon emissions. By encouraging commuters to use e-scooters combined with buses for shorter distances, bus trailers could help decrease the number of private vehicles on the road. This potential reduction in traffic congestion could result in smoother traffic flow leaning to a sustainable urban environment.

In this light bus trailers can help create a harmonious link between bus system of public transportation and e-scooters, as personal vehicles. Commuters can effortlessly transition from buses to e-scooters, enjoying the benefits of both modes of transport without disruptions. This seamless multimodal experience encourages greater adoption of sustainable transportation options.

Integrating e-scooters into public transportation can be a cost-effective alternative to establishing separate infrastructure. Compared to constructing designated e-scooter stations, charging stations, and traffic routes, bus trailers require minimal investment. This cost efficiency makes the adoption of bus trailers for e-scooter transportation an attractive and transitory option for transportation authority’s seeking sustainable and budget-friendly solutions.

2. E-SCOOTER SPECIFICATIONS

Since there is a lot of different types and models of e-scooter on world market, as well as in Serbia, for the purpose of taking of a model into account, the most approachable model in use will be emphasised.

Most affordable model of an e-scooter mostly used on the streets of Novi Sad is “Xiaomi 3 Lite” [6].

Table 1. E scooter characteristics

XIAMI 3 LITE CHARACTERISTICS	
Speed [km/h]	25
Range [km]	20
Weight [kg]	13
Carrying capacity [kg]	100
Nom. Power [W]	300
Dimensions [mm]	1105x430x1137
Driver height [cm]	120 - 200

Figure 3. Xiaomi 3 Lite e-scooter [6]

Due to the characteristics of e-scooter in consideration, it is clear that onboard requirements of bus trails would not need to significantly change interior design of passenger compartment to meet the needs of a combined passenger – scooter transport.

3. ROAD BUS REQUIERMENTS

A bus designed for transporting e-scooters would have certain features to accommodate the unique requirements of these vehicles. Some characteristics that such a bus might have should be:

- Special necessity capable of safely suiting every passenger and his e-scooter,
- Potential in-bus charging system: Using the on-bus travel time to the advantage of further e-scooter travel range. This would allow the e-scooters to charge while being transported, ensuring they are even more ready for use upon arrival to the desired destination.
- Tie-down or securing mechanisms as well as passenger safety: The bus may feature mechanisms such as straps, clamps, or locking systems to securely fasten the e-scooters in place, preventing them sliding through passenger compartment during transit. Standing posts for passengers with adequate handrail equipment, depending on the transportation capacity.
- In-Out Accessibility: The interior layout of the bus should provide enough space for passengers to comfortably board and disembark with their e-scooters. Wider aisles and designated side areas with regard to e-scooter manoeuvre necessities.

- Information displays: Screens or digital displays that provide information about the location, charging status, and availability of e-scooters within the bus. This option would have its elementary purpose to inform the outside users on the number of free stands inside the bus.

It's important to note that as e-scooter transportation evolves, bus manufacturers and operators may need to explore innovative solutions to meet the needs of this growing mode of transportation.

Possible solution to this transportation project could be Suisse HESS BusTrain [7]. HESS BusTrain, transport companies can react on-site to fluctuations in passenger numbers and save overcapacities and fuel: At lower passenger frequency, the economic standard bus is used, and at peak times, the trailer is used.

In short, HESS BusTrain generally manufactures buses as well as bus trails for passenger transport. Thus, bus trails can be custom made, and set up to match the towing characteristics of the bus.

Figure 4. HESS BusTrain [8]

Next thing is to analyze the interior of the bus trail in question, and consider remodeling options, to match the needs of potential e-scooter/passenger transport.

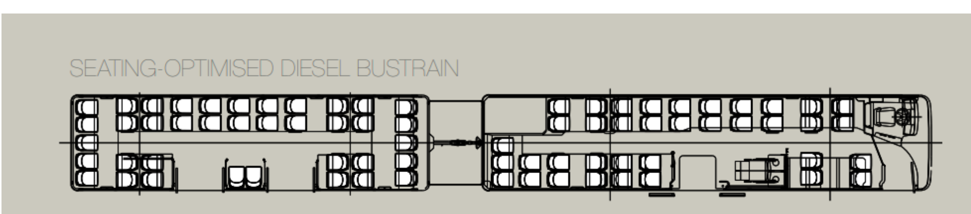

Figure 5 – Schematics of a HESS BusTrain featuring Bus and the trail [8]

In order to adapt existing bus trail to meet the needs of wanted transport, all seats or most of them need to be removed to make way for standing room, since most of e-scooter users are pictured standing and holding on to the handrail with one hand, while holding on to their e-scooter with the other during transportation.

Regarding standing/seating positions on-board the standard HESS bus trailer type, number of seats is app. 28, while the standing room numbers 57. For the case of proposed intermodal system, this would need to change. Since the dimension of e-scooter do not change much in spatial sense as compared to exclusive passenger transport, the only necessity in trailer interior change is to have minimum number of seats, and therefore maximum in standing room. This would also imply more handrail joints, and potential safety rails, for safe transport of e-scooter, as well as their charging ports.

Initial difficulties in a system like this would be longer detains of busses in stations, due to the slower disembark of e-scooter equipped passengers, opposed to those that are just regular passengers in the bus (towing vehicle). This would further leave consequence of proposed time schedules of stationary buss arrivals, which in case of implementation would have to be compensated through time redistribution.

All things considered for “pilot” laps of the potential reprogramming of the existing public transport mode, approximately the same number of standing passengers that can be transported, could be equaled to the potential number passengers of intermodal system linked to the e-scooter use.

The question of safety of passengers must be considered, first and foremost by choosing adequate selection of public transportation lines that correspond to the densest network of e-scooter urban mobility routes. Prone to this in consideration must be put the safety of regular passengers, and their potential endangerment by e-scooter passengers on stations, during embarkation and disembarkation.

4. DISCUSION

Due to the increasing use of e-scooters for the purpose of urban mobility, in most world urban centers, it would not be unusual for the proposed system to find its integration spot inside the Novi Sad public transport network. Due to its ease of conjuring with the existing public transportation system, a combined intermodal transit system could emerge, benefiting both the passengers as well as the public transportation operators.

Pros for such a system would definitely be shorter travel time, maneuver independence and a cost-efficient transportation benefits. Cons of such integration would definitely highlight the absence of adequate regulations, which could take e-scooter into lawfulness, thus disabling the chaotic movement and misuse of various traffic surfaces and areas by mostly, in terms of traffic regulations and traffic safety, uneducated and unaware e-scooter users.

5. CONCLUSION

Bus trailers present a viable and efficient means of integrating e-scooters into existing public transportation systems. By utilizing these trailers, cities can enhance last-mile connectivity, optimize space utilization, reduce traffic congestion and emissions, achieve seamless multimodal integration, and do so in a cost-effective manner.

The combined efforts of e-scooters and bus trailers have the potential to revolutionize urban transportation, creating more sustainable and accessible cities for the future.

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URBAN LOGISTICS AND PARKING MANAGEMENT

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Vladimir Ilin[1]
E-mail: v.ilin@uns.ac.rs
Dragan Simić[1]
E-mail: dsimic@uns.ac.rs
Marko Veličković[1]
E-mail: marvel@uns.ac.rs
Nemanja Garunović[1]
E-mail: garunovic@uns.ac.rs
[1] Faculty of Technical Sciences in Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad

ELECTRIC VEHICLE ROUTING PROBLEM: VARIANTS AND INDUSTRY IMPLICATIONS

Keywords

Transportation
Electric vehicle routing problem
Sustainability
Industry trends

Abstract

Transportation is the largest contributor to global greenhouse gas emissions. However, alternative-fuel powered vehicles can reduce pollutions and transportation cost as well. The focus of this study is on electric vehicles (EV) and particularly on one class of combinatorial problems: Electric vehicle routing problem (EVRP). The mathematical model for EVRP is presented, its variants are discussed and industry implications of EV are elaborated with special focus on battery-related issues, such as price, charging mechanisms and lifespan.

1. INTRODUCTION

The transport sector is responsible for 30% of the CO_2 emissions in European Union (EU), while this share reaches the 40% in urban areas [1]. At the same time, environmental concerns and operative issues in distribution process become key topics for many logistics companies that aim to reduce pollutions (greenhouse gas emissions) and transportation costs. The pollution problem (emissions of CO_2, SO_2, and NO_x) led to increase in research for more environmental transport solutions. From the industry perspective, many alternative-fuel powered vehicles are developed. They rely on the following energy sources: hydrogen, natural gas, electricity, etc. The focus of this study is on electric vehicles (EV) as they offer to reduce both, transportation costs and pollutions in comparison to fossil-fuel vehicles.

EVs are generally divided into battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs). An advantage of BEVs and HEVs is their ability to use their electric motor for regenerative braking to recuperate kinetic energy [2]. The process of recharging EV is an important issue as it greatly determines their use, both in terms of availability and flexibility. There are several different methods for charging: slow charging, fast charging, battery swop stations and inductive charging [1]. Hybrid EVs have recently been developed to reduce the necessary stops and dependence on infrastructure by using two different engines, a pure electric motor and an internal combustion engine [3].

That promising perspective of EVs to be included in everyday logistics processes, and particularly in last-mile delivery, motivated the authors to consider a specific class of combinatorial optimization problems: the electric vehicle routing problem (EVRP). The EVRP is approached from practical and scientific perspective.

The paper is organized in the following way. Section 2 presents a problem definition and mathematical model of EVRP. Section 3 overviews variants of EVRP and different algorithms that are used to solve EVRP. In Section 4 we present future perspectives of conventional and electric vehicles, and finally, Section 5 provides concluding remarks.

2. PROBLEM DESCRIPTION AND MODEL

The EVRP is an extension of the traditional vehicle routing problem (VRP) that specifically deals with finding optimized routes for electric vehicles, taking battery constraints and charging operations into account. The EVRP can be described as finding a set of vehicle routes, where each route services a set of customer nodes and starts and ends at a given depot node. The problem aims to find the best route plan for electric vehicles that minimizes a given cost function while satisfying a number of restrictions and operational procedures for electric vehicles [4]. An illustrative example of a route of the EVRP in shown in the Figure 1.

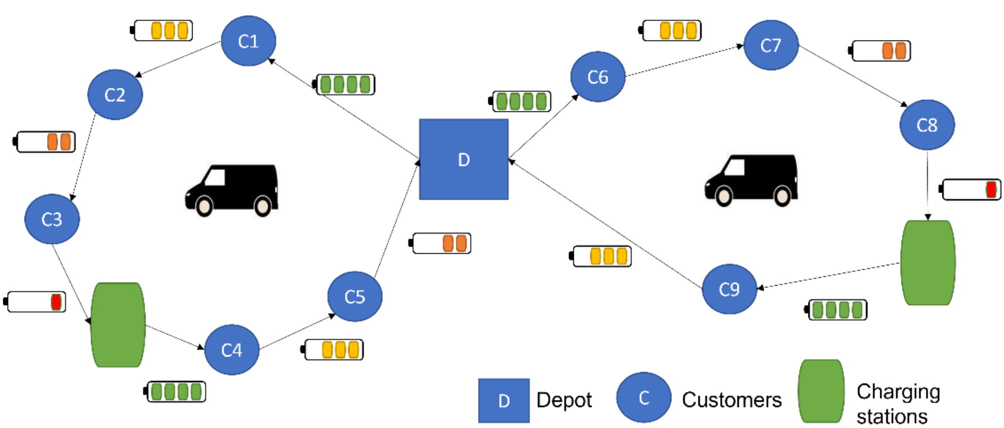

Figure 1. An illustrative example of a route of the EVRP

2.1. MATHEMATICAL MODEL

From the scientific perspective, the most often criterion in VRP and also EVRP is the minimization of total distance and consequently fuel consumption and CO_2 emissions. A mathematical formulation of the basic EVRP can formulated as follows.

Notation:

Depot nodes: *N*
Set of charging stations: *F*
Set of customers: *V*
Set of vehicles: *K*
Energy consumption rate of the vehicles per unit distance: *h*
Battery capacity of the vehicles: *Q*
Traveling distance from node i to node j: *dij*

Objective function:

$$\sum_{i \in V_0'} \sum_{j \in V_{N+1}'} \sum_{k \in K} d_{ij}\, x_{ij}^k \rightarrow min \tag{1}$$

Subject to:

$$\sum_{j \in V_{N+1}'} \sum_{k \in K} x_{ij}^k = 1, \forall\, i \in V \tag{2}$$

$$\sum_{j \in V_{N+1}'} \sum_{k \in K} x_{ij}^k \leq 1, \forall i \in F' \tag{3}$$

$$\sum_{j \in V'} x_{0j}^k \leq 1, \forall k \in K \tag{4}$$

$$\sum_{i \in V_0'} x_{ij}^k = \sum_{i \in V_{N+1}'} x_{ij}^k\,, \forall j \in V', \forall k \in K \tag{5}$$

$$y_j^k < \; y_i^k - \left(h * d_{ij}\right) x_{ij}^k + Q\left(1 - x_{ij}^k\right),, \forall i \in V, \forall j \in V_{N+1}',\; \forall k \in K \tag{6}$$

$$y_j^k < \; Q - \left(h * d_{ij}\right) x_{ij}^k\,, \forall i \in F' \cup \{0\}, \forall j \in V_{N+1}',\; \forall k \in K \tag{7}$$

$$y_0^k < \; Q, \forall k \in K \tag{8}$$

The objective function (1) aims to minimize the total distance of electric vehicles. Constraints (2) handle the connectivity of the customer nodes. Constraints (3) ensure that each dummy charging station can be visited at most once. Constraints (4) make sure that each electric vehicle can be used only in one route plan. Constraints (5) ensure that the total number of outgoing arcs is equal to the total number of incoming arcs at customer and charging station nodes, which provides continuity in the routes. Constraints (6)-(8) track the battery level of the electric vehicles and their battery state after the recharging operations at the charging stations following a full charging policy. Described model considers capacity of the battery as the only constraint. In the case of a capacitated EVRP, EVRP with time window, and EVRP with a heterogeneous fleet additional constraints need to be added.

3. VARIANTS OF EVRP

The maximum driving range of most EVs is between 160 and 240 km [5]. However, it decreases significantly by the impact of weather conditions (e.g. low temperatures) and terrain configuration (e.g. hills). As a direct consequence, the driving range of EVs is often not sufficient to complete logistics services and charging stations need to deployed throughout the transportation network. It basically depends on the capacity of the battery, specific logistics task (objective function), available fleet (EV, hybrid vehicles, drones), and so on. From the practical and scientific perspective, at least three different classes of EV problems can be highlighted (Table 1).

Table 1. Variants of EVRP [6]

Variant	Decision Variables	Constraints	Objectives
Fleet size and mix	(1) The number and type of EVs to be purchased. (2) The ideal composition of the heterogeneous fleet.	(1) Environmental standards and price incentive to acquisition of EVs. (2) Fixed and variable charging times. (3) Limited budget to renew the fleet of vehicles.	(1) Minimize the acquisition and operating costs of new EVs. (2) Maximize the satisfaction of customer needs. (3) Minimize the environmental impact.
Charging networks	(1) Number and geographical position of recharging stations. (2) Capacity of recharging stations. (3) Technology of recharging stations (low or fast recharge). (4) Swapping or recharging of batteries.	(1) Limited budget to install new recharging stations. (2) Needs of EVs to recharge or exchange batteries.	(1) Minimize the investment and operating costs of charging networks. (2) Maximize the level of service to customers.
Routing	(1) The number of visits to recharging stations. (2) The timing of visits to recharging stations. (3) Available recharging resources to vehicles in recharging stations. (4) The option of recharging or swapping batteries.	(1) Geographical position of recharging stations. (2) Capacity of recharging stations. (3) Fixed or variable recharging/swapping times.	(1) Minimize routing cost considering recharging operations. (2) Minimize routing times considering recharging operations. (3) Minimize recharging and swapping costs.

To solve previously mentioned aspects of EVs many exact and approximate algorithms have been developed (Figure 2). Approximate algorithms can be analyzed as heuristics and metaheuristics.

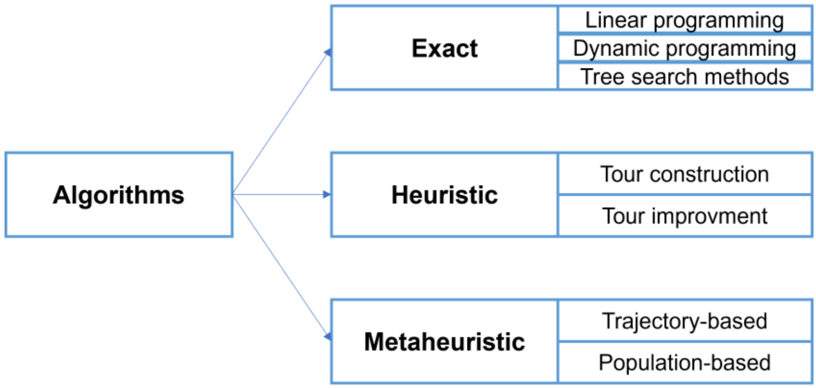

Figure 2. Algorithms used to solve different EVRPs

Exact algorithms for EVRP include branch and bound, cutting planes, dynamic programming, linear programming, and other methods. Exact algorithms are mostly used to address small scale EVRPs, as their complexity increases exponentially with the number of nodes. Approximate algorithms encompass heuristics and metaheuristics approaches. Heuristic algorithms for EVRP include tour construction and tour improvement algorithms. Metaheuristic algorithms for EVRP include a wide range of methods, including trajectory-based and population-based search. One of the classifications is presented in the Figure 2.

4. INDUSTRY IMPLICATIONS

According to the 2019 report of the world energy outlook series, the future estimation of energy systems indicates that a serious loss will happen by 2040 [7]. Tremendous progress and development of information and communication technologies (ICT), particularly in security aspects, offer opportunities for ICT-supported energy transition, including investigation of hydrogen and renewable energy However, there are predictions that the share of electric energy in final consumption will exceed the oil by 2040 [8], mainly due to EVs. Having that in mind, EU has targeted a 40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 (European Commission, 2014). This will be a great challenge for the transportation sector and logistics companies.

The main aspects that determine the competitiveness of EV are the purchase price, battery costs and lifespan, and practical implications of vehicle operations. Between them, battery-related issues, such as specific energy, specific power, and price will have the major role in development of the ecosystem for EV. While future lithium-ion cells' specific energy could reach 300 Wh/kg, development of technologies such as lithium-sulfur (Li-S) and lithium-air (Li-air) batteries should allow reaching values above 500 Wh/kg [9]. Zinc-air (Zn-air) batteries are another option in development that could improve specific energy [10]. Projections for different BEV battery types are provided in Table 2.

Table 2. Projections for promising BEV battery types [11]

Battery type		Li-S	Zn-air	Li-air
Specific energy (Wh/kg)	< 2025	400	250	500
	> 2025	500	350	1000
Specific power	< 2025	300	Unknown	Unknown
(W/kg)	> 2025	400	Unknown	Unknown
Cost	< 2025	Uncertain	Uncertain	Uncertain
($/kWh)	> 2025	250-500	100-300	350-700
Issues		Safety Cycle life	Specific power Charge efficiency	Specific power Cycle life Safety

To make the use of electric vehicles as accessible as possible the price of mostly-used lithium-ion batteries need to decrease over time. In the Table 3 the prediction of price range for lithium-ion batteries is presented.

Table 3. Projections for Lithium-Ion Battery Pack Cost [12]

Period	2010-11	2012-13	2015	2020	2025	2030
Estimate ($/kWh)	650-1000	500-800	400-700	300-500	225-400	200-300

Two more important aspects are battery lifespan and battery charging. Lithium-ion batteries' health can be negatively influenced by the way they are used and stored, and, therefore, the vehicle's range can be decreased. The most common way of charging batteries is with cable and connector. Charging modes are defined by the communication protocol between the vehicle and the charging equipment [12].

5. FINAL REMARKS AND FUTURE WORK

EVs reduce transportation costs and pollutions more efficiently in comparison to conventional vehicles. On the other side, EVs have one main disadvantage compared to conventional vehicles: they have batteries that need to be charged which limits their range and often cause long charging periods. Therefore, EVs and particularly EVRP are attracting growing interest from researchers, practitioners, non-profit organizations, and governments.

By introducing EVs in distribution and logistics processes, urban transportation is faced with transition. Infrastructure, traffic network, signalization, and traffic regulations will need to be adapted to create transportation ecosystem for EV.

The future work could focus on extending the research on detailed investigation of algorithms used to solve EVRP. In addition, battery technology, charging technology, and regulatory consideration can be further explored.

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9th INTERNATIONAL CONFERENCE
''TOWARDS A HUMANE CITY''
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Novi Sad 19th and 20th October 2023

Dragan Simić[1]
E-mail: dsimic@uns.ac.rs
Vladimir Ilin[1]
E-mail: v.ilin@uns.ac.rs
[1] Faculty of Technical Sciences in Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad

THE ANALYSIS OF ELECTRIC VEHICLE APPLICATIONS IN TRAVELLING SALESMAN PROBLEM

Keywords

Electric vehicles
Transportation logistics
Unmanned aerial vehicle
Battery recuperation
Metaheuristics

Abstract

Many corporate policies aim to promote transportation modes with lower emissions of pollution and greenhouse gases. Travelling salesman problem (TSP) is among the most well-studied optimization problems in operations research. The solution of the TSP by exact solutions, heuristics solutions, and approximation algorithms can be applied. Rather than focus on finding the most effective route, TSP is often concerned with finding the cheapest solution. Electric vehicles (EVs) are an emerging alternative to internal combustion engines. Recently technical and technological implementation of TSP extends classical TSP which in general presents electric travelling salesman problem (ETSP), which applications present hybrid solutions of: (i) drones cooperate with classical trucks; (ii) drones cooperate with electric trucks, and (iii) drones operate on their own. The capacity of electric vehicle (EV) battery in TSP; (ii) hybrid simulated models the electric TSP; and (iii) deploying EV and unmanned aerial vehicles as extension of TSP are analised in this study.

1. INTRODUCTION

Transport is the backbone of the European economy, accounting for about 7% of the gross domestic product (GDP) due to the fact that transport industry offers over 5% of total employment in the European Union (EU). As a network industry, transport requires elements such as infrastructures, vehicles, equipment, information and communication technology (ICT) applications and operational procedures to interact smoothly in order to move people and goods efficiently. Public revenues also benefit from transportation: 0.6% of the GDP is collected from vehicle taxes; and the greatest part of energy taxes, that counts 1.9% of the GDP, comes from taxes on fuel [1].

In the environmental aspects, transportation has been the sector with the largest growth rate of greenhouse gas (GHG) emissions compared to 1990. Moreover, road transport caused 39,000 deaths in EU in 2008. 60% of the global oil consumption and 25% of energy consumption are due to transportation [1]. 69% of road accidents occur in cities, and 25% of the CO_2 emission of the whole transport sector comes from urban transport [2]. Therefore, one can easily understand the importance of transportation in urban areas for private individuals, public authorities and enterprises.

The rest of the paper is organized in the following way: Section 2 overviews the last of travelling salesman problem. Section 3 presents mathematical formulation of basic TSP model. The analysis of electric vehicle applications in the following aspects: (i) minimising capacity of electric vehicle (EV) battery in TSP; (ii) hybrid simulated models the electric TSP; and (iii) deploying EV and unmanned aerial vehicles as extension of TSP are presented in Section 4. Finally, Section 5 provides concluding remarks and some points for future works.

2. THE LAST OF TRAVELLING SALESMAN PROBLEM

The traveling salesman problem (TSP) is an algorithmic problem tasked with finding the shortest route between a set of points (nodes) and locations that must be visited. It was first described by Irish mathematician Sir William Rowan Hamilton (1805–1865) and British mathematician Thomas Penyngton Kirkman (1806–1895) in the 1800s through the creation of a game that was solvable by finding a Hamilton cycle, which is a non-overlapping path between all nodes. After about one century, the Austrian mathematician Karl Menger (1902–1985) invited the research community to consider from a mathematical point of view the following problem taken from the everyday life. A travelling salesman has to visit exactly once each one of a list of cities and then return to the home city. It is known the cost of traveling from any city to next other city. It is known the cost of travelling from any city to next other city, and the point of interesting is the tour of least possible cost the salesman can take. Therefore, TSP is actually one of the most significant problems in the history of applied mathematics, since the TSP is NP-hard (nondeterministic polynomial time) problem. But on the other side TSP's problems are wide applicability, such as: school bus routes, home service calls problems.

TSP has been studied for decades and several solutions have been theorized. The simplest solution is to try all possibilities, but this is also the most time consuming, expensive, and not efficient method. On the other hand, many solutions use heuristics, which provides probability outcomes: *nearest neighbor*, *the Greedy heuristic*, *insertion heuristics*, *Christofides algorithm* [1]. However, the results are approximate and not always optimal. Once a tour has been generated by some tour construction heuristic, the solution could be improved. There are several ways to do this, but the most common ones are the 2-opt, 3-opt, and finally *k*-opt local searches.

Their performances are somewhat linked to the construction heuristic used [2]. Other solutions include branch and bound [3], Monte Carlo [4], and Las Vegas algorithms [5], and some other simple applications of the TSP [6].

However, since the TSP is NP-hard, it will be very time consuming to solve larger instances with guaranteed optimality. Rather than focus on finding the most effective route, TSP is often concerned with finding the cheapest solution. In TSPs, the large number of variables creates a challenge when finding the shortest route, which makes approximate, fast and cheap solutions all the more attractive, used by wide area of metaheuristics algorithms: ant colony optimisation [7], tabu search algorithm [8], particle swarm optimization [9], firefly algorithm [10].

3. MATHEMATICAL FORMULATION OF TRAVELING SALESMAN PROBLEM

Like any other mathematical problems, it is necessary to translate the TSP into its mathematical description. Many literatures had attempts this but one the easiest to understand is in [11] where TSP is described as follows:

“The TSP can be defined on a complete undirected graph $G = (V, E)$ when it is symmetric or on a directed graph $G = (V, A)$ if it is asymmetric. The set $V = \{1, \dots, n\}$ is the vertex set, $E = \{ i, j : i, j \in V, i < j\}$ is an edge set and $A = \{ i, j : i, j \in V, i \neq j\}$ is an arc set. A cost matrix $C = (c_{ij})$ is defined on E or on A. The most matrix satisfies the triangle inequality whenever $c_{ij} \leq c_{ik} + c_{kj}$" for all i, j, k. In particular, this case planar problems for which the vertices are points $Pi = (Xi, Yi)$ in the plane, and c_{ij} is the Euclidean distance. The triangle inequality is also satisfied if c_{ij} is the length of a shortest path from i to j on G.” Some of the literatures calculated the cost (distance), c_{ij} using Manhattan distance or geometric distance instead of Euclidean distance.

4. ELECTRIC VEHICLES AND TRAVELING SALESMAN PROBLEM

There are many different TSP scientific researches and also the applications applied in industry and transportation. Effort has been devoted to the solution of the TSP by exact solutions, heuristics solutions, and approximation algorithms which can be applied. On the scientific-practical point of view, TSP is not a solitary example of NP-hard transportation problem. The *vehicle routing problem* (VRP) constitutes a generalization of the TSP that consists of determining the shortest circuit or cycle passing through each of *n* cities only once. However, from a practical point of view, VRPs are in general much more difficult to solve than TSPs of the same size. The most algorithms for the VRP are heuristics, reflecting the relative difficulty of the problem. The *last-mile delivery* has witnessed an enormous increase in quality demand in a continuously growing market, especially due to the rapid spread of distribution, online shopping platforms, e-commerce, and in general in e-business.

On the other hand, recently technical and technological implementation of TSP extends classical TSP which in general presents electric travelling salesman problem (ETSP), which applications present hybrid solutions of: (i) drones cooperate with classical trucks; (ii) drones cooperate with electric trucks, and (iii) drones operate on their own.

4.1. Minimising capacity of electric vehicle battery in TSP

The energy in a hybrid vehicle is one of the things that have been paid attention to, one of which can be seen from the research on optimal energy regulation for each process [12]. There is research that tries to optimise the electric vehicle route by considering the charging station [13]. However, so far it is not easy succeed in finding research that tries to find the optimal route with the assumption that charging stations are present at each destination.

Various public transportations can start using electric power sources. However, there are battery capacity constraints. When the distance is too far, the battery capacity is not sufficient to provide the required power. In the research paper [14], is explained how the bottleneck TSP is applied to minimize battery capacity requirements. So that vehicles can choose the right route by minimizing the maximum distance between destinations. The optimization process is carried out with the Brute Force algorithm in python programming language.

Due to the limited battery capacity of EVs and the fixed locations of stationary charging stations (SCs), EVs typically require additional travel distance to be charged via SCs, Wireless charging (WC) allows EVs to recharge while traveling, potentially reducing travel distance, consumed time, and land use. This problem is formulated as a mixed integer programming model in which the travel speeds on Wireless charging locations (WCLs) are considered as multiple given options. The algorithm is used, to solve small-scale instances to optimality and heuristics for larger instances [14].

4.2. Hybrid simulated annealing and tabu search method for the ETSP

The electric travelling salesman problem with time windows (ETSPTW) is an extension of the well-known TSP with time windows (TSPTW) is presented in study [15]. The ETSPTW additionally considers recharging operations of the electric vehicle at identical charging stations. However, different charging technologies used at public or private stations result in different charging times of the electric vehicles. Therefore, that study extends the ETSPTW by additionally considering charging operations at customer locations with different charging rates, called hereafter the electric travelling salesman problem with time windows and mixed charging rates (ETSPTW-MCR). That study is the first which considers both private and public charging stations for the ETSPTW. In addition to the extended version of the ETSPTW, the paper introduces a new and effective hybrid simulated cooperation of annealing and tabu search (SA/TS) algorithms to solve the ETSPTW-MCR problem efficiently. Distinct from the existing hybridization of SA and TS, the proposed hybrid SA/TS algorithm employs efficient search procedures based on the TSPTW restrictions, a modified solution acceptance criterion, and an advanced tabu list structure.

4.3. Electric vehicle and unmanned aerial vehicles in extended TSP

Last mile delivery includes the activities necessary for the customer to obtain the goods purchased, and these activities are typical for urban areas, city centres, home deliveries, and rural logistics regions. The idea of deploying electric vehicle and unmanned aerial vehicles (UAV), also known as drones, to perform "last-mile" delivery in logistics operations has attracted increasing attention in the past few years. In this paper, an electric vehicle TSP with drone (EVTSPD) is formulated as a mixed integer linear program, in the research paper [16]. Logistic organizations with a new method of delivering parcels which can extend the driving range of both vehicles and decrease the operation cost.

There are several challenges in EVTSPL: the vehicle driving range limitations, the existence of charging's station that can possibly be visited multiple times or not at all, and planning the UAV's route alongside that of the EV, introduce major complications to the problem. In the previous research which did not include electricity constraints, report a solution time of about 3 hours to solve a network containing 10 nodes, using a commercial solver [17]. Thus, heuristics designed for EVTSPD are necessary to solve a problem with practical size. An iterative three-step decomposition heuristic algorithm is presented [16]. The heuristic algorithm decomposes the problem into three sub-problems: (i) electric vehicle path construction; (ii) UAV node insertion; and (iii) final solution feasibility check. There are a variety of different combinations of electric vehicle node and UAV node, an iterative approach is used to improve the final result and record the best-known solution.

The research paper [18], is proposed solution and an algorithm based on a combination of the combinatorial optimisation algorithm which includes genetic algorithm (GA). This algorithm solves the truck drone in tandem team or last mile effort for TSP problem for parcel delivery operations. The aim of this approach is to minimise total last mile delivery cost. Each truck carries a drone which is launched from a stop to deliver a parcel within range to a nearby stop while operating in parallel with the truck. The truck and drone work in parallel operations to deliver packages. Therefore, the search optimisation problem is divided in two sub-problems: (1) first, it is being optimised for the truck routing; (2) and second, it is being optimised for the drone routing. The drone is constrained with its range (fly distance) and speed. An operation is when a truck launches the drone, truck and drone deliver to separate locations, and the truck then recovers the drone at a rendezvous location for battery swaps and loading. The main idea is to determine a route for truck and drone, as well as operations, whose cost function minimises total time which is calculated from minimum total last mile delivery cost. Total time is based on the times for the operations (launch – deliver – recover). The maximum time of an operation for truck or drone is used to calculate total time for the route.

5. CONCLUSION AND FUTURE WORK

In recent years, a growing number of logistics companies have introduced electric vehicle or unmanned aerial vehicles in the delivery operations and solve TSP and its extension in typical for urban areas and city logistics. The aim of this paper is to analyses electric vehicle applications based on TSP, and its extension such as last mile delivery. Recently, as is shown there are many challenges in different fields on applications for solving NP-hard TSP. Unfortunately, this paper cannot mention *all* possible problems which could be found in previous and also recently research papers.

There are so many challenges for the researchers in travelling salesman problem, last-mile delivery, vehicle routing problem and all their extensions. On the other side applications: (i) individually electrical vehicle application; (ii) classical truck and drone; (iii) electrical truck in tandem with drone; and/or (iv) singly electrical drone applications; are open fields for all researchers in relatively new field.

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9th INTERNATIONAL CONFERENCE
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Nenad Ruškić[1]
E-mail: nruskic@uns.ac.rs
Nataša Čačić[1]
E-mail: ncacic@uns.ac.rs
Dragana Šarac[1]
E-mail: dsarac@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21102 Novi Sad, Serbia

THE EFFECTS OF SWITCHING THE VEHICLE OF THE POST OF SERBIA TO ELECTRIC DRIVE IN NOVI SAD

Keywords

Ecological postal operators
Transport cost
Savings

Abstract

European Parliament Directive 94/2014 mandates the development of new technologies and innovations to improve air quality in densely populated areas, urban and suburban areas. Within this paper, the positive effects (savings) of switching to electric vehicles operated by Public Enterprise Post of Serbia in the working unit Novi Sad are considered. Taking into account the fact that with the expansion of e-commerce, the volume of postal items has increased significantly, the transition to greener modes of transport represents the environmentally responsible business of postal operators.

1. INTRODUCTION

Today's way of life causes a lot of noise and pollution, especially in large cities and urban environments. According to the World Health Organization's estimation, noise represents a significant environmental impact factor. The field of environmental noise is regulated by the Environmental Protection Act ("Official Gazette of the Republic of Serbia, No. 135/04, 36/09, 36/09 - amending law, 72/09 - amending law, and 43/11 – decision of the Constitutional Court"), as well as the Noise Protection Act ("Official Gazette of the Republic of Serbia, No. 36/09 and 88/10"), and other sublegal acts in accordance with European Union (EU) regulations [1]. Noise indicator values significantly exceed the permissible limits. Accordingly, improving the quality of life in urban areas is a top priority, as the population and vehicle numbers in the city of Novi Sad are constantly increasing. In the Vojvodina Region, the number of newly registered passenger cars is 9539 [2]. Based on Article 8 of the

Law on the Budget of the Republic of Serbia for 2023, the Government of the Republic of Serbia has issued a regulation on the conditions and procedures for subsidized purchases of new vehicles that are solely electric-powered, as well as vehicles powered by internal combustion engines and electric power (hybrid power) [3].

The world has been facing considerable populational growth rates, including an agglomeration in cities. Currently, more than 50% of the global population lives in cities, and by 2050 the percentage of people living in urban locations is expected to exceed 70% [4].

Overall, 15% of global CO2 emissions are attributed to the transport sector, with the majority of these emissions caused by road transport. Urban transport accounts for a large share. In the EU, it is estimated to be responsible for 23% of greenhouse gas emissions [5]. Therefore, reducing transport emissions is key to meeting the EU's climate neutrality objectives. Recently proposed legislation sets targets to cut CO2 emissions from cars by 55% and vans by 50% by 2030. 2021 saw a significant increase in the uptake of electric cars and vans in the EU-27. Electric car registrations for the year were close to 1,729,000, up from 1,061,000 in 2020. [6]. The European Green Deal set the blueprint for this transformational change. All 27 EU Member States committed to turning the EU into the first climate neutral continent by 2050. To get there, they pledged to reduce emissions by at least 55% by 2030, compared to 1990 levels [7].

In postal transportation, it is important to develop a good transportation plan and to efficiently manage the plan. Postal operators worldwide are considering the possibilities of transitioning to faster, safer, and more environment-friendly alternative postal delivery models. Authors analyzing the postal traffic field have conducted numerous analyses and studies that yielded results regarding alternative delivery methods and contemporary business models. Papers examining the benefits of eco-driving using electric vehicles are presented in Table 1.

Taking into account the fact that electronic commerce greatly affects the increase in the volume of traffic for CEP (Courier, Express and Parcel) operators and thus causes great pollution as a consequence of work, this paper provides an analysis of the possible positive effects of crossing the fleets of Public Enterprise Post of Serbia on electric drive. The analysis was carried out on the territory of the city of Novi Sad.

Table 1. Previous research

Ref.	Problem	Method	Results
[8]	Estimation the delivery time and energy cost of e scooter vehicles in postal sector	Machine learning, considering 15 different input parameters	The delivery time of a package to short-distance delivery addresses using e-scooter vehicles is 20.21% shorter than other traditional delivery vehicles.
[9]	"This paper proposes a methodology that combines routing optimization and large-scale distribution planning algorithms, to perform a realistic assessment of the electrification of parcels' transportation"	A Route Optimization Model (ROM) and Reference Network Model (RNM)	The estimated absolute emissions of the electrified fleet for a decentralized scenario are up to 50% lower compared to a centralized one. the results reveal that smart charging strategies also contribute to lessen the incremental costs and significantly reducing the cost of energy supply.
[10]	A comperhensive analysis of Electric vehicles charging station usage at the University of Georgia	The data collection method is time- and cost-effective	The results from this study can be used as a reference for possible expectations of EV charging station usage on other college campuses.
[11]	This work evaluated the use of electric vehicles of smaller dimensions, tricycle and LDV in the last mile of parcel deliveries	Economic assessment, Social assessment	"The analysis showed that the electric tricycle alternative is feasible in the economic, environmental and social aspects, as well as in the maintenance of the level of service".
[12]	This work analyzing the effects that eco-driving has on fuel consumption and GHG emissions on courier deliveries in Spain	Statistical Analysis (A Sequential Method), Interview and Observation	Eco-driving with courier delivery does not lead to average fuel savings per vehicle.
[13]	The Proton Exchange Membrane Fuel Cell (PEMFC) health monitoring and management	Model-driven method Unscented Kalman filter	"The results show that the proposed model-driven method is able to accurately estimate the voltage degradation trend of PEMFC in the FCEV".
[14]	Conducted a cradle-to-grave life cycle greenhouse gas (GHG) assessment for two scenarios	Life-cycle analysis (LCA) tool	"The BEV NGDV has almost double the vehicle cycle emissions as the ICEV NGDV due to the production emissions of the Li-ion battery".
[15]	A comparison between the EVs and the ICEVs used to perform last-mile deliveries in business-to-consumers (B2C) e-commerce	The life cycle assessment method	EVs turned out to be the best option in all the scenarios assumed.
[16]	"This paper identifies and reviews, from an OR/CS perspective, several open research challenges related to the introduction of EVs in L&T activities"	Use of metaheuristics and simheuristics to deal with optimization problems	"This paper has reviewed some of the existing literature related to the introduction of electric vehicles in road transportation, paying special attention to environmental issues".

2. ELECTRIC VEHICLE MARKET

The transport sector accounts for 25% of total greenhouse gas (GHG) emissions. By categories of transport, road transport represents almost 95% of emissions [12]. The report of electric vehicles market provides a peek into this fast-growing industry. This market is currently focusing on battery electric vehicles, plug-in hybrid electric vehicles and electric vehicles infrastructure which includes information about public charging stations. Compared to 2020, sales of new electric vehicles more than doubled in 2021 with an increase of 51.8%. The volume weighted average price of electric vehicles market in 2023 is expected to amount to US$51.98k. China conveniently topped the global sales charts in 2021 with more electric vehicles sold than the rest of the world combined and almost five times more than Germany, which was in second place. Europe recorded an increase between 2020 and 2021, reaching about 66%, with the plug-in hybrid share of all electric vehicle sales being the biggest in the world. Driven by the availability of more models, as well as the market expansion and purchase incentives, the European market is expected to continue along this trend as countries within the EU adopt stricter CO2 emission standards and move toward zero-emissions vehicle mandates [17]. At COP-25 in Madrid 73 States have committed to being carbon neutral by 2050 [12,18].

2.1. The use of electric vehicles in postal traffic

CEP (Courier, Express, and Parcel) operators, through their business programs and development strategies, aim to reduce CO2 emissions. The European Parliament Directive 94/2014 (access to European Union law) mandates the development of new technologies and innovations to improve air quality in densely populated areas, both in urban and suburban environments [19]. The introduction of electric vehicles provides CEP operators with the opportunity for enhanced mobility in city centers and a reduction in the number of fossil fuel-powered vehicles. According to the Business Program of the Public Enterprise "Post of Serbia," environmental protection measures and fleet renewal are planned for the year 2023 [20]. The Public Enterprise "Post of Serbia" has adopted a public procurement plan for 2023, which includes open procurement procedures for electric bicycles in the first quarter of 2023 and electric vehicles in the fourth quarter of 2023 [21]. According to data from 2022, the United States Postal Service announced that it expects to acquire at least 66,000 battery electric delivery vehicles as part of its 106, 000 vehicle acquisition plan for deliveries between now and 2028. [22]. Since 2015, the Croatian Post has included 180 electric bicycles in its vehicle fleet, which have reduced CO2 emissions by 100.31 tons annually, along with 26 electric mopeds that contribute to a yearly CO2 emission reduction of nearly 20 tons [23, 24] (Figure 2). The electric vehicles of the Public Enterprise "Post of Serbia," are shown in Figure 1.

Figure 1. Electric vehicles of the Public Enterprise "Post of Serbia" [25]

Figure 2. Electric mopeds and electric quadricycles of Croatian Post [24]

In 2021, Swiss Post operated 6,000 electric scooters and 260 electric delivery vans for emission-free delivery of letters and parcels. In 2022, Austrian Post operated the largest fleet of EVs within Austria (2462 EVs) and is com-mitting to switch its entire fleet of more than 8,500 vehicles to EVs by 2030, resulting in a carbon-free delivery process [26]. Using the Green Strategy, Royal Mail has so far reduced greenhouse gas emissions by 31.9%. Bio-CNG vehicles cut carbon emissions by 85%. Royal Mail has introduced 295 zero-emission electric vehicles. Effectively, Royal Mail is reducing greenhouse gas emissions by 459 tons of CO2 through eco-driving. DHL's mission is to achieve net-zero emissions by 2050. The plan is for DHL to have more than 80,000 electric vehicles on the roads by 2030 [27]. Many of the largest private fleet operators, including FedEx, UPS, Amazon, and Walmart, have begun electrifying their fleets [14].

3. ASSESSMENT OF CO2 EMISSION REDUCTION IN THE CITY OF NOVI SAD

According to the data obtained from the Public Enterprise Post of Serbia, it has been determined that a total of 78 vehicles operate daily in the city of Novi Sad to provide services to customers. The vehicles are of different categories and carrying capacities. Table 2 provides the adopted factors for estimating CO2 emissions depending on the type of fuel used by the vehicles.

Table 2. Factors of CO2 emission

Type of fuel	kgCO2/kg fuel
Petrol	3,18
Diesel	3,14
LPG*	3,02
CNG**	2,75

*liquefied petroleum gas; ** compressed natural gas

Table 3 provides an overview of the number of vehicles and vehicle types owned by the observed postal operator. Average daily distances traveled and average fuel consumption per day are also provided. Based on available data, CO2 emissions on an annual basis have been calculated for the territory of Novi Sad for the observed postal operator.

Table 3. Postal Service vehicles

S. N.	Type of vehicle	Amount of fuel (L)	Average daily mileage (km)	Number of working days	Fuel	Average spending	Total annual consumption per vehicle	Number of vehicles in the group	Emission CO2 on an annual basis (kg)
1	A passenger vehicle	141	49	23	ED	6	1692	6	31.877
2	Cargo vehicle	142	38	25	ED	11	1704	58	310.332
3	Cargo vehicle	586	247	27	ED	8,9	7032	10	220.805
4	Cargo vehicle	1330	187	27	ED	25,39	15960	4	200.458
Total							**29.289**	**78**	**763.472**

The obtained CO2 emission values per vehicle type are given on an annual basis. It has been determined that the observed postal operator emits a total of 763,472 kg within the territory of Novi Sad city. It should be noted that in the observed area, in addition to the observed postal operator, around 15 postal operators provide services, and their CO2 emission analysis has not been considered. As there is a drive to reduce CO2 emissions, a large number of CEP operators are considering the possibility and effects of transitioning to electric-powered vehicles, encouraged by state incentives for eco-driving, especially in urban city environments. Taking into account that the price of 1 ton of CO2 is €101.16 in the EU [28], the costs incurred solely from the observed postal operator's CO2 emissions amount to €77,233.

4. CONCLUSION

The trend of transition to electric vehicles is present all around the world. Local pollution reduction is imperative for larger cities, and one of the ways to achieve this is by having a greater number of vehicles use electric power for propulsion. While it's currently challenging for vehicles that travel longer distances to utilize electric energy, vehicles that operate within cities and for shorter distances can be electric. Electric vehicles, as well as public transport vehicles, have proven to be ideal for transitioning to electric propulsion, especially with the option of overnight battery charging in their company garages.

In the context of this study, a preliminary analysis was conducted regarding the transition to electric propulsion for vehicles operated by the Public Enterprise Post of Serbia in the Novi Sad branch. According to the analysis, if all vehicles in this branch were to switch to electric propulsion, a reduction of approximately 764 tons of CO2 emissions, equivalent to around €77,000 annually, would be achieved solely through pollution reduction. The study did not analyze other benefits of transitioning to electric vehicles (reduced consumption, maintenance costs, depreciation, etc.), nor did it examine the reduction of other pollutants originating from the combustion of fossil fuels within the territory of Novi Sad city and its surroundings.

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Bojan Jovanović[1]
E-mail: bojanjov@uns.ac.rs
Dragana Šarac[1]
E-mail: dsarac@uns.ac.rs
Nataša Čačić[1]
E-mail: ncacic@uns.ac.rs
Estera Rakić[2]
E-mail: estera_rakic@hotmail.com
[1] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21102 Novi Sad, Serbia
[2] Faculty of Transport, Communications and Logistics Budva, Adriatic University
Žrtavafašizma 56, 85310 Budva, Montenegro

URBAN LAST-MILE DELIVERY SOLUTIONS

Keywords

Urban area
E-commerce
Last-mile delivery

Abstract

Trend in population growth at urban areas, and also intensive development e-commerce present a significant challenge for last mile delivery systems. Requirements placed on development last mile delivery systems are more complex, both from the customers’ point of view and as well as racional exploitation available resources and reduce destructive impact on environment. E-commerce is defined by a large number of small individual packages, which besides increase complexity of situation in urban areas from the last mile delivery, also lead to significant increase costs. According that, solutions in last mile delivery domain must be efficient in terms of speed, price, service and quality. The aim of the paper is to enable solutions review in last mile delivery domain, as well as to compare their advantages and disadvantages in function of sustainable urban development.

1. INTRODUCTION

The urbanization process is progressing rapidly. More than half of the world's population lives in urban areas, and the forecast is that the urban population will reach 6 billion by 2045 [1]. Current trends lead to a situation where urban areas demand more and more quantities of goods and services. In the urbanization process, it comes an increasing number of inhabitants move away from necessary resources, so expectations of last-mile delivery are to solve it. Those systems need to find efficient ways for the proper functioning of urban areas. The consequence of that is greater pressure on the urban infrastructure, so it is necessary to find innovative approaches that enable sustainable and effective exploitation. Also, the goal that is set for participants in urban life is to achieve sustainable development.

2. LAST-MILE DELIVERY

Digitalization is the dominant cause of changes in all spheres of human activity. Digital technology development crucially reshapes relations in the e-commerce field. Electronic commerce, or e-commerce, is defined as the production, distribution, marketing, sale, or delivery of goods and services by electronic means [2]. With technological development, the e-commerce environment becomes more dynamic. Under the influence of digitalization in the retail domain, customers are buying more and more products online. During 2022, 91% of the EU population aged from 16 to 74 used the internet, and of them, 75% had e-commerce experience [3].

Last-mile delivery is the final phase in the e-commerce value chain. It can be said that last-mile delivery includes all activity from the final sorting center to end-customer delivery. Last-mile delivery is observed as one of the most expensive, inefficient, and most polluted parts of the supply chain [4].

E-commerce growth generates an increasing number of parcels, so last-mile delivery operators (postal or logistics) face significant challenges. Last-mile delivery problems are caused, first of all, by customer expectations according to delivery, and secondly, there is urban infrastructure with limited capacity to support increasing parcel flows.

The B2C segment has the fastest development. An essential characteristic of the B2C segment is the many small deliveries. To develop a successful business model, value chain members need to be effective and must reduce costs.

The initial conditions of last-mile delivery are set up by an e-retailer that defines services, and it is transferred to other value chain members by defining conditions for efficiency and cost optimization. Providing different delivery options to customers becomes an important factor in the selection process of e-retailer. In that way, customers expect a range of delivery options, so they can choose what they need. Thus, last-mile delivery solutions belong to critical factors.

Different strategies in the field of last-mile delivery must take into account certain elements specific to the observed urban area [5]: demand characteristics, customer preferences, and environmental regulations. Better approaches to resource management and innovations present basic elements for last-mile delivery optimization.

3. DEVELOPED SOLUTIONS

Execution of delivery is key to customer satisfactionwith e-commerce. The vast majority of deliveries from e-commerce are directed to urban areas. Considering the intensive growth of e-commerce, it has negative impact on last-mile delivery activities. Urban areas make demands on delivery systems in terms of higher speed, higher reliability and lower negative impact on safety and the environment. Space in cities is limited, and attempts to increase transport infrastructure cannot follow the demands generated by the last-mile. Customer decision to cooperate with e-retailer is defined according to the spectrum of services offered by e-commerce [6].

Ordering products in small quantities, urbanization and the evolution of customer behaviour, make restrictions on the investments in developing concepts of last-mile delivery. Technological development and innovations strive to improve current solutions, as well as to develop new ones. Last-mile delivery in the B2C segment is based on: service promise, cost optimization and sustainable impact on the environment. Thus, the quality of developed solutions is necessary to evaluate through the prism of these dimensions.

E-customers, when making decisions about buying, give an important place to attributes of particular delivery options such as delivery cost, delivery speed and delivery place. E-commerce development leads to situation where delivery options are adjusted to end customers. Mutual connections as well as information sharing between customers, trace the path to a wider range and adaptable delivery options.

Various solutions for last-mile delivery can be observed by the level of interaction between the delivery operator and the end customer. Widely adopted and promising solutions are: attended home delivery, attended collection-and-delivery points, parcel lockers, mobile parcel lockers, crowd-shipping services, drones and autonomous delivery vehicles.

3.1. Attended home delivery

Attended home delivery is the dominant solution for last-mile delivery. This solution demands the customer's presence at home, and the customer confirms the delivery. Failed delivery occurs in cases when a customer is absent. The delivery failure rate can reach up to 25% [7]. Last-mile delivery activities in attended home delivery are under the influence of different factors[8]:increasing demands for services, sustainability questions (increasing number of delivery vehicles), attended home delivery being the most expensive option, time pressure generated by e-retailer (delivery same or next day) and labor shortage.

Traditional home delivery is very expensive. Factors that contribute to high costs, in this case are: failed delivery – the recipient is not available, traffic jams, parking problems and negative influence on the environment. Operators tend to optimize delivery routesin function of reducing delivery stops and increasing the number of deliveries per stop.

Considering that source of customer satisfaction is in customer-employee contact during the service [9], delivery man skills (like competency, training and courtesy) have a crucial impact on customer perception of the entire e-commerce process. In particular, customers appreciate it when the delivery man is flexible if they have special requests. Beside that, the situation of failed delivery causes additional costs, which is also a potential source of customer dissatisfaction.

The absence of adequate parking space can lead to delivery vehicles spending one hour a day cruising for parking [10]. Also, parking problems lead to many parcel operators having a significant financial allocation for fines as a result of illegal parking.

Implementing alternative solutions, that do not demand customer attendance at home, can achieve cost reductions of up to 70% [11].Even though attended home delivery is the most time-consuming and expensive solution for last-mile delivery from any point of view, it is still the dominant option for customers. Customers recognize this option as one of the main e-commerce advantages. In an aim to improve this delivery solution, efforts are to achieve intensive implementation of electric vehicles.

3.2. Attended collection-and-delivery points

Solving last-mile delivery in this way is based on the utilization of different locations (post offices, local shops, gas stations, parcel shops or other locations) the customers select as an alternative delivery address. Atattended collection-and-delivery points, we have personnel that havecontact with end customers. Compared to traditional delivery, operators avoid failed deliveries and route optimizations, but on the other hand, active participation is expected from customers.

3.3. Parcel lockers

In contrast to previous solutions, parcel lockers present an approach there are no human interactions. Parcel lockers are available 24/7. Compared to traditional delivery, parcel lockers bring certain advantages [12]:decrease inefficiency caused by failed deliveries, consolidate parcels at a certain location (that leads to better utilization of delivery vehicles), reduce the number of delivery trips, avoid customers waiting, reduce traffic congestionand reduce negative impacts on the environment.

In the conceptdevelopment of parcel lockers, it is most important to determine their adequate location. Optimal parcel locker location is defined by [13]: customers' income, fixed installation costs, operating costs, and potential loss of customers if the location is outside of their acceptable distance.

There is a strong investment trend in the development of parcel locker networks by postal operators. Some examples are Deutsche Post DHL and InPost. Deutsche Post DHL started with this concept in 2003. The tempo of development was 7,000 parcel lockers by 2021 and 11,500 parcel lockers by 2022, with a plan to achieve 15,000 parcel lockers in Germany during 2023[14].InPost had 16,445 parcel lockers in Poland by 2021, and that number increased to 19,306 by 2022[15].The estimated market value of parcel lockers in 2021 was 722.1 billion USD, and the forecast is 1883.9 USD by 2029 [16].

One variation of this approach is mobile parcel lockers. Mobile parcel lockers can change their location during the day. They can be managed by humans or they can be autonomous. This solution improves accessibility for customers who are not tied to one place [17]. The tasks, in this case are: route optimization and waiting time estimation at proper locations.

3.4. Crowd-shipping services

The basic idea for crowd-shipping services is that the parcelis delivered from a person who needs to travel, so the delivery process does not cause new kilometers [18]. In this case, the delivery process is realized by privately owned vehicles. The development of crowdsourced services is based on digital technologies, which is necessary to ensure a digital platform for communication between participants. Apart from bringing benefits, crowd-shipping opens the questions of parcel safety and data privacy concerns.

3.5. Drones

Drones are a very popular option for resolving problems in last-mile delivery. In comparison to attended home delivery, drone delivery has advantages in: speed, costs and environmental impacts. This approach is not limited to traffic conditions and existing urban infrastructure. Drones' ability to take off and land vertically, give them a chance to operate in various environments. In terms of using drones, their energy demands define their performances (flight distance, costs etc.) [19].One parcel per delivery is also a significant limitation.

Taking all into account, drones are a promising solution in urban areas, because they move activities from the ground to the air.

3.6. Autonomous delivery vehicles

Autonomous delivery vehicles are driverless electric vehicles, equipped with sensors, cameras and navigation system [20].Considering urban conditions, autonomous delivery vehicles optimize their delivery routes. The elementary advantage of autonomous delivery vehicles is reflected in their profitability when we have labor shortages and wage growth[21].

The intensive development of artificial intelligence and sensor technologies creates an area for much more application of this approach. In that way, the last-mile delivery achieves cost reduction, energy savings, smaller negative environmental impact, reduction in traffic congestions and improvement of traffic safety. A major barrier to this approach is the adaptability of urban infrastructure for vehicle movement.

4. CONCLUSION

The increased demand for last-mile delivery services brings additional problems for inhabitants, parcel operators and urban planners. Optimization and innovations are the basis for solving problems in urban last-mile delivery. Anyway, it is necessary to include the limitations that the concept of sustainable development defines.

The success of individual solutions in last-mile delivery is caused by the level of customer acceptance. Thus, the impact on creating a proper customer experience by using different options becomes essential for a successful business.

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Gabriela Poljak[1]
E-mail: gabriellapolyak8@gmail.com
Marinko Maslarić[1]
E-mail: marinko@uns.ac.rs
Slaviša Dumnić[1]
E-mail: dumnic.s@uns.ac.rs
[1] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad

A METHODOLOGY FOR EVALUATING AND IMPLEMENTING LOCATION SELECTION APPROACHES: A CASE OF CITY FREIGHT HUB

Keywords

Location selection
City freight hub
Methodology

Abstract

Currently, more than half of the world's population lives in cities, whose population has doubled in the last five decades. What has long been a problem is that the mobility of the majority of the urban population and the logistics flows in the city depend on cars and other motorized vehicles. Traffic congestion, insufficient number of parking places, increasing energy consumption, and air pollution are just some of the problems people face. City hubs are one way to partially solve these problems by consolidating goods from different suppliers in a hub and cooperating in last mile delivery. The idea of integrating micromobility initiatives as innovative urban transport solutions can enhance the effectiveness of city hubs even further. However, due to the limited urban space available, finding a suitable location for such a hub is a major challenge. Numerous location selection models can be found in literature, reflecting the ongoing relevance of this logistics challenge. Continuously, new models emerge, often as variations of existing ones. Hence, the primary objective of this research is to present a pragmatic approach for assessing existing models regarding their applicability to a specific location selection case. The potential practicability of the developed methodology was demonstrated through its application in the case of identification of the city freight hub's location in Novi Sad.

1. INTRODUCTION

There is a need to boost the efficiency and effectiveness of logistics operations in cities since global trends indicate a rising demand for commodities in urban areas [1]. City logistics refers to activities involved in the delivery of goods within urban areas, and according to [2] represents one of the subgroups of green logistics.

The fundamental objective of the European Commission's White Paper on Transport is to achieve carbon dioxide (CO_2)-free city logistics in major urban centers by 2030. In addition, the increasing urbanization and rising urban freight transport volumes necessitate radical changes in current patterns of urban freight transport. This is crucial because, according to [3], urban freight distribution accounts for an impressive 20% of all motor traffic in metropolitan areas.

Urban environments are particularly negatively affected by the movement of commodities by a certain type of freight vehicle. The movement of freight vehicles in cities creates additional problems compared to nonurban driving. For instance, traffic jams, visual encroachment ([4], [5]) and kerbside space occupation [6] are all examples. Unfortunately, if current patterns continue, the negative effects will undoubtedly get worse over time. As confirmation of this are the following two trends. Firstly, according to United Nations research from 2014, nearly all population expansion is anticipated to occur in metropolitan areas, which will raise demand for commodities. Secondly, the demand for faster delivery is growing, forcing logistics service providers (LSPs) to transport items more quickly using smaller or less-loaded vehicles ([7], [2]). Both trends will likely lead to an increase in the number of freight trucks delivering goods in cities.

Using urban consolidation centers or city hubs with a two-stage urban delivery method is a viable answer to these issues [8]. Delivering items from outside the city to the hub within the city limits constitutes the first stage. A combined last mile distribution of commodities to the end recipients is part of the second stage. Thus, by better utilizing freight vehicle capacities, the number of vehicles entering the urban area can be decreased. Air pollution and noise levels can be reduced much further if the second stage is completed by electric or other low-emission cars [9].

Discovering suitable transshipment facilities in urban regions, which already have a shortage of urban space, is a notable challenge problem. One of the primary and potentially most crucial steps in addressing this issue involves definition, assessment, and evaluation of the criteria on which the decision on the location of such a hub depends. Numerous location selection models can be found in literature, reflecting the ongoing relevance of this logistics challenge. Continuously, new models emerge, often as variations of existing ones. Therefore, the main motivation of this paper is not to reinvent the wheel but to provide a practical methodological approach for applying an existing model to a specific problem. That is, the primary objective of this research is to present a pragmatic approach for assessing existing models regarding their applicability to a specific location selection case. The potential practicability of the developed methodology was demonstrated through its application in the case of identification of the city freight hub's location in Novi Sad.

2. STATE OF THE ART

When designing any kind of city hub, the hub's location is a key factor. Costs and the availability of transportation are frequently deciding considerations in this decision. Standards for the environment and society might be taken into consideration in addition to these economic ones to meet all dimensions of sustainability [10]. Traditionally, choosing a hub location involves reducing costs and/or time [11]. In light of this, common techniques for choosing a location tend to be quantitative in nature and range from company-driven and pure utility-based assessments to optimization-based facility location and hub location problems [12] and [13]. In these optimization issues, often only one objective is addressed. However, by converting them into expenses, qualitative criteria can also be easily included in such a model [14]. However, multi-objective optimization can also be utilized to address several objectives [15]. Paper [16] conducted a thorough literature analysis on facility location issues related to choosing a city hub location.

In [9] the authors elaborate in detail about the concept of city hubs or urban consolidation centers (UCC), which are located close to the end delivery area to minimize the last-leg trips and to boost responsiveness. Typically, these centers are utilized to consolidate the flow of people and goods into the city [17]. It is typically referred to as a micro-hub or micro-consolidation center, particularly if such a center aspires to carry goods within its close proximity using emission-free vehicles like cargo bikes [18] and [19]. An interface between outbound and inbound freight transports, a UCC can be described as a logistics facility that serves an entire city or portions of it. According to several studies [20] and [21], UCC is also one of the most researched municipal logistics programs. The advantages of city hubs can be separated into two categories: benefits aimed at various stakeholders and benefits related to reducing the negative consequences of distribution of goods. First, fewer freight cars may be required by consolidating commodities near to the city [17]. This is done by achieving a high load factor on the freight vehicles approaching the city. The damaging environmental and social repercussions brought on by freight vehicles can be lessened with fewer of them. Additionally, UCCs allow for the switch to smaller, more environmentally friendly cars due to shorter delivery distances [22] and [23] also remark that energy usage can be decreased. By introducing and expanding the concept micromobility, it is possible to alleviate the existing problems of city logistics. That is why micromobility solutions are increasingly being considered in the analysis of city freight hub location.

3. METHODOLOGICAL APPROACH

The evaluation process for an existing site selection model will concentrate on multiple levels of analysis to identify strategic and operational possibilities for potential implementation. This approach is tailored to the notion that distinct location criteria hold relevance in various specific cases. To apply an existing location selection model effectively in a specific situation, the following steps need to be followed:

- *Understand the location selection method being considered*: study the methodology, steps, and requirements of the given approach in detail. Ensure a clear understanding of how the method works and what data inputs it requires.
- *Define objectives and criteria*: clearly define the objectives of location selection process that is the subject of investigation. Determination of the specific criteria and their potential adjustments to the specifics of the location selection being resolved.
- *Gather data*: collection of the necessary data for the location selection process and ensure their accuracy and comprehensiveness.
- *Adapt the existing method to the specific case*: customize the existing method to suit the specifics of case in question. Adjust the weights or scores assigned to different criteria based on the specific project's requirements.
- *Application and analysis of data*: application of the adapted method and assessment of the suitability of each of proposed locations. Interpretation of the results of analysis and proposing top-ranked locations.
- *Decide about potential implementation of the analyzed method*: based on the analysis and interpretation of the results a decision regarding suitability of the explored method should be made.
- *Implement and monitor*: development of implementation plan for the application of chosen method.

By following these steps, an existing method for location selection can be assessed and implemented in a specific case. It should be noted that adaptation of the method to suit the unique requirements and circumstances of the specific case and ensuring data accuracy and consistency is of extremely importance.

4. APPLICATION EXAMPLE OF THE DEVELOPED APPROACH

In this section, the feasibility of implementing the developed methodology will be examined using the case of evaluating the location for a city freight hub in Novi Sad. It is important to emphasize that this particular example will focus solely on the application of the initial three phases of the developed approach. Therefore, an analysis of the location selection model proposed in the paper [10] was carried out. This model is based on the Analytic Hierarchy Process (AHP) and was used for the hub location selection problem in Vienna. The reason behind selecting this type of location selection model is widespread utilization of the AHP method, which proves to be practical among existing models. Consequently, accomplishing the first step (*Understanding the location selection method)*, becomes straightforward by understanding the steps and requirements of the AHP methodology and comprehending its underlying logic.

The analyzed model [10] defines three main types of criteria that can be used in the case of Novi Sad. These are: costs, environmental and social aspects and location-specific characteristics and features. The outcomes of implementing steps two (*Define criteria*) and three (*Gather data*) of the developed methodology, involving the definition of criteria and collection of the necessary data, are displayed in Table 1. Therefore, the focus is on the proposed criteria and their adoption in the case of the hub location in Novi Sad, as well as identification of sources and availability of the necessary data.

Table 1. The location criteria and its characteristics

Criteria	Adoption to the case of Novi Sad	Availability of data source
Costs		
Real estate costs	Real estate costs are increasing and thus very important factor in Serbia (fully applicable)	Information obtained from municipal planners; market analysis
Costs of local logistics companies	Most costs have risen suddenly in the last couple of years, among others due to the complex geopolitical situation in Eastern Europe and the inflation rate typical of most countries in the world (fully applicable)	Information obtained from logistics companies; market analysis
Environmental and social aspects		
Number of nearby E-charging stations	Unfortunately, there are still very few, not only in the city of Novi Sad, but in the entire country (limited applicability)	Planning documentation; aerial photos
Bike lanes	At the national level is at the forefront, but still lags behind developed countries (fully applicable)	Existing planning documentation, aerial photos
Air-quality	There is space for development. Especially in the winter months the air is polluted, and the region is often among the most polluted regions (fully applicable)	Regional scan of available regional and city data sets
Population density	Is constantly increasing. It has been a trend in the country for residents to more from the villages to the cities, so the city's population is constantly growing, new apartment blocks are constantly being built ((fully applicable)	Existing planning documents; municipal information
Location-specific characteristics and features		
Number of traffic accidents	There is a decreasing trend over the years due to increased regulations and police supervision as well as tightening of fines and penalties (fully applicable)	Existing publicly available data
Access to the highways	International highway A1 (E-75) passes directly by Novi Sad (fully applicable)	Strategic road network; planning documents
Access to the rail	The section of the railway network is currently under renovation, but when it is completed, it will form a section of the international railway network, which will facilitate traffic and freight transport between neighboring countries (fully applicable)	Strategic rail network; planning documents

5. CONCLUSIONS

The hub's location is important when designing any kind of city hub. Choosing a hub location typically entails saving money and/or time. In urban areas where there is already a shortage of urban space, finding suitable transshipment facilities is a significant challenge.
This paper introduces a methodology for assessing the suitability of existing models for specific location selection cases. The practical feasibility of the developed approach was demonstrated by applying it to the criteria selection process for selection the city freight hub's location in Novi Sad.

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Hrvoje Pavlek[1]
E-mail: hrvoje.pavlek@yahoo.com
Marko Slavulj[2]
E-mail: mslavulj@fpz.unizg.hr
Dino Šojat[2]
E-mail: dsojat@fpz.unizg.hr
Hrvoje Prskalo[3]
E-mail: h_prskalo@yahoo.com
[1] Zagreb Holding Ltd, Zagreb parking Subsidiary
HR-10000 Zagreb, Ulica Pavla Šubića 40
[2] University of Zagreb Faculty of Transport and Traffic Sciences
HR-10000 Zagreb, Ulica Lavoslava Vukelića 4
[3] City of Berlin
DE-10367 Berlin, Stefan-Heym-Platz 1

THE EFFECT OF PARKING PRICING ON KEY PARKING PERFORMANCE CHARACTERISTICS IN PUBLIC GARAGES

Keywords

City of Zagreb
Key parking performance characteristics
Parking pricing
Public garage
User composition

Abstract

A sound parking policy is crucial for sustainable urban mobility. Since mostly fixed public garage supply often makes up a significant proportion of urban parking supply, matching it to demand becomes a challenge. This paper researches the impact of changes in parking pricing on key parking performance characteristics in urban garages. Compared to previous research, this paper focuses on user composition for daily parking with data obtained from parking system management. For the study area, two public garages in the City of Zagreb were chosen. This paper offers a solution for managing garage parking in urban areas sustainably. Based on user composition and key parking performance characteristics, this paper argues for introducing dynamic parking pricing based on occupancy. The results of analysing key parking performance characteristics and user composition showed that the impact of price changes affects the observed public garages differently. Based on the analysis, solutions will be able to be offered for a more rational urban parking policy.

1. INTRODUCTION

The last two decades saw an increasing importance of car parking in urban planning, because car ownership and usage are continuously increasing, and urban space becomes scarcer. This is more emphasized by the residents of city centres, who usually park their cars in the vicinity of their homes, often blocking sidewalks and roads [1].

The research on parking has been dominated for several decades by “grey literature” – reports and unscientific papers published by parking experts. Scientific publications were comparably rare until the end of 1990s [2]. Despite being a relevant factor in urban transport demand management, compared to other traffic fields, parking is still insufficiently researched.

Parking demand management is a set of policies and measures resulting in more efficient usage of parking resources. If parking demand management is implemented rationally, the number of offered parking spaces can be significantly reduced, enabling several economic social and ecological benefits. Improved parking demand management is often the best solution to problems with parking [3].

Previous work researched optimal parking policies in urban areas [4], and some authors focused on the financial aspect [5-7]. The base of arguments for parking policies were considered, concluding that more research should be done to fully understand the impact of parking on availability and city attractiveness [8].

The cities could manage parking facilities more efficiently to improve public well-being by setting higher occupancy as a goal instead of higher incomes. This was proven by a good practice example from San Francisco, where the SF Park program was used to manage public off-street parking, such that parking prices were reduced, garage occupancy was increased, with unchanged income for the city [9].

Since parking pricing is an important parking demand strategy [3, 10], this paper analyses changes on key parking performance characteristics (KPPC) in public garages [11] in case of increased prices. Price changes only do not completely contribute to a rational parking policy, so this paper introduces user composition to see the impact of price changes on short-term users and long-term users.

2. RESEARCH METHODOLOGY

The research was conducted on two public garages in the City of Zagreb – Gorica and Kvaternikov trg. The observed garages are positioned in close vicinity (Figure 1). The Kvaternikov trg garage is an underground public garage with 354 spaces. The Gorica garage is a combined overground and underground public garage with 353 parking spaces. The garages are located on the eastern edge of the city centre. Since 2023-01-01, parking prices in both garages became higher.

To better understand the means of price changes influencing garage users, user composition was determined for garage parking spaces before and after price changes, divided into two major categories:

- Short-term users, who pay for parking by hour,

- Long-term users, who pay for parking with pre-paid parking tickets.

The research was conducted by collecting the data from parking management system. An entire day was separated into 24-hour intervals, such that the starting number of vehicles in garages was measured at the beginning of the observation period. The parking management system provided the number of parking tickets registered at entering and exiting for every hourly interval.

The focus of the research is the impact of price changes on KPPC, provided by mandatory literature [11], before and after the price changes for one workday in each garage, and they are:

- Average occupancy (O_a),
- Average accumulation (A_a),
- Number of vehicles parked in the garage (V_p).

Figure 1. Public garages Kvaternikov trg and Gorica – aerial view [12]

Previous methodologies usually had a survey to collect data regarding user composition and determining optimal parking pricing in garages [13]. The methodology of this study is based on determining user composition by a detailed analysis of the data obtained from the parking management system. However, the difficulties of the research arise in data processing because the system is not well-adjusted to calculate KPPC automatically, so additional data transformations had to be done.

3. RESEARCH RESULTS

Since 2023-01-01, the prices in both garages have risen (Figure 2). Because of rising prices, vehicle occupancy reduced (Figure 3, Figure 4). Before price increase, the period of overcapacity was from 09:00 to 14:00 in Gorica garage, and from 08:00 to 15:00 in Kvaternikov trg garage. After price increase, the problem with overcapacity resolved. The results of the analysis showed that the price changes had an impact on each of KPPC differently (Figure 5) in 24-hour period. For both garages, higher prices resulted in less average accumulation and average occupancy throughout the observed day. Higher prices also influenced the number of vehicles parked, with decrease in Gorica garage and increase in Kvaternikov trg garage. The price change also had an impact on user composition (Figure 6) in 24-hour period. The analysis showed that there was a decrease of short-term and long-term users in Gorica garage. Consequently, the number of available spaces increased by 10%. In Kvaternikov trg garage, the number of long-term users decreased, however, the number of short-term users increased, but this also resulted in 10% more parking spaces.

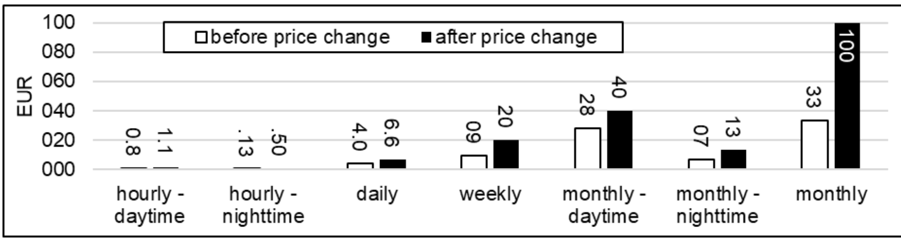

Figure 2. Parking prices in both garages

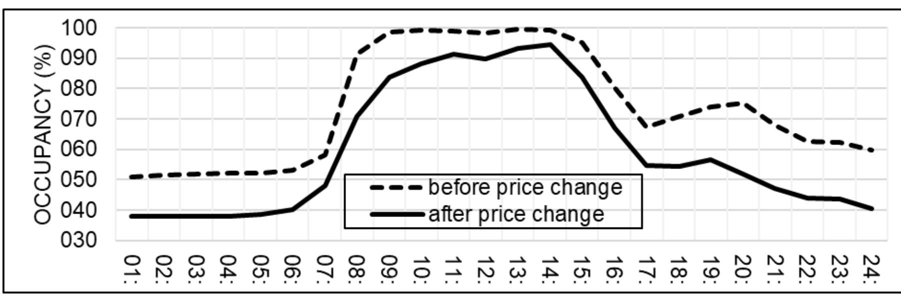

Figure 3. Occupancy in Gorica garage before and after price change

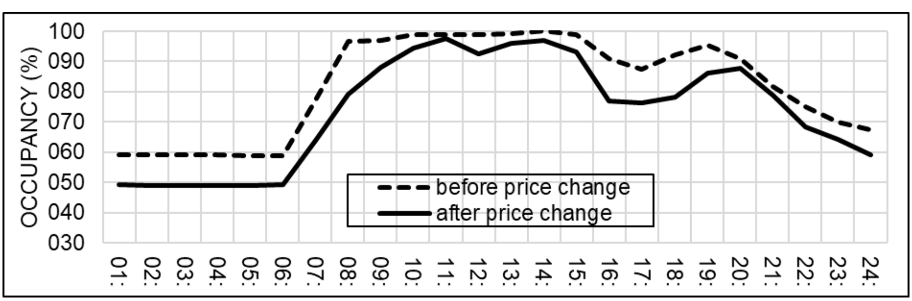

Figure 4. Occupancy in Kvaternikov trg garage before and after price change

The increase in the number of parked vehicles in Kvaternikov trg garage is related to the amount of short-term parking, because the number of long-term users occupying parking spaces in peak periods decreased, thus enabling short-term users the opportunity to occupy additional parking spaces.

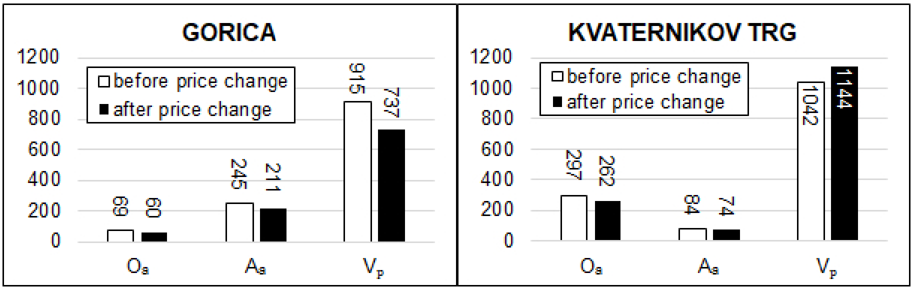

Figure 5. Parking demand parameters – comparison

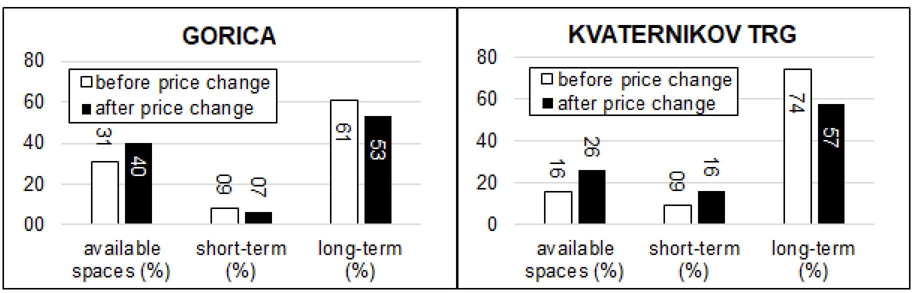

Figure 6. User composition – comparison

4. DISCUSSION

The results of the analysis showed that each parking area needs to be approached individually. When there are problems with parking in specific area, besides the data obtained from the field, the corresponding user composition also needs to be analysed. This creates more rational guidelines for sustainable parking management for the area.

In this example, parking policy creators saw the problem with overcapacity in garages, so they decided to change parking policy with price increase. Although overcapacity resolved, the implementation of this strategy does not mean it will always have the same impact on user behaviour. Therefore, the problem needs to be tackled in the same manner as in San Francisco [9] to use the capacity optimally and to manage parking spaces sustainably. The solution to the problem should include:

- Determining and monitoring hourly parking demand parameters (O_a, A_a, V_p),
- Determining and monitoring hourly user composition for both short-term and long-term users,

- Depending on hourly O_a and user composition, increasing or decreasing parking fees every hour or limiting the number of long-term users by not allowing monthly ticket purchases.

A proposal of the solution is shown in Table 1, where parking fees change according to occupancy.

Table 1. A proposal for dynamic parking prices based on occupancy

Occupancy	Hourly tickets, 08:00 to 18:00	Hourly tickets, 18:00 to 08:00
< 40%	0.80 EUR	0.30 EUR
40% - 85%	1.10 EUR	0.50 EUR
> 85 %	1.40 EUR	0.80 EUR

According to the analysed data in this research which considers occupancy and user composition:

- in Gorica garage, daily monthly fees should be increased to remove corresponding users from the garage in peak periods, and nightly monthly fees should decrease, and this type of parking should be popularized,
- in Kvaternikov trg garage, the nightly monthly fees should decrease, and this type of parking should also be popularized.

Additionally, rational guidelines regarding user composition should be proposed, such that the composition is monitored throughout the day. This could prove as the best way to manage parking capacities. Since the garages have identical capacity and are very close to each other, it is necessary to investigate why the user composition differs. The solution could imply as Kvaternikov trg garage being more recent with wider parking spaces. Certainly, a user survey should be conducted to provide the actual predictors.

5. CONCLUSION

Urban areas have many traffic-related problems, with parking being one of them. A great challenge in resolving parking problems is matching parking supply to parking demand. This paper researched the impact of price changes on KPPC in public garages. The research results showed that changes in pricing influence differently on each KPPC, despite the garages being very close to each other. To better understand the impact of price changes, in addition, the relationship between prices and user composition was also analysed. The results show that price changes have a different impact on user composition in each garage. This implies that every parking area should be approached differently when introducing new models and strategies for improving parking policies.

The research lacks a user survey to investigate the reasons why the users park their cars more in one garage than the other, although the prices are the same and the garages are very close to each other. The paper presented a parking management model where prices are dynamic based on occupancy. This model should enable a more rational parking space management. The goal is to have as high as possible occupancy, accumulation, and the number of vehicles, but to prevent overcapacity at the same time. This would enable a more sustainable parking space management, which is certainly favourable to any administrative body.

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Zoran Papić[1]
E-mail: z.papic@uns.ac.rs
Vuk Bogdanović[1]
E-mail: vuk@uns.ac.rs
Nemanja Garunović[1]
E-mail: garunovic@uns.ac.rs
Slavko Davidović[2]
E-mail: slavko.davidovic@banjaluka.rs.ba
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21 000 Novi Sad, Serbia
[2] City of Banja Luka
Department of Trafffic and Roads, Banja Luka, BIH

CHANGING THE PARKING REGIME IN NOVI SAD BY INTRODUCING AN EXTRA ZONE IN THE CITY CENTER

Keywords

Parking characteristics, parking regime, accumulation

Abstract

With the increase in the number of registered vehicles and the degree of motorization in Novi Sad, the requirements for parking have increased significantly. Research conducted in 2017 determined the basic characteristics of parking in the central zone of the city of Novi Sad, and in 2019 certain measures were proposed to improve the parking system. Since the demands for parking in the central city zone exceed the parking capacity and in some parts of the day they reach up to 140% of the capacity, a measure was proposed in the form of a change in the parking regime and the introduction of an "extra" zone in the parking system. This paper shows the impact of this measure on the parking system in Novi Sad.

1. INTRODUCTION

With the increase of motorization and individual motor traffic, Novi Sad has faced increasing traffic problems. Problems related to vehicle parking are among the most significant, since they have a number of negative effects, such as reduction in the capacity of city roads conditioned by the slow movement of the vehicle and maneuvering in the process of parking, occupation of areas intended for pedestrians and cyclists, irrational use of available areas, noise and exhaust emissions, dissatisfaction of citizens and users of parking lots, etc. The need to park vehicles in central city zones arises as a consequence of numerous factors, whereas parking requirements have random value. Constant increase of demands for parking is a direct consequence of:

- concentration of numerous activities in central urban areas;
- lifestyle changes;
- an increased mobility of the population;
- high representation of individual car traffic in the total traffic structure of mechanized modes of movement [1].

Over time, it has been established that the capacities of city parking lots cannot meet the growing demands for parking. On the other hand, in the interest of the development of the city, new capacities cannot be created indefinitely, but the existing parking areas must be used optimally. In order to improve the functioning of the parking system and harmonize the needs for parking with the needs and general tendencies of the development of urban areas, it is necessary to periodically analyze the existing parking system. One of those studies was carried out in 2017 for the purposes of the SMART PLAN study - data collection [2]. Within the framework of the SMART PLAN study - the second phase, a correction of the existing parking regime in the narrower central city zone was proposed, which introduces an "extra" zone. In relation to the existing parking regime, a time-limited parking of up to 60 minutes was proposed for the "extra" zone, as well as a higher fee for the parking service in this area [3].

Within this paper, the characteristics of parking in parking lots in the inner city zone will be analyzed, before and after the proposed change in the parking regime in the central city zone.

2. FIELD OF RESEARCH

Within the framework of the SMART PLAN - the second phase, the introduction of an "extra" parking zone was proposed. The parking lots that are proposed to be redistributed to the new zone are as follows:

- Mihajlo Pupin Boulevard (section between the intersection with Narodnih heroja Street and Žarko Zrenjanin Street) - on both sides of the road,
- Modena Street,
- Ilija Ognjanovića Street,
- Narodnih heroja Street.

However, as the construction of the parking garage in Modene Street has started in the meantime, the entire street is closed to traffic, and the parking spaces on this street are temporarily usurped. In addition to this street, the dead end of Ilija Ognjanovića Street is also closed to traffic, so the parking capacity in this street is reduced. In addition to the proposed streets, to the “extra” zone were also reassigned the streets Isa Bajić, Ignjat Pavlas, Konstantina Danila and the continuation of

Mihajla Pupina Boulevard (from the intersection with Modena St. to Pionirska St.). The capacity of the parking lot in Mihajla Pupina Boulevard (the section between the intersection with Narodnih Heroja Street and Žarka Zrenjanin Street) has been reduced because part of the parking lot has been repurposed as a taxi stand. The display of the "extra" zone in the parking system in Novi Sad is shown in Figure 1.

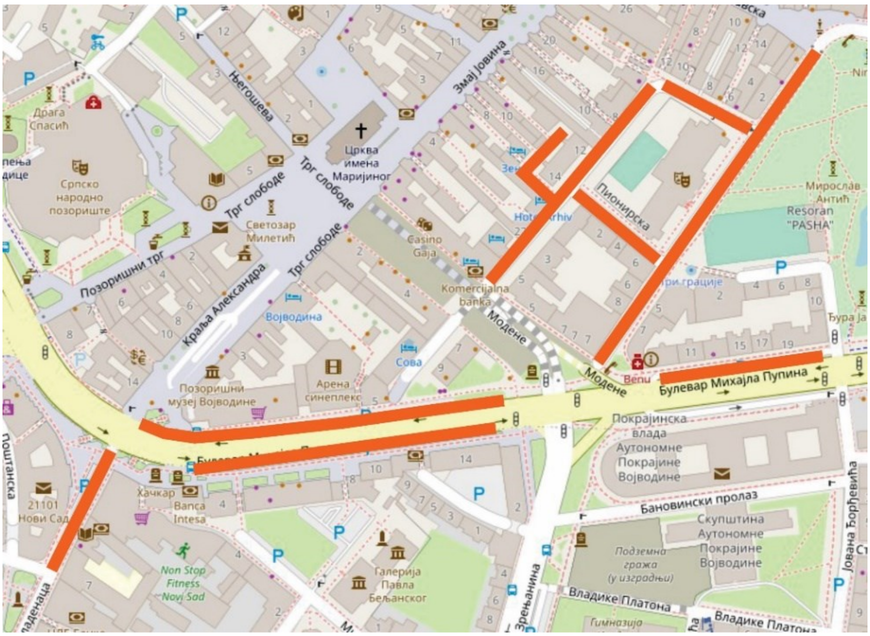

Figure1. Overview of the research area

The initial research was carried out in 2017, as part of the Smart Plan project - data collection, commissioned by the City of Novi Sad. During the research, a full-day count of vehicles in parking lots was carried out, from 7:00 a.m. to 9:00 p.m., that is, during the period when parking fees are charged in Novi Sad.

The second survey was carried out in May 2023, as a control count and verification of requests, in order to determine the requests for parking in the period when the measure was applied in the parking regime. Control counting determined the average hourly parking requirements in all parking lots.

3. COMPARATIVE ANALYSIS OF ACCUMULATION BEFORE AND AFTER THE INTRODUCTION OF THE EXTRA ZONE IN THE PARKING SYSTEM

Since the licence plate numbers of the vehicles parked in the observed parking lots were not recorded by the control counting, of all parking characteristics only a comparative analysis of the accumulation can be performed.

Figure 2 shows a comparison of the occupancy of parking spaces in parking lots located in the extra zone, obtained from the research in 2017 and 2023. It is observed that the accumulation of vehicles during the survey in 2023 decreases throughout the day. Also, it can be seen that the occupancy of parking spaces does not exceed 100% in any part of the day. It is also necessary to take into account the fact that the capacities of certain parking lots have been reduced due to the construction of a parking garage in Modena Street and by relocating taxi stands (the capacity in the observed area was reduced by over 10%). As the total accumulation in all parking lots is less than 100% throughout the day, it can be concluded that users can find a free parking space at any time of the day in the observed area.

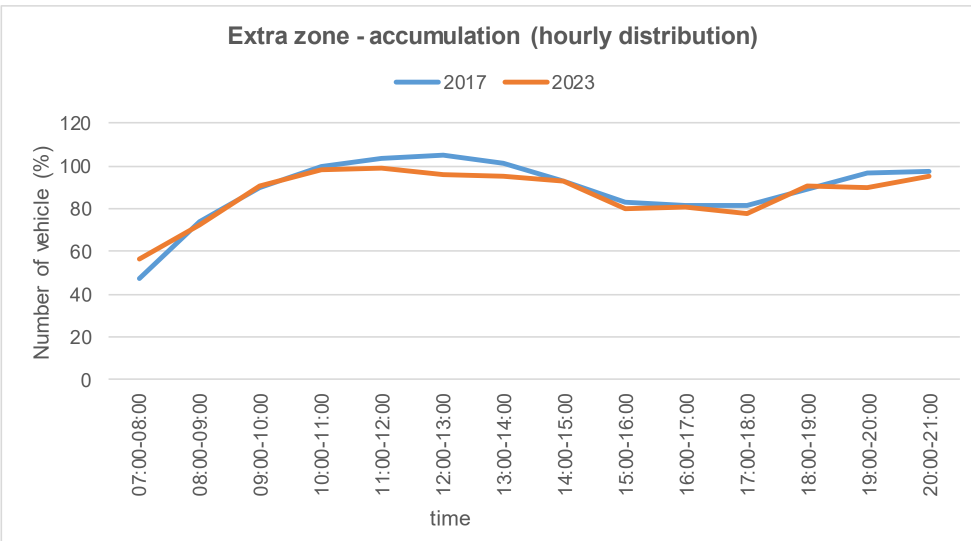

Figure 2. Hourly distribution of accumulation

The following table shows separate parking accumulations in parking lots located within the "extra" zone, with a comparative analysis of the results of the research conducted in 2017 and 2023. Parts of the day when parking capacity occupancy was lower in 2023 compared to 2017 are shown in green, while parts of the day when parking lot utilization was higher in 2023 compared to 2017 are marked in red. Differences in parking lot occupancy up to 10 % are not marked. The results of the research for the parking lot in Isa Bajića Street differ from other parking lots, given that during most of the day the occupancy of the parking lot is higher in 2023 compared to 2017, and the reason for this is that at certain moments some vehicles were improperly parked in the observed area. In other parking lots, during a longer period of the day, the parking accumulation determined by the 2023 survey is less than or equal to the accumulation determined by the 2017 survey.

Table 1. Occupancy of parking spaces in parking lots, within the "extra" zone

Name of the street	Year	07:00-08:00 h	08:00-09:00 h	09:00-10:00 h	10:00-11:00 h	11:00-12:00 h	12:00-13:00 h	13:00-14:00 h	14:00-15:00 h	15:00-16:00 h	16:00-17:00 h	17:00-18:00 h	18:00-19:00 h	19:00-20:00 h	20:00-21:00 h
Narodnih heroja	2017	61	96	93	96	93	93	89	93	86	86	64	89	86	89
	2023	50	84	92	92	97	92	89	92	84	87	87	74	79	87
Bulevar Mihajla Pupina (Bazar)	2017	23	63	89	95	95	95	93	88	91	82	81	91	93	93
	2023	21	46	97	110	100	95	95	100	74	74	67	97	87	100
Bulevar Mihajla Pupina (DDOR)	2017	29	85	98	95	98	97	93	97	93	80	85	92	97	100
	2023	15	43	92	98	96	92	92	89	75	89	70	96	91	94
Bulevar Mihajla Pupina (režijska)	2017	100	100	97	97	100	100	97	97	83	83	76	76	97	97
	2023	54	71	80	97	103	100	97	94	83	86	77	77	89	97
Ilije Ognjanovića	2017	65	86	103	111	116	123	114	98	88	89	93	97	103	102
	2023	96	102	109	115	115	110	108	109	100	90	94	100	100	106
Ise Bajića	2017	62	69	92	100	100	108	115	100	92	92	100	85	100	108
	2023	109	82	136	118	136	127	127	118	82	100	64	73	82	118
Konstantina Danila	2017	64	73	91	100	100	100	100	91	64	100	82	91	73	100
	2023	55	91	100	100	100	100	100	82	100	82	100	100	64	100
Ignjata Pavlasa	2017	27	46	67	94	103	101	98	84	68	68	69	81	96	95
	2023	54	65	66	80	82	82	83	74	61	63	66	88	89	85

4. CONCLUSION

Problems related to vehicle parking are among the most significant problems in the field of traffic, which have arisen due to the increase in the degree of motorization and individual motorized traffic. Demands for parking in the central area of the city are increasing due to its attractiveness, and the space for expanding parking capacities is decreasing. That is why it was necessary to change the parking regime and introduce an "extra" zone, where parking will be limited to a maximum of one hour. This provides an opportunity for a greater number of users to use the services of the parking lot.

The results of the research, which was conducted in 2017 as part of the Smart Plan study - data collection, and in 2023, after the implementation of the proposed measure of changes to the parking regime, were compared. Since in 2023 only a control count was carried out, only a comparative analysis of the occupancy of parking spaces, i.e., the accumulation, could be carried out.

The comparative analysis concluded that the accumulation of vehicles during the research in 2023 was less throughout the day. Also, it can be seen that the occupancy of parking spaces does not exceed 100% in any part of the day. It is also necessary to take into account the fact that the capacities of certain parking lots have been reduced due to the construction of a parking garage in Modena Street and by relocating taxi stands (the capacity of these parking lots has been reduced by over 10%). As the total accumulation in all parking lots is less than 100% throughout the day, it can be concluded that users can find a free parking space at any time of the day in the observed area.

ACKNOWLEDGMENT

This research has been supported by the project "Development and application of modern methods and technologies in education and research in traffic and transportation", founded by the Department of Traffic Engineering, Faculty of Technical Sciences in Novi Sad, University of Novi Sad, Republic of Serbia.

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Darko Polić[1]
E-mail: darko.polic@nsurbanizam.rs
Nenad Saulić[2]
E-mail: n.saulic@uns.ac.rs
Miloš Kopić[2]
E-mail: miloskopic@uns.ac.rs
[1] Urbanism, Institute for Urban Planning Novi Sad
Bulevar cara Lazara 3, 21 000 Novi Sad, Serbia
[2] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21 000 Novi Sad, Serbia

RESOLVING THE PARKING SPACE DURING THE RECONSTRUCTION OF THE ALMAŠKI REGION IN NOVI SAD

Keywords
Urban reconstruction
Ground floor arrangement
Parking
General regulation plan
Public parking garages

Abstract

The reconstruction of the old and protected part of Novi Sad (Almaški region) will require a design solution that derives from the basic guidelines of the General Urban Plan of Novi Sad. These guidelines are reflected in the new ground-floor arrangement of the Almaški region and the formation of a pedestrian zone. The paper analyzed whether and to what extent the design solution responded to the requirements of the general regulation plan by introducing parking garages on the perimeter of the reconstructed settlement.

1. INTRODUCTION

The analyzed area represents the protected zone of the spatial, cultural and historical unit of the Almaški region in Novi Sad. This area represents the old part of Novi Sad, north of the traditional city center. The street network of this area is very characteristic due to the unusual mix of narrow streets. The narrowness of the space is reinforced by the large number of parked cars, given that the residents' need for at least one vehicle is expressed. The problem is that, after the Second World War, a large number of residential units were formed in courtyard wings on plots of mostly single-story buildings. During that time, the number of inhabitants increased significantly, forming the so-called horizontal solitaires. This conflicts with the capacities of the urban matrix, which is dimensioned for family and not multi-family housing. This results in a significant lack of space for parking cars.

In practice, it is not possible to satisfy the norms prescribed by the valid General Regulation Plan of the Almaški Region in Novi Sad [2]. That is, one housing unit has one parking space. The new General Urban Plan of Novi Sad until 2030 is even more restrictive. It prescribes 1.1 to 1.8 parking spaces per building plot.

In this paper, the planning documentation that predicts the parking solution in the observed area, as well as the design documentation that led to the final ground floor solution for Almaški kraj (including the parking solution) was analyzed. Through a comparative analysis of planning documentation from several different periods, and technical documentation of the design solution, this work should determine whether the set goals for the arrangement of public space, as well as the parking solution for Almaški Kraj, have been met.

2. ANALYSIS OF THE EXISTING SITUATION

The area analyzed in the paper is the southern part of the Podbara settlement. The area is adjacent to the city center of Novi Sad. It covers the space between Pašićeva and Gundulićeva streets and Temerinska and Kosovska streets, which can be seen in Figure 1.

Figure 1. Scope of research

The existing situation with parking at the analyzed location is such that people park in the public space of the street (Figures 2 and 3). There are two reasons why this is so. The first is due to the fact that few buildings have a car entrance to the lot. The second reason is that those who have a car entrance to the plot do not use the yard space for parking, but do so in the public space of the street (public purpose area).

Where the street regulations are wider, the parking spaces in the street are marked, and in the streets where the regulation is narrower, the parking spaces are not marked. Vehicles are parked on sidewalks or on the road. Parking is mostly free of charge. This is a very important fact. Research by designers of the public part of the space and the parking lot of the analyzed area showed that those who park in the streets of the mentioned area are employed in institutions in the surrounding boulevards and streets. They take advantage of free parking, which is a particular problem during business hours.

Figures 2 and 3. Presentation of the current way of parrying in the streets of the Almaški region

3. POSSIBLE SOLUTIONS

Possible options for parking within the observed area appeared as early as in the Plan of General Regulation of the Almaški Region. The first option provided for the organization of a parking lot with a larger capacity around the perimeter of the Almaški region. This primarily referred to larger plots in the zone where access is possible from Temerinska Street (which is the border street of the area). The second option provided for the creation of a parking garage for the users of Matica Srpske and for public use, in payment mode, within the spacious plot of land of Matica Srpska. The third option provided for parking garages to be organized on the outskirts of the Almaški region. Two locations are defined for this. The first location is between Kosovska and Šumadijska Streets next to the heating plant [3], and the second is in Temerinska Street itself [4] (figure 4). It is an effective concept of how to release the protected zone and meet the parking needs.

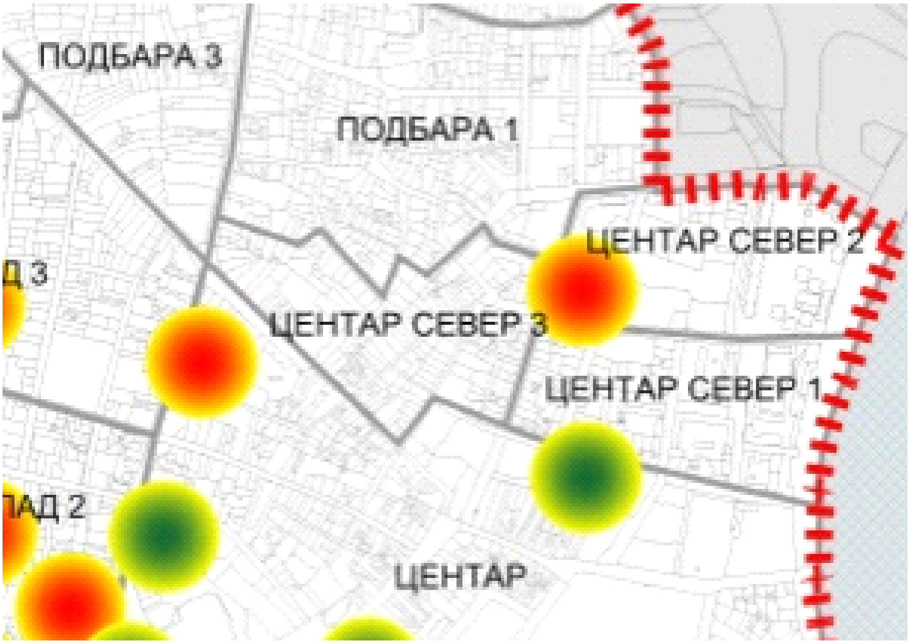

Figure 4. Locations provided for public parking garages in the Almaška region (Smart Plan – Phase II)

4. DESIGN SOLUTION

In order to reconstruct the Almaški region, which involves the replacement of dilapidated communal infrastructure (water, electrical energy, traffic and others), ground floor and horticultural landscaping, AP Vojvodina and the City of Novi Sad initiated and financed the development of project documentation in 2021. In 2022, the first phase of the reconstruction of the part bordering the pedestrian zone of the traditional center of Novi Sad began. The project documentation was prepared by the company "DB ARCHITECTS" from Novi Sad. Their project task was to design a new ground-floor apartment with the guidelines from the planning documentation. Among other things, there are several key guidelines. The first is that the observed space is a protected zone and that must be maintained (by turning off the car). The second is that the buildings are mostly ground level, so they cannot be seen in the space of the parked cars in front of those buildings. The third guideline is greening, so it is suggested that the space be greened rather than used for parking.

The approach of the designers was to arrange the space in a way and in accordance with the architecture and spirit of the Almaški region, which implies pedestrian communication and movement, i.e. the establishment of pedestrian zones in those parts where street regulations are the narrowest. This approach excludes the current way of parking and makes it difficult for vehicles to access some lots, but this will be regulated by a special regime.

5. CONCLUSION

In the previous processes of urban reconstruction of parts of Novi Sad, there was rarely an opportunity to design and arrange traffic areas in such a way as to reduce the conditions for the movement of car traffic. Although the regime of pedestrian zones in Novi Sad was established only once, in the city center at the beginning of the 1980s, the next one will be implemented in the Almaški region, according to the project from 2021. The protection of this part of Novi Sad, as a spatial cultural-historical entity, promotes the preservation and restoration of the existing architectural structure and public space of the part of the city dominated by family housing in single-story buildings. This is the main reason for the change in priorities, i.e. the emphasis on pedestrian versus car traffic. Although this way seems to lower the standards of the modern needs of the inhabitants, the value of public space and the inherited structures of the Almaški region deserve it. Along with the necessary definition of the access regime to the existing facilities, the new ground floor arrangement makes it impossible to park in locations that were not designed for it. At the same time, the lack of parking spaces will be compensated with new alternative locations for parking garages around the perimeter of the Almaški region or in the peripheral zones of the immediate neighborhood. This way of planning, designing and realizing the urban reconstruction of a valuable cultural heritage zone can be a good example for those localities where conditions for a freer and safer stay of people should be provided. Alternative modes of movement (pedestrian and bicycle) are also promoted compared to automobile.

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Miloš Kopić[1]
E-mail: miloskopic@uns.ac.rs
Darko Polić[2]
E-mail: darko.polic@nsurbanizam.rs
Nenad Saulić[1]
E-mail: n.saulic@uns.ac.rs
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21 000 Novi Sad, Serbia
[2] Urbanism, Institute for Urban Planning Novi Sad
Bulevar cara Lazara 3, 21 000 Novi Sad, Serbia

CRITICAL REVIEW OF THE IMPLEMENTATION OF UNDERGROUND PUBLIC GARAGE IN THE CENTER OF NOVI SAD

Keywords

City center
Public parking garages
Urban transformations
Urban plans
Wider scope of the city center

Abstract

Solving parking in city centers is a big challenge. In Novi Sad, this is a long-standing problem. For many years, temporary parking areas and prefabricated public garages in spare locations have been alternative solutions to unrealized planning solutions. Today, public parking garages are being built in the city center in accordance with the planning documentation. This paper analyzes whether the locations of parking garages in the city center are the only and optimal solution, taking into account several factors. First of all, it is the danger of the consequences of demanding construction works in the vicinity of old buildings, then the need for a parking solution in dense multi-family residential construction in the wider scope of the city center, then the potential for further urban transformations, as well as other urban topics related to the functionality of the space and the urban context.

1. INTRODUCTION

The concept of building public parking garages in the strict center of the city is characteristic of the circumstances in which cities functioned in previous decades. At the level of Novi Sad, a whole series of planning documents from the previous cycle planned public parking garages in the city center. This is being realized today. The question arises whether such a system for solving parking in the city center is justified in terms of the optimal functioning of the city and urban development?

An alternative approach to the current solution assumes that the city center will be freed from car traffic, so that public parking garages are planned in the wider area of the center. Such garages would be easier to access by cars. Also, such garages would have a larger number of users, given that they would be used by those who use the central facilities from the inner core of the city, but also by those who live in the wider area of the city center. In the city center of Novi Sad, there are few residents compared to other areas of the city.

By analyzing planning documentation and urban planning principles for the design of functional public spaces and urban units, this work should determine whether the existing solutions for parking in the center of Novi Sad enabled further urban development and functioning of the city or whether additional interventions in the urban fabric are necessary. This paper should also determine the advantages and disadvantages of the current realization of public parking garages and how they are reflected on the example of Novi Sad.

2. ANALYSIS OF THE EXISTING SITUATION

The scope of research of this work is the center of the city of Novi Sad. The inner-city center is the area defined by the streets: Mihajla Pupin, Ignjat Pavlas, Žarko Vasiljevića, Republic Square, Daničićeva, Nikola Pašić, Jovan Subotić and Uspenska streets. The wider scope of the city center is shown in Figure 1.

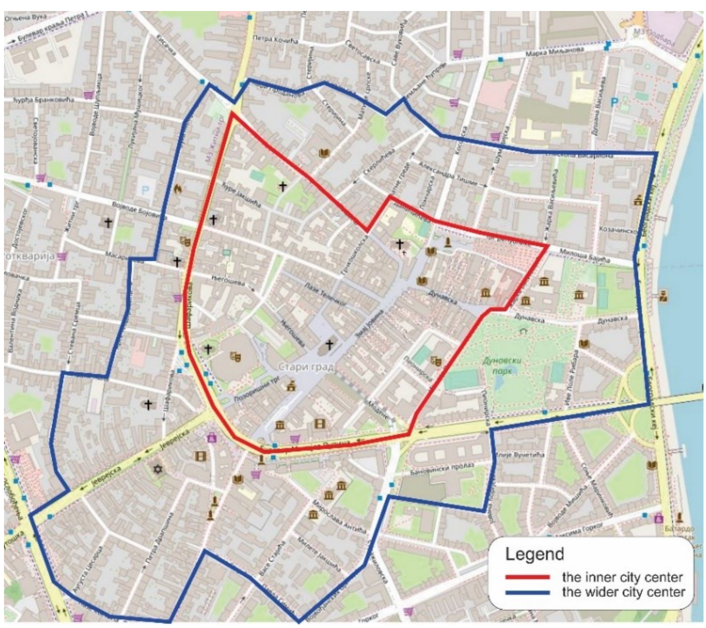

Figure 1. The inner city center and the wider scope of the city center of Novi Sad

For many years, the question of where to locate public parking garages in the central part of the city figured. At the end of the 20th century, Novi Sad experienced a demographic and construction boom, so the need itself became many times greater. For decades, the lack of public parking garages in the city center was compensated by alternative parking locations [1]. These are temporary garages and parking areas at the locations (Figure 2). Street parking in almost all streets in the central city area represents the largest share of parking space capacity. The total number of street parking spaces in the central zone is more than 1,000 parking spaces [5].

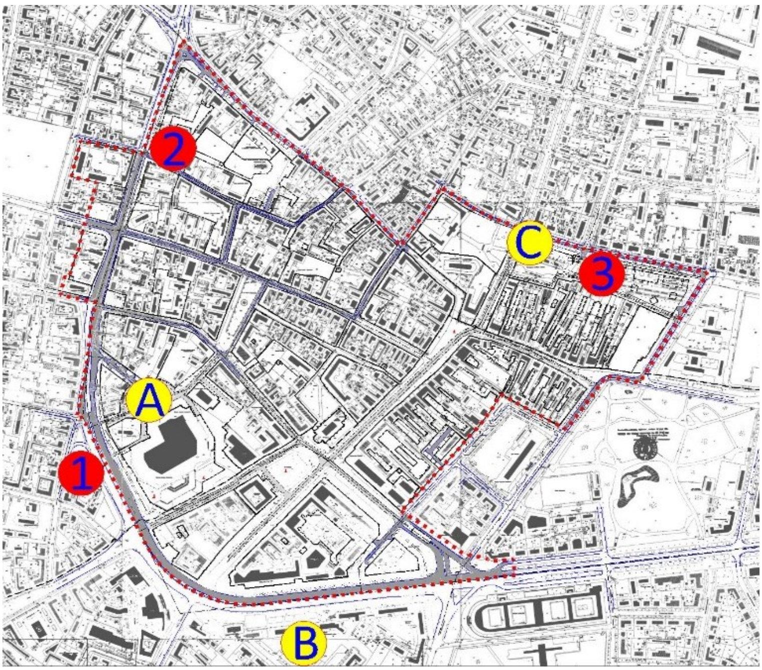

Figure 2: Arrangement of planned public garages (red circles) 1. The corner of Uspenska and Šafarikova streets 2. The corner of Jovana Subotića and Đure Jakšića streets and 3. Trg republike/Riblja pijaca (the Republic Square/Fish Market) and temporary parking spaces (yellow circles): A. Plateau from the Serbian National Theatre, B. Trg galerija/Erste banka (the Galleries` Square/Erste Bank) and C. Trg republike (the Republic Square).

3. CURRENT SOLUTION

Solving parking in the city center is based on the construction of public parking garages in the city center. The location of the first garage is in Modene Street, next to the pedestrian zone itself. The second location is near the Banovina building. The locations of the parking garages are shown in Figure 3. In addition to the locations of the parking garages, the figure also shows the gravity area of both garages (radius of about 300 m, which is an acceptable walking distance to the final destination of the trip). All garage locations are planned as underground facilities.

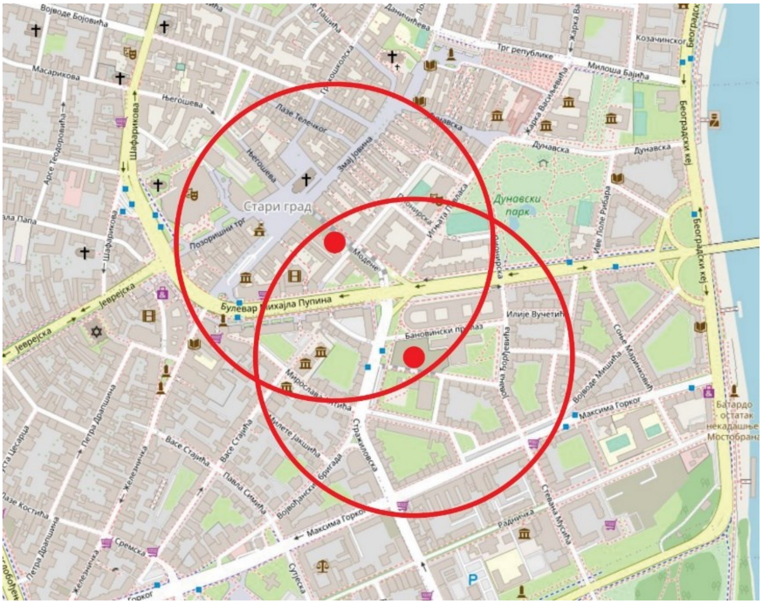

Figure 3. Locations of parking garages in the central zone of the city, with a marked gravity area

This solution was recorded in the general urban plan of Novi Sad from the previous period [2]. Current realization of this is allowed by new plans of more detailed elaboration. For these localities, the rules of arrangement and construction are determined by the current plans, for the garage in Modene Street by the Detailed Regulation Plan of the Protected Old City Core Zone in Novi Sad [3], and for the garage near Banovina by the Detailed Regulation Plan for Mali Liman in Novi Sad [4].

4. URBAN REVIEW OF THE CURRENT SOLUTION

The positioning of public parking garages in the city center should be analyzed from several aspects. The first is realization. The second is the impact of this concept on the functioning of the pedestrian zone in the city center and its further development. The third is the possibility of using these garages by users from a wider area of the city center, and primarily residents of those areas. The existing solution, which is in the implementation phase, will solve parking in the city center. The question is what are the consequences of implementing that project, and what are the advantages.

From the aspect of realization, it can be stated that there are more consequences in terms of construction and urbanism in the early phase of this process. Tanurdžić's palace, which is a symbol of the city and a cultural and historical asset, has cracked due to the consequences of the works. During the works, the foundations of the first building of the Serbian Motherland were removed.

The works are carried out in the strict center of the city in the surroundings of old buildings protected by regulations. They are often statically quite unstable. They are located on terrain that is quite unfavorable for construction works. The terrain is sandy with groundwater. Very aggressive underground interventions are and will be performed on such terrain.

Another aspect from which the current solution was analyzed is the impact of this concept on the functioning and development of the pedestrian zone. The existing pedestrian zone in the very center of the city (Figure 4) was created in 1981 and corresponded to the city's functioning conditions and needs at that time. Since then, 42 years have passed and the demographic, urban, economic, political and other circumstances, as well as the needs for the functioning and development of the city, have changed significantly. In all those years, the pedestrian zone did not expand. It needs to be done in a planned manner in accordance with the densification of construction, the distribution of new programs and content, and the construction of new urban values and projects.

The current construction of public parking garages is taking place in the very center of the city, on the very edge of the already existing pedestrian zone (Figure 4). By expanding it, these garages would remain deep inside the pedestrian zone instead of being planned on the perimeter of the future expansion, thus relieving the city center from the movement of cars even more on the one hand, and on the other hand, they would have the same function as now but in the planned wider scope.

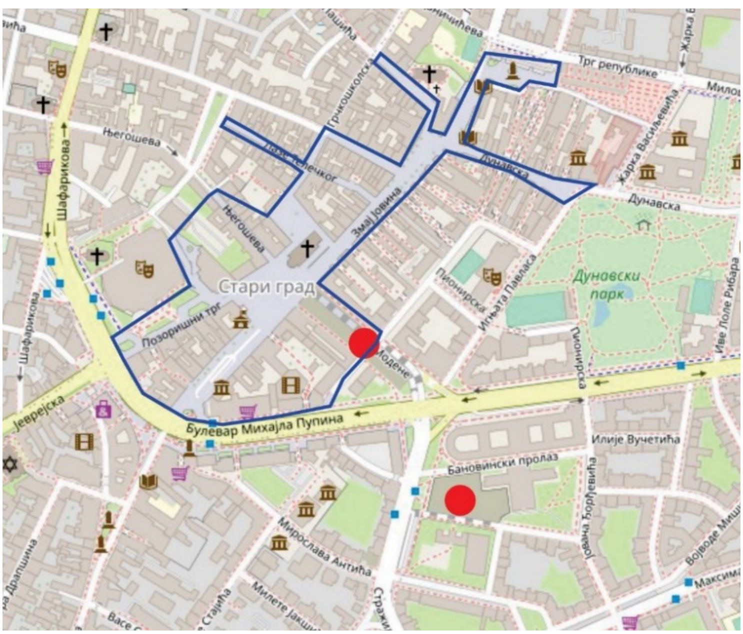

Figure 4. Pedestrian zone in the city center of Novi Sad and marked parking garage locations under construction

The third aspect is the question of the users of these public parking garages. They primarily cover a large number of users who come to the city center to fulfill a wide range of daily needs within a large number of central contents from a multitude of activities, and which in Novi Sad are significantly concentrated in the very center of the city, i.e., the old core of the city. However, a small number of tenants live in this area. A large number of tenants live in the wider area of the city center (Figure 1). From the perspective of their needs, garages should be planned in this area as well.

5. CONCLUSION

The current parking solution based on two parking garages (on Modene Street and near the Banovina building) will meet current parking needs in the city center. However, for the reasons stated in this paper, it is necessary to continue with the construction of parking garages. New garages should be built around the perimeter of the wider center of Novi Sad. In addition to meeting the downtown parking needs of those who visit the center due to the wide range of programs and central amenities, these garages will serve a large number of people who live in the wider downtown area and beyond. Also, this parking concept will enable the expansion of the existing pedestrian zone through the wider center. These pedestrian zones, as well as the parking garages to which they would lead, will serve the purpose of easier access to the city center, as well as forcing pedestrian traffic in comparison to car traffic.

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Milan Stanković[1]
E-mail: milan.stankovic@akademijanis.edu.rs
Vladimir Popović[1]
E-mail: vladimir.popovic@akademijanis.edu.rs
Jovan Mišić[1]
E-mail: jovan.misic@akademijanis.edu.rs
Pavle Gladović[2]
E-mail: anaipavle@gmail.com
Ilija Perić[3]
E-mail: ilija2peric@gmail.com
[1] Academy of Technical-Educational Vocational Studies
Aleksandra Medvedeva 20, Niš
[2] Faculty of Technical Sciences in Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad
[3] Niš-ekspres doo, Niš
Stevana Sinđelića 59, Niš

INFLUENCE OF INTERVAL DISTURBANCE ON EXTENDED PASSENGER WAITING TIME

Keywords

Waiting time
Interval disruption
Public transport
Quality of service

Abstract

Modern vehicle tracking technologies have created the possibility for a positive action of the transport organizer on the user, in order to mitigate the estimated times with accurate information about the actual arrival of the vehicle. As previous research has shown, the waiting time at the stop, as the only static part of the journey, has the greatest importance for the user. Determining the interdependence of interval disruption and waiting time estimation would allow quantifying the importance of the measures needed to maintain the interval, and then also on user behavior and the effects of that behavior. In the paper, on the chosen corridor, on the example of the observed bus stop in Nis, research was carried out based on the recording of vehicle tracking in order to obtain data on the size of the average achieved interval of vehicle tracking, as a basis for determining the disturbance of the interval that affects the extended waiting time of passengers, as and recording the accumulation of passengers, to determine the unevenness of the accumulation.

1. INTRODUCTION

In practice, the realization of the movement of vehicles along the line often does not coincide with the planned one, that is, there are deviations in the realization of the projected timetable. Depending on the size of the deviation, the unreliability of the service occurs. In public urban passenger transport systems, deviations of the realized vehicle tracking interval from the designed are the main parameter of service unreliability.

Traffic accessibility as a function of public transport strengthens the economy, deals with the conservation of energy and resources, reduces congestion, improves the quality of air and our health, provides critical assistance in emergency situations and catastrophes, increases the development and value of real estate, increases mobility in small urban and rural communities, and reduces health costs. All of this contributes to a better quality of life [1].

The user's experience of the quality of the public transport system is subjective, so the user actually behaves according to his assessment of the suitability of the transport, which is usually not objective [2].

The tracking interval represents one of the most significant dynamic elements of the line, both from the point of view of the organization of transport, and from the point of view of the quality of transport important for passengers.

Under ideal conditions, the public urban passenger transport system functions with an even interval of vehicle tracking. Interval disturbances occur due to the negative influence of certain factors on certain time components of the planned turnaround time. Then the vehicle moving on the line is in a hurry or late compared to the designed interval of the vehicle.

After the introductory part, the paper presents an analysis of waiting time and its components, as one of the elements of travel time. In the third part, the methodology used during the research is explained. After that, the analysis of the results and the obtained data was started based on the recording of the accumulation of passengers and the achieved vehicle intervals. A conclusion is given at the end of the paper.

2. ANALYZING WAITING TIME

The importance of travel time variability has been the objective of much research in the past and has therefore been extensively analysed from the traveller's perspective. Many studies have concluded that although travel time is an important factor affecting the traveller's route choice behaviour, travel time variability can be even more important. Travellers are interested in how long it will take them to reach their destination, but are even more concerned with how reliable their prediction of total travel time is. A wrong travel time prediction results in either an early arrival at the destination or in a delay [3].

Poor service reliability affects both passengers waiting time and crowding. To have a small probability of arriving late at their destination, passengers must plan on waiting longer than the average platform waiting time. While passengers vary in their willingness to accept the risk of arriving late at their destination, a reasonable working assumption is that passengers will accept a 5% risk of arriving late. Therefore, the 95th-percentile waiting time can be interpreted as budgeted waiting time.

Budgeted waiting time can be divided into two parts: the part that passengers actually spend waiting and the remainder, called "potential waiting time." For example, if a passenger budgets 10 min for waiting, but the bus arrives after only 4 min, the 6-min difference is the potential waiting time. Potential waiting time is not spent on the platform; it is spent at the destination end of the trip, where the traveler will arrive 6 min earlier than budgeted. However, because it was set aside for waiting, that time cannot be used as freely as if it had not been so encumbered; therefore, it still represents a cost to passengers. For example, passengers going to work in the morning could not spend their potential waiting time sleeping a few minutes later or staying at home with the kids a few minutes longer. Potential waiting time is a hidden cost associated with waiting, manifested in passengers having to start their trips earlier than they would otherwise have to if waiting time were certain [4].

Passenger waiting time can be divided into two parts: ideal and excess. Ideal waiting time is the average waiting time that would result from service exactly following the schedule; excess waiting time is the difference between actual and ideal waiting time and is, therefore, the component of waiting time that can be attributed to operational issues. Separating excess from ideal waiting time provides a good idea of the quality of operations and the extent to which passenger service could be improved by improving service reliability.

2.1. Waiting Time Components

Passengers can use their waiting time more productively, select which route they would want to take, or choose to select an alternative mode of transportation. Whatever the prospective passengers' choices are, providing them with real-time information reduces the uncertainty inherent to transit systems [5].

Two components of waiting time are not avoidable and are, therefore, part of ideal waiting time, not excess waiting time:

- *Schedule inconvenience*: a well-known form of hidden waiting time that arises from departures or arrivals not being scheduled when passengers want to travel. It is manifested in passengers who are going to work arriving before their work start time because the next bus would get them there too late. Likewise, after work, passengers may consistently have time to kill between leaving work and the next scheduled departure.
- *Synchronization time*: the cost, in equivalent minutes of waiting, of ensuring that one is at the station by the target arrival time. To be sure of hitting that target, many passengers will arrive early because of uncertainty in access time, the limits of human punctuality, and risk aversion. The waiting time between when passengers arrive and the ideal arrival time is part of synchronization time.

Schedule inconvenience and synchronization time are unavoidable; they are responsible for planning, as they are the inevitable consequence of designing a service with a long headway. In contrast, random waiting time that occurs after the ideal arrival time is due to service unreliability and is, therefore, excess waiting time.

3. METHODOLOGY OF RESEARCH

The research methodology is based on recording the waiting time of passengers at the stop, that is, their accumulation in each minute of the interval of vehicles using the observed stop.

The choice of the corridor for researching the quality of transport service was chosen on the basis of transport requirements in peak and off-peak periods in the direction of the city center, the convenience of all lines for all passengers, the importance of transporting pupils and students and the high percentage of service time during the day.

The research period during the day was chosen, so as to include the peak period (from 6 - 8 a.m.) and the off-peak period (from 9 - 11 a.m.) of the working day during the validity of the summer timetable. The direction towards the center of the city of Nis was chosen during the period of going to work or for another purpose, as the primary direction in terms of the importance of reliable transportation.

At the observed bus stop, all vehicles were registered by line, namely line 6 (Duvanište - Ž. stanica), line 11 (Duvanište - Medoševac) and line 13 (Bulevar Nemanjića - Trg K.A.), with their frequencies in the direction of the city center. Considering that the lines of this corridor have mostly the same itinerary, the choice of the line by the passengers did not affect the waiting time, but the passengers used the first bus that came along. The stop is organized at the level of the carriageway, from the canopy. The recording was made on a working day.

At the same time and on the same section of the corridor, the accumulation of passengers at the bus stop was recorded by minutes after the departure of the previous bus. The research included all passengers heading towards the center. The investigation of passengers waiting for the bus was carried out by numerical processing of the investigation of the accumulation of passengers according to the minutes of waiting in relation to the arrival time of the next bus.

4. ANALYSIS OF RESEARCH RESULTS

The unevenness of the intervals and the accumulation of passengers were recorded at the bus stop of the observed corridor (Park Sveti Sava - city center), in the peak and off-peak periods, which obtained data on the sequence of bus passes, the duration of the interval and the number of arriving passengers per minute of the interval. Figure 1 shows the relationship between timetables and passenger purchases. The congestion shown results in increased passenger waiting time, compared to the minimum expected waiting time that would occur if the intervals were even.

Different values of vehicle intervals on lines in peak and off-peak periods are shown in the following table:

Table 1. Interval of following vehicles on the lines

	Peak period	Off peak period
Line No 6	9 min	11 min
Line No 11	/	60 min
Line No 13	14 min	15 min

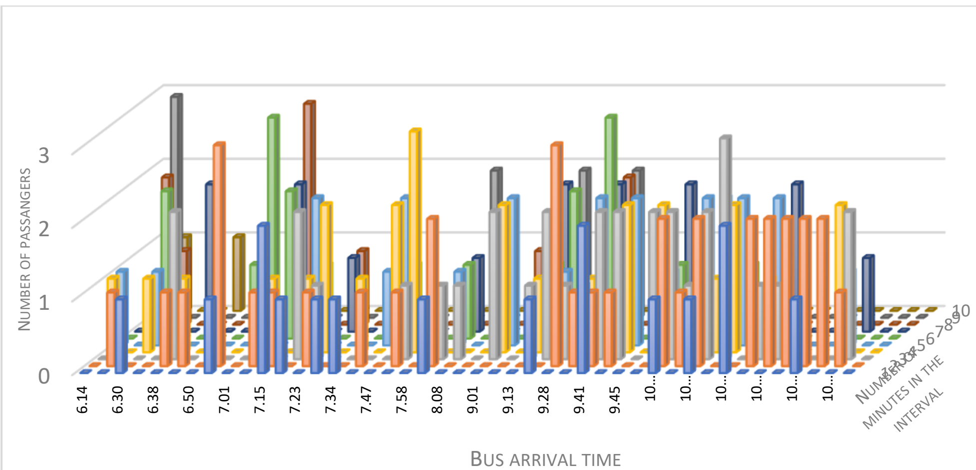

Figure 1. Display of the unevenness of the accumulation of passengers for the recording period at the observed bus stop

The results of recording the interval disturbances, on the selected characteristic section of the corridor, show that in the peak period from 6:14 to 8:10 a.m., that is, for a duration of 116 minutes, 22 intervals were realized, while in the off-peak period from 9:01 a.m. to 11:01 a.m., i.e. for a duration of 120 minutes, 22 intervals were also completed. The average achieved interval was 5.5 minutes and 5.7 minutes, respectively.

The accumulation of passengers for the same time showed that an average of 1.4 passengers/min or 1.08 passengers/min arrived per minute.. Looking at the intervals achieved, the number of passengers ranged from a minimum of zero passengers to a maximum of 14 passengers, or an average of 4.41 passengers per interval.

Comparing the maximum deviations from the average values of the intervals and the number of accumulated passengers per interval, the unevenness of the accumulation of passengers was more favorable than the unevenness of the intervals. This leads to the conclusion that the disruption of the bus following interval will have a much greater impact on the extended waiting time than the unevenness of the accumulation of passengers. Passengers behave individually or in pairs, and rarely in smaller groups, so their accumulation cannot be significantly different from a randomly even one.

The total waiting time for the recorded intervals and the number of passenger accumulations was 579 passenger min and 747 passenger min respectively.

The percentage of passengers in the peak and off-peak periods, and according to the minutes of the interval before the departure of the bus (from the end of the waiting interval), is shown in the Figure 2:

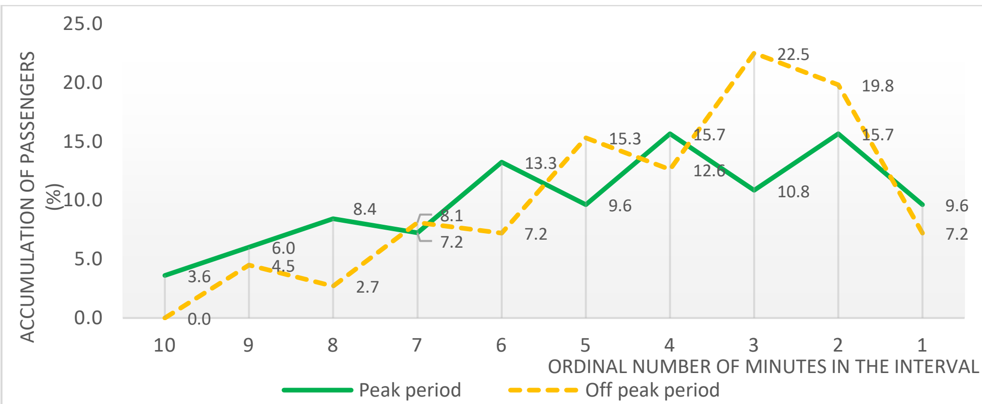

Figure 2. Accumulation of passengers by the minute

The accumulation of passengers, in the peak period, grows more slowly from the beginning of the interval, to increase sharply in the last minutes of the interval. The accumulation of passengers, in the off-peak period, is even with visible fluctuations, with a sudden drop at the end.

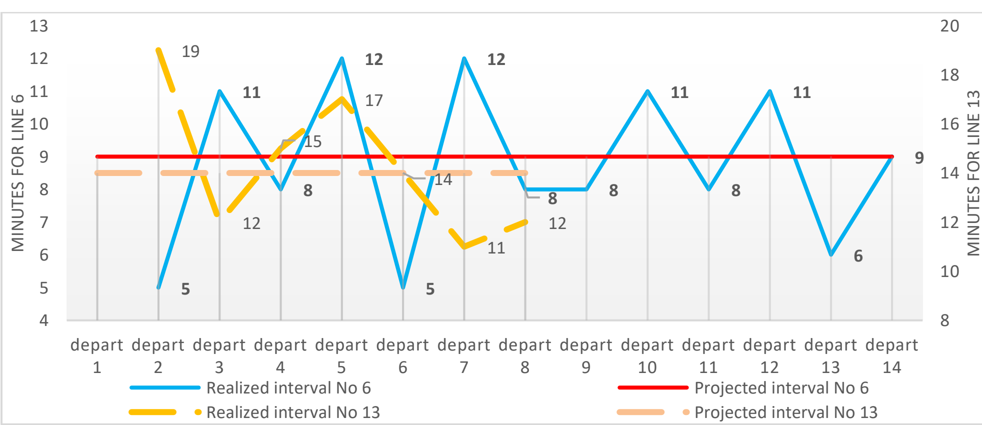

Figure 3. Presentation of unevenness of intervals on lines 6 and 13 during peak hours

Figure 3 shows the unevenness of the peak hour intervals on lines 6 and 13 at the observed bus stop. Interval deviations on line 6 ranged from 0 to 4 minutes based on the realized interval compared to the projected interval of 9 minutes. On line 13 in the same observation period, the deviations ranged from 0 to 5 minutes based on the design interval of 14 minutes.

5. CONCLUSION

High level of passenger satisfaction and competitiveness of the public transport system is achieved exclusively by high quality of service. The high quality of service in public transport implies that users experience a short waiting time at the stop and a short driving time. The main characteristic of city lines is the high frequency of vehicles, which provides users with shorter waiting times at stops and higher transport speeds. However, the operational functioning of the system in high frequency conditions is difficult. During the operational functioning of the system due to the action of various factors, there are frequent variations in the time of movement of vehicles along the line.

Based on the recording that initiated the continuation of similar and larger research, significant results were obtained that can help in understanding the accumulation of passengers and their behavior, at the expense of uneven arrivals of vehicles. Namely, this way of observing these two mutual entities can in the future help in a new way of designing and better functioning of the system.

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Olivera Petrovska[1]
E-mail: olivera.petrovska@unt.edu.mk
Jovan Hristoski[1]
E-mail: jani.hristoski@unt.edu.mk
Daniel Pavleski[1]
E-mail: daniel.pavleski@unt.edu.mk
Andon Petrovski[2]
E-mail: 24ingbt@gmail.com
Darko Spasenovski[2]
E-mail: 24ingbt@gmail.com
[1] Faculty of Technical Sciences, University Mother Teresa-Skopje, R. of N. Macedonia
Mirce Acev str., no. 4, 1000 Skopje, MKD
[2] 24 ING dooel Bitola
Borka Talev str., no 24, 7000 Bitola, R. of N. Macedonia

INTRODUCING BRT (BUS RAPID TRANSIT) AS MASS PUBLIC TRANSPORTATION SYSTEM FOR CITY OF SKOPJE

Keywords

Bus rapid transit system
Simulation
Public transportation system

Abstract

Skopje, as capital city, does not differ much in terms of traffic problems from the other cities that use transport system that primarily relies on the car. Although it is a city with more than half a million inhabitants, today's public transport system includes only a bus system. The network of lines relies on the concept of direct lines, city buses do not have any kind of priority, adding travel time loss due to traffic jams (transport speed is below 14 km/h), and relatively low frequency and reliability service (transported only 50 million passengers per year).

Bus Rapid Transit (BRT) has been demonstrated to provide efficient and effective public transport that can even increase transit ridership and attractiveness within defined urban corridors in both developing and developed countries. The merit of the BRT system lies in its ability to provide a high-quality public transit service with limited infrastructure and at a relatively low capital and operating cost.

This paper summarized results of the BRT study for City of Skopje for implementation of optimal solution for Line no. 1. For this purpose, alternative solutions have been made for placement of the alignment in the cross-section profile of the roads. The setting of the BRT alignment can be performed in several different ways, and each of these solutions has its advantages and disadvantages, and a detailed analysis has been made for each of them.

The subject is introduction of bus rapid system - BRT in the city of Skopje, i. e construction of line 1 with an alignment starting from Gjorce Petrov to Novo Lisice with an approximate length of 12.81 km in one direction and with 21 bus stops and two terminals. The objectives are reduction of traffic jam (attractive public transport and reducing the number of car travels), reduction of the travel time, reducing environmental pollution. In the process of designing line 1 as a part of the bus rapid system-BRT which is planned for the city of Skopje, to provide fast, high-capacity, reliable, environmentally friendly and attractive public transport.

1. INTRODUCTION

Bus rapid transit (BRT) is an innovative bus system with sophisticated vehicles and inflexible bus ways integrated in the cities, high capacity and high quality, high speed and frequency, distinctive image and comfort, inflexible bus ways that target improved integration with cities and lucrative promise of flexible capacity and high quality at lower costs than the railway systems. In contrast to the conventional bus systems which operate predominantly in mixed traffic, on streets or dedicated lanes, BRT achieves high capacity by canalizing passenger flows in a system of segregated busways, partially or fully separated from other traffic. The system comprises bus-only lanes which are given priority at intersections, with fares paid at stations instead of on the bus itself. BRT is much cheaper to implement than light-rail or underground metro systems, and benefits local economies, traffic and emissions. It can be implemented in phases to minimize disruption.

The capital of Macedonia, Skopje, does not differ much in terms of traffic problems from the other cities that use transport system that primarily relies on the car. Traffic jams, lost time, lack of parking place and increased environmental pollution are problems that city residents face every day. To solve these problems, the greatest results are seen in the application of solutions that already include urban mobility, which turns cities into human cities. Today, the city of Skopje has a population of 554,972 inhabitants (data for 2019 according to the estimates made by the State Statistical Office), but together with the surrounding municipalities that gravitate towards the city and are included in the system of public urban and suburban transport, this number is 633 273 inhabitants.

The public transport system in Skopje includes only a bus system. The network of lines operate on principle of direct lines and is not in line with the urban development of the city, there is an extremely high number of passengers who changing the buses, which is contrary to the concept of direct travel, the buses don't have priority and resulting in long transport times. If we add the fact that the frequency and reliability of the service are relatively low (in peak hours only one line has a follow-up interval less than 6 min, and more than half of the lines have an interval longer than 20 min), then the low attractiveness of the public transport and residents' orientation for car use is obvious.

To overcome all these problems and improve the service of public city transport in the city of Skopje, it is necessary to introduce a fast, high-capacity, ecological and attractive type of transport, and all this is achieved by introducing a fast bus system - BRT.

2. DEFINITION AND BASIC CHARACTERISTICS OF THE BRT

BRT is a bus-based mass transit system. The system has a concrete design, services, and infrastructure oriented to improve service quality and reduce delays. Sometimes described as a surface subway, BRT aims to combine the capacity and speed of a light rail or metro system with the flexibility, cost, and simplicity of a bus system. Its main drawback compared to other urban transport systems is its demand for urban space. In many cases, when BRTs are being constructed, road space for private vehicles is reduced, as there may be no opportunity to expand the total road space. For this reason, to be most effective, BRT systems, as well as other modes, should be integrated into a comprehensive mobility and transport strategy to support and promote public transport that can include measures to discourage car use, for instance increasing vehicle and fuel taxes, land-use controls, limits, and higher fees on parking, and integrating transit systems into a broader package of mobility for all types of travelers.

Five basic features that define BRT. These features most significantly result in a faster trip for passengers and make travelling on transit more reliable and more convenient.

1. Dedicated Right of Way – Bus-only lanes make for faster travel and ensure that buses are never delayed due to mix traffic congestion.
2. Busway Alignment – Centre of roadway or bus-only corridor keeps buses away from the busy curb-side where cars are parking, standing and turning.
3. Off-board Fare Collection – Fare payment at the station, instead of on the bus, eliminates the delay caused by passengers waiting to pay on board.
4. Intersection Treatment – Prohibiting turns for traffic across the bus lane reduces delays caused to buses by turning traffic. Prohibiting such turns is the most important measure for moving buses through intersections – more important even than signal priority.
5. Platform-level Boarding – The station should be at level with the bus for quick and easy boarding. This also makes it fully accessible for wheel chairs, disabled passengers, strollers and cart with minimal delays.

3. ALIGNMENT BRT IN CITY OF SKOPJE – LINE 1

In the framework of the efforts for improvement of the public transport system in Skopje and the realization of the need for introduction of fast, high-capacity, ecological and attractive transport, the City of Skopje, based on several previous studies decided to introduce a system of rapid bus system - BAS (in the English speaking area Bus Rapid Transit - BRT). The move that is subject to processing is defined in the following boundaries: from Gjorce Petrov depot to Novo Lisice depot in Skopje with a total route length of 12,800.00 meters, as well as the scope of the approaches to the intersections (Figure 1).

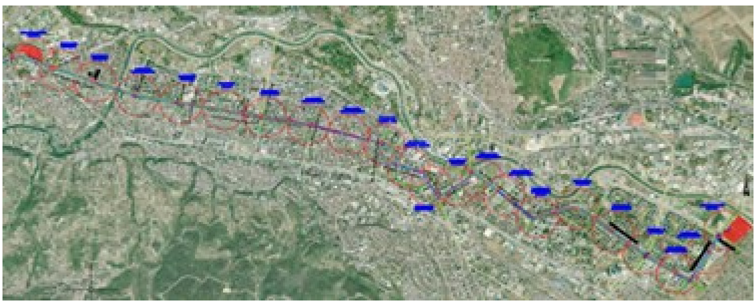

Figure 1. Alignment of BRT from Gjorce Petrov to Novo Lisice in the length of 12.8 km

3.1. Analysis and selection of alternative solutions for placement of the alignment of the BRT

Several alternative solutions for placement of the alignment of the BRT have been made, so each of them has positive and negative aspects of its implementation. Those solutions are the following:

- Alternative A - placement of BRT lanes on the further right side of the roads
- Alternative B1 – with central BRT station for both driving directions and with vehicles with doors on the left side – this option will be considered as one of the possible alternative solutions.
- Alternative B2 – with vehicles with doors on the right side, separated side BRT bus stops – This alternative will be treated as one of the possible alternative solutions.
- Alternative B3 – One central BRT station, vehicles with doors on the right side, BRT lanes in the opposite direction from the rest of the traffic (contraflow) – this alternative will not be considered further.
- Alternative B4 – One central BRT station for both directions, vehicles with doors on the right side, intersecting of BRT lanes before and after the BRT station – this alternative will not be considered further.

Of the proposed variant solutions, Alternative B1 and B2 have been processed and analyzed in detail. For these alternatives, a Run Time model was made, tool for calculating the travel time that is applied in the early stages of planning or designing fast passenger transport systems. The model is based on the calculation of time needed to pass each section or segment that is along the alignment of the rapid transit system used to transport passengers. A micro-simulation model was also created in order to perform a visual representation of the optimal solution for BRT and its impact in the spatial scope. According to the output results of the two variant solutions, alternative B2 – Separate side BRT bus stops, vehicles with doors on the right side, BRT line 1 in Skopje provides a more optimal solution and traffic solution has been made for it.

4. TRAFFIC SOLUTION

The designed traffic solution envisages a central separate alignment of BAS along Blvd. Partizanski Odredi from Gjorce Petrov depot to the intersection with Blvd. VMRO, guidance the alignment on Blvd. VMRO, st. Dimitrie Cupovski and 11th October on the same road surface with the rest of the traffic (separation of the alignment of BRT with traffic equipment), central separate alignment from Blvd. Kocho Racin to Blvd. Vidoe Smilevski Bato, guidance the alignment on st. Februarski Pohod on the same roadway surface with the rest of the traffic (separation of the BRT alignment with traffic equipment). The traffic solution is made in accordance with the world standards for designing BRT systems and the following standard widths of the cross-section profile elements have been adopted:

- BRT lane width: 3.0-3.5m
- Width of BRT traffic lane in the station area: 3.0-3.5m
- Width of BRT station: 3.5-4.5m
- Safety area between BRT and other traffic 0,5-1,0m
- Width of traffic lanes for the other traffic: min 3.0m.

Along the subject alignment are 22 BRT station, where the starting station - terminus is Gjorce Petrov and the end station - terminus is Novo Lisice. Novo Lisice Terminus is the starting/ending point for BRT, as well as other public transport lines, which should cover the surrounding area of the eastern Skopje region. The facility is located in the western corner of the planned location for a bus depot in the settlement of Novo Lisice, closest to Bul. ASNOM, which enables angular entry of BRT vehicles, their proper turning and stopping on the right side of the platform. Three 24-meter buses should stop at the terminus which sets its length and size.

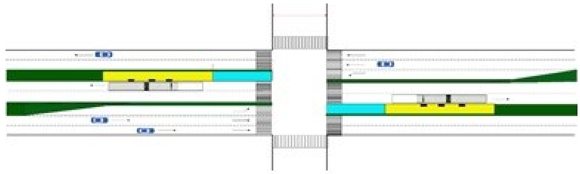

Figure 2: BRT lanes placed in the central area, vehicles with doors on the right side, BRT stations separated according to their direction, repositioning of BRT lanes before and after the BRT station

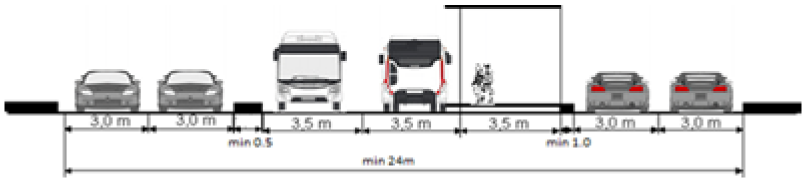

Figure 3: View of one bus stop after the intersection (the same cros section profile for the station in the opposite direction) - BRT lanes placed in the central area, vehicles with doors on the right side, separate BRT bus stops according to the direction of movement

Gjorce Petrov Terminus Station is located in the area of the existing, unregulated parking between the depot and Bul. Partizanski Odredi, under the one-level car park. It is the end point of PTC suburban buses and the starting point for BRT buses. This station will accommodate passengers coming from the suburbs in the western part of Skopje, passengers traveling by car through "Park-and-ride" and passengers traveling by bicycle, BRT buses and vice versa. From the parking lot on the first floor, access to the station is provided through 3 communication cores, while for bicycle traffic there are two parking lots provided nearby with a capacity of about 100 bicycles. At the end of the shift, the BRT and PTC bus drivers leave the passengers at the terminus station and enter the depot through the station. Appropriate horizontal, vertical and traffic light signalization has been used to mark the areas intended for the movement of BRT vehicles.

4.1. Strategy for ensuring the priority of public transport vehicles

A traffic signal control system UTOPIA has been implemented in the city of Skopje, which guidance the traffic on a network of 92 intersections and independent pedestrian crossings. UTOPIA has the ability to assign absolute, weight and selective priority to transport vehicles at signalized intersections. The priority assurance function is based on the predictions of the estimated time of arrival of the vehicle for public transport at the signalized intersections. The priority of public transport vehicles is achieved through a process of optimization of traffic control at the intersection. The optimization is performed every 3 seconds, which allows the system to react quickly, in case of changes in the scheduled time of arrival of public transport vehicles at the intersection. A system for automatic location of vehicles (ALV) for public transport has been established in the city of Skopje which enables monitoring of vehicles in real time, i.e determining the current location of vehicles (localization). The ALV system is connected to the UTOPIA traffic control system via TCP / IP connection.

5. CONCLUSION

Alternative B2 – with vehicles with doors on the right side, separated side BRT bus stops is characterized by the most optimal results from the performed analyzes and is proposed for the implementation of BAS line 1 in Skopje. The positive features are: vehicles with doors on the right side, same as the rest of the carriers' bus fleet; keeping the advantages of a BRT alignment placed in the central area; possibility to provide a special lane used for left turns for the rest of the traffic and wider possibility for optimizing the network of public transport lines.

The implementation of this alternative is also justified according to the goals that have been set, i.e. reducing transport time one terminal to another reducing the current 70 min by more than 50%, which has been achieved and is proven by the Run Time model and "VISSIM" application for micro – simulation modeling – the result of transport time is 30 min. The goal has also been achieved to offer service in the rush hours with frequency of every 3-4 minutes, as well as the selection of environmentally friendly vehicles, articulated CNG hybrid vehicles, and minimize the necessary interventions in the cross-section profile of the existing roads.

In order to develop a tool that will establish the possibility for objective and standardized evaluation of the planned BRT systems, and considering the wide range of available project solutions for the alignment and the way the system works, an evaluation system has been developed. This system was established by the Institute for Transportation and Development Policy and is accepted worldwide. According to this system, BRT systems are ranked in one of four classes: Basic, bronze, silver and gold. The ranking method according to the total number of points is as follows: Gold standard - 85 points and more; Silver standard 70 to 84 points and Bronze standard - 55 to 69 points. Criterions of the project solution for BRT line 1 Skopje are points according to BRT standards with total 72 points = silver standard.

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Atanasova Vaska[1]
E-mail: vaska.atanasova@uklo.edu.mk
Stojanoska Marija[1]
E-mail: marijastojanoska3112@gmail.com
Krstanoski Nikola[1]
E-mail: nikola.krstanoski@uklo.edu.mk
[1] Faculty of Technical Sciences – University of St. Kliment Ohridski
Makedonska Falanga 37, 7000 Bitola, Macedonia

BUS RAPID TRANSIT, POSSIBILITY FOR APPLICATION

Keywords
Rapid transit
Bus
Passengers
Application

Abstract

Bus Rapid Transit (BRT) is a high-quality bus-based transit system that provides fast, convenient and cost-effective mobility services. BRT achieves this through dedicated bus lanes, fast and high-frequency service, and a focus on marketing and customer service. This is a bus-based public transportation system designed to improve capacity and reliability over a conventional bus system. BRT aims to combine the capacity and speed of the train with the flexibility, lower cost and simplicity of the bus system. Fully implemented BRT systems have been proven popular with developing countries as a public transport mode that can offer high quality service comparable with LRT or even metro at lower costs.

European cities are less enthusiastic in investing into BRT systems for several reasons. Many cites already have well-developed rail public transport modes such as metro, LRT and tram. These rail systems offer good quality of service, have long tradition of usage and are well known to public, unlike BRT which is relatively new concept and often perceived with suspicion. In addition, there are cases when implementation of BRT projects become subject of political confrontations and battlefield of politicians. Such recent example is the city of Skopje where the newly elected major has stopped the BRT project despite the fact that project documentation and project financing has been already worked out.

1. INTRODUCTION

Transportation is an essential aspect of our daily lives, affecting our mood and well-being. People who use public transport to work are often happier than those who use their own vehicles, and it also reduces environmental pollution since a bus can transport 60 passengers and replaces 20-30 cars, which is economically justified. Public transport is available for use by the general public, unlike private transport, and operates on pre-defined schedules along established routes with a charge for the journey. Public transportation includes metro, tram, rapid bus systems and regional railways. Bus Rapid Transit (BRT, BRTS) is a bus-based public transit system designed to improve capacity and reliability over conventional bus systems. Introducing a system of fast bus transportation, which enables the integration of intelligent billing systems, systems for informing passengers in real time at stations, stands, as well as in the vehicles themselves, shorter travel time, greater safety and security, good accessibility, better comfort, the use of ecological vehicles with large capacity, lower transportation costs.

2. BUS RAPID TRANSIT

Bus Rapid Transit (BRT, BRTS) is a system of mass passenger transportation by buses. The system generally has specialized design, services and infrastructure to improve the quality of the system and mitigate the typical causes of bus delays. It does this by providing dedicated lanes, with bus routes and stations, as well as collecting fares outside the bus. BRT (Bus Rapid Transport) has several benefits, including reduced congestion, air and greenhouse gas pollution, and improved service for people in developing countries. The main advantages of BRT (Bus Rapid Transport) compared to other MRT options are its significantly lower investment cost, while its main disadvantage is its demand for space in the city.[1] In many cases, when BRT (Bus Rapid Transport) is built, the road space for private vehicles is reduced, as there may not be an opportunity to expand the total road space. With its dedicated lanes, accommodating service areas, technologically advanced stations and GPS tracking systems, bus lanes and bus priority at intersections where buses can interact with other traffic, along with design features are aimed at reduce delays caused by passengers getting on or off buses or paying for tickets. [2]

Figure 1. Bus rapid transit

3. MAIN COMPONENTS OF BUS RAPID TRANSPORT

To have the application of the system for fast bus transport, we need defined routes for the movement of vehicles, adaptation of bus stops, an increase in the capacity of vehicles, services for passengers, the method of fare collection, real-time information, and the application of intelligent transport systems. These components provide us with a complete system for high-speed bus transport, which promises confidence and readiness to meet the demands of users.

3.1. Defining a vehicle movement route

Bus rapid transit lanes are the main feature, for economic reasons. The dedicated lane prevents delays of buses, ensuring greater safety and speed. [3][4]

Figure 2. Physically separated route for bus rapid transport

If the route passes through a traffic light intersection, priority is given to the vehicles of fast bus transport. Traffic light intersection priority techniques can generally be classified as "active" or "passive".[5] [21]

Figure 3. Priority of bus service at a signalized intersection

Figure 4 shows the route of high-speed bus transport that passes through a roundabout.[6]

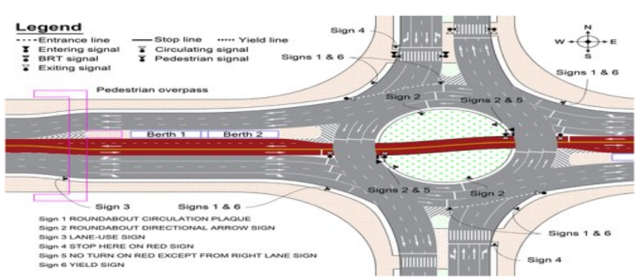

Figure 4. Bus rapid transit route through a roundabout

Exclusive bus lanes are the most impressive element of the BRT system. It is shown in figure 5.[7] [23]

Figure 5. Elevated route for bus rapid transport

3.2. Adapted bus stops and stations

The most important safety feature is closed stations, regardless of whether the bus system uses outside or inside fare collection. The stands need to be well secured, lit, with urban equipment, greenery, to have enough space for all people, to have an area intended for individuals.[8] [24]

Figure 6. Bus stations and bus stops - protective fence, urban equipment

3.3. Increase in vehicle capacity

When it comes to the vehicles that will be used to transport passengers, it is essential that they accommodate more passengers than conventional bus lines, have doors on both sides, be uniquely branded and designed, electric and environmentally friendly. All over the world, articulated buses have proven to be the best option for BRT systems. Figure 7 shows a Mercedes Benz vehicle. [9]

Figure 7. Vehicle for rapid bus transport

3.4 Billing system

Passengers should pay the ticket price at the station instead of on the bus, reducing the waiting time and traffic jam. BRT systems are flexible where an automatic, contactless ticketing system can operate, minimizing waiting time and the need for cash.[10] [25]

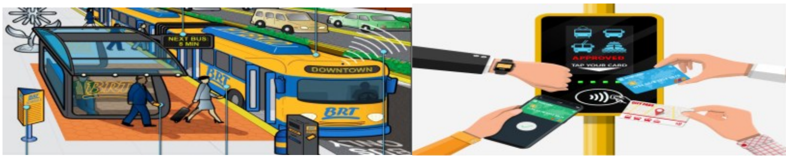

Figure 8. Billing system for bus rapid transport

3.5 Real time information

One essential element of Bus Rapid Transit (BRT) is real-time information communication.[11] [26]

Figure 9. Real Time Information

3.6 Intermodal connections and the application of intelligent transport systems

BRT lines are part of a public transport network with different modes of transport, generally well coordinated with each other.[12][13] [22]

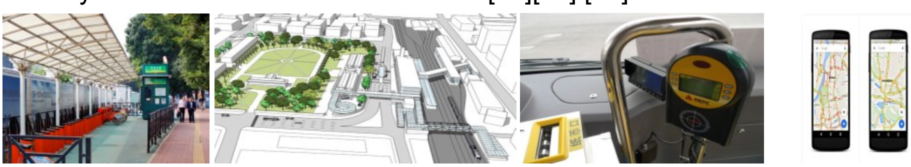

Figure 10. Intermodality between BRT, BRT and cycling, P&R system and intelligent transport system in BRT

4. APPLICATION OF BUS RAPID TRANSPORT

BRT has emerged as successful public transport mode in the cities of South America during the last decades of the 20th century. Since, it has been accepted as cheaper alternative for providing higher quality of service in many, mostly developing countries, around the world. In these countries, the BRT has been recognized as public transport system that can match operational features of the LRT or even metro systems, but at considerably lower costs.

In Europe, the BRT systems are rare, often introduced with only one line in newer parts of the cities and without full features of the BRT, that is without implementation of closed type of stations (payment out of the vehicles at stations) and fully separated right-of-way over the entire length of the line.

There are several reasons for this situation. Firstly, most of the European cities have already well-developed rail public transport systems such as metro, LRT or tram systems. The rail transport systems have stronger image, long tradition and offer very good quality of service compared to the relatively new and unknown BRT systems.

Another obstacle for greater implementation of BRT in Europe is that often the public does not recognize the major operational features of BRT that makes it at least equal to LRT in terms of the service it provides. The general perception of the public seems to be that BRT is another bus system that is inferior to the features of the rail systems.

Also, there are several examples where the proposals for building BRT system has become battlefield of the confronting political parties. The political parties that oppose the introduction of BRT system use the fact that BRT is greatly unknown to the public, and overfloat the media with half-true and untrue arguments against BRT.

Such example can be found in case of Italian city of Rimini. Despite the BRT project documentation was finished in 2006 and was supported by the Italian government, the realization of the project took place between 2012 and 2017 due to long political battle and opposition form the politicians of the local government.[29]

Most recent case of political battle for and against introduction of BRT can be found in the city of Skopje, North Macedonia.

Skopje is a city with about 600000 citizens. Its public transport system includes only buses that operate on congested streets without any measure to provide any type of priority for buses. Many surveys confirm that public transport in Skopje is perceived to offer bad quality of service: low commercial speed, low reliability in terms of keeping the timetables, lack of capacity on some lines, old vehicles without heating and cooling that are operated by private operators etc.

But the greatest deficiency of the transport system in Skopje is not related only to the problems of the existing bus public transport system. The size of Skopje in terms of population and area it covers, points to bigger system problem. Skopje definitely needs to introduce high-capacity, fast and ecological public transport modes, because the bus system itself is not enough to meet the increased need for higher quality public transport service.

The project for the introduction of rapid bus transport (BRT) in the City of Skopje included two lines with corridors reserved for rapid bus transport - Line 1 (east - west, from Gjorce Petrov through Centar to Novo Lisiche) with a length of 12.81 km and 21 bus stops, Line 2 from the northern station-BIH on Blvd. Kuzman Josifovski Pitu, with a length of 10.4 km with 20 bus stops. The two lines overlap in the Center. The travel time will be reduced by 50% from the current 70 minutes. A dedicated route for high-speed buses, which will be physically separated from the rest of the traffic, cuts the travel time in half, and the bus frequency of 3-4 minutes during peak traffic prevents the city congestion. The traffic priorities at intersections allows BRT buses to move without stopping through central city streets and boulevards. Frequency, accessibility, safety, comfort and speed are indicators of quality transport services that encourage citizens to use the public transport system instead of private vehicles.

Unfortunately, the BRT project documentation was finished just before the end of the mandate of the local government that supported the project, and during the campaign for the new local government elections, the BRT has found itself in the middle of political battle. The election was won by the BRT opposing political party, and the new mayor has stopped the project despite the fact that the financing was already approved and available by the EBRD.[30]

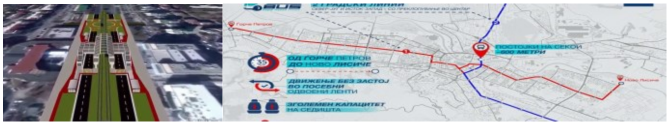

Figure 11. Project for the introduction of bus rapid transport in Skopje

4. CONCLUSION

BRT systems that is planned with all its major operational features that guarantee high quality of service such as dedicated right-of-way, closed type od stations, ecological, higher capacity articulated od double articulated buses, intelligent fare payment and contemporary system of passenger information, have been proven to offer high quality of service that can easily match the one provided by the LRT or even metro systems at considerably lower investment costs. Therefore, BRT has become popular option mostly in developing countries.

European countries have been less enthusiastic in building BRT systems for several reasons. Most of the European cities already have well-developed rail public transport systems such as metro, LRT or trams. These rail systems offer good quality of service, they have long tradition of usage and are very well known and widely accepted by the public, unlike the BRT systems that are relatively new concept and which operational features often are unknown to general public. BRT image is plagued by the fact that the vehicles are buses, and it seems that people perceive it as another bus system that is characterized by low commercial speed, low reliability and low capacity.

In addition, there are cases when the BRT projects became subject for political battle, in which the opponent politicians misuse the fact that the concept is new for majority of the public, presenting it often falsely as public transport mode that can not meet the requirements for higher quality of service.

The latest such example is the city of Skopje, where the newly elected mayor has stopped the project despite the fact that the BRT project documentation and the project financing were already approved and available by the EBRD and the central government.

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Novi Sad 19th and 20th October 2023

Mihailo Pajević[1]
E-mail: spiks@spiks.org.rs
Dragan Đorđević[2]
E-mail: dragan.djordjevic@egis-group.com
Nikola Ristić[2]
E-mail: nikola.ristic@egis-group.com
Ana Vulević[3]
E-mail: a.vulevic@sicip.co.rs
[1] Association of Paraplegics and Quadriplegics of Serbia - SPIKS
MIlentija Popovića 1, 11000 Belgrade, Serbia
[2] Egis-Belgrade
Resavska 31, 11000 Belgrade, Serbia
[3] Institute of Transportation CIP
Nemanjina IV, 11000 Belgrade, Serbia

OVERVIEW OF ACCESSIBILITY ELEMENTS ON RAILWAY TRANSPORT FACILITIES AFTER THE PERFORMED WORKS FROM ASPECTS OF PERSONS IN WHEELCHAIRS: SECTION STARA PAZOVA – (NOVI SAD)

Keywords

Cross-checking
wheelchair
Users
Rail
Accessibility

Abstract

The work represents the continuation of the monitoring of existing modernizations and reconstructions on the railways of the Republic of Serbia, including the application of standards both in design and in the execution of works, on different lines and sections. The obligation to comply with the application of domestic and foreign standards, instructions and regulations is defined by the Law on Planning and Construction. Although the project documentation provides the necessary control and approval of buildings that need to be reconstructed or modernized, in practice it has been observed that some built buildings do not meet the needs of all users or are not constructed in an adequate manner. The observed section in this paper is Stara Pazova – (Novi Sad). The paper presents elements of accessibility, with observed advantages and disadvantages, on facilities and planned services of railway traffic after the works performed from the perspective of persons in wheelchairs.

1. INTRODUCTION

Although significant progress has been made in the development of transport infrastructure for many years, there are still obstacles and it is not fully accessible to all service users [1]. The implementation of measures on infrastructure and vehicles, to which it is necessary to ensure adequate access, must be observed universally, with the aim of providing better service to all transport users.

This paper presents certain problems that people in wheelchairs may face when using railway traffic on reconstructed or modernized parts of railways and stations, in the Republic of Serbia.

2. LITERATURE REVIEW

Expertise, education, responsibility, development of general social awareness, along with necessary financial investments, can significantly increase the equality of persons with disabilities in all aspects of social needs, [2-3]. Solving the problem of people with disabilities in wheelchairs and access to railway stations is mainly done by physical arrangement. In order to assess the problems and needs regarding the level of accessibility to trains and the possibilities for barrier-free travel by region in the Czech Republic, an analysis was carried out, after certain interventions on the infrastructure, as well as a comparison of the situation with other countries [4]. Taking certain accessibility criteria into account, a database was created on city railway systems and their assessment by continent for people in wheelchairs [5]. With this approach, it is possible to identify and present criteria for improving the accessibility of railway systems. On the other hand, it is possible to get the most reliable observations and evaluations of transport systems from users by assessing how satisfied users are with the trip, the quality of the service provided, and availability. In the paper [6], it was determined that on the railways, as an important influence on the overall satisfaction of passengers with the trip, accessibility is ranked very high. In documents [7-8], an overview of the necessary solutions was carried out in connection with the provision of accessibility to transport and services in the station area in large and small stations.

3. FUNCTIONAL SPACE OF RAILWAY STATIONS AND STOPS

In the zones of stations or stops, it is necessary to plan safe access, easy navigation and movement in space with good connectivity and orientation that such an object requires. Passengers need to be brought and taken away in the shortest possible way, and within the vicinity of the station or stop, they need to be able to see and be given all the information about the content of the station [9-10], and the arrangement of accessibility needs to be carried out according to [11].

4. ASSESSMENT OF THE FUNCTIONAL SPACE OF THE RAILWAY STATIONS AND STOPS ON THE STARA PAZOVA – (NOVI SAD) SECTION

There are four stations on this reconstructed and modernized section.

4.1. Inđija station

In the area of the station, there are parking spaces for people with disabilities, figure 1. Access to the platforms is via traffic roads to inclined fixed ramps, underpasses and moving staircase, figure 2. The platforms are set at a height of 0.55 m, through which it is possible to enter in vehicle in the level, figure 2.

Access to another platform is via underpass that further lead to stairs and moving staircase. Tickets are purchased at ticket office and ticket machines, picture 3. Station toilet is also open for people with disabilities, figure 4.

Figure 1. Parking space in front of station (source: photo author)

Figure 2. Platform with stairs to underpass (source: photo author)

Figure 3. Station building ticket office (source: photo author)

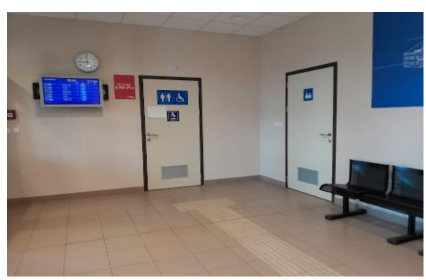

Figure 4. Station building toilets and waiting room (source: photo author)

4.2. Beška station

In the area of the station, there are parking spaces with public city bus traffic, figure 5. Access to the platforms is via traffic roads to inclined fixed ramps (Figure 6), underpasses and moving staircase. The platforms are set at a height of 0.55 m, through which it is possible to enter in vehicle in the level, figure 7.

Access to another platform is via underpass that further led to stairs and moving staircase. Tickets are purchased at ticket office and ticket machines, figure 8. Station toilet is also open for people with disabilities.

Figure 5. Parking space in front of station and bus station (source: photo author)

Figure 6. Station building main entrance (source: photo author)

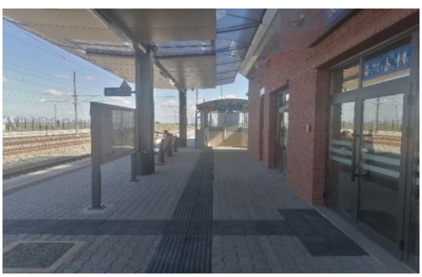

Figure 7. Platform with stairs to underpass (source: photo author)

Figure 8. Station building ticket office (source: photo author)

4.3. Sremski Karlovci station

In the area of the station, there are parking spaces for people with disabilities, figure 9. Access to the platforms is via traffic roads to inclined fixed ramps, underpasses and moving staircase. The platforms are set at a height of 0.55 m, through which it is possible to enter in vehicle in the level, figure 10.

Access to another platform is via underpass that further lead to stairs and moving staircase. Tickets are purchased at ticket office and ticket machines, picture 11. Station toilet is also open for people with disabilities, figure 12.

Figure 9. Station building main entrance and parking space (source: photo author)

Figure 10. Platform with stairs to underpass (source: photo author)

Figure 11. Ticket office and main exit to platforms (source: photo author)

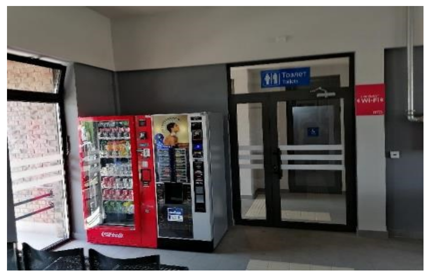

Figure 12. Station building toilets and waiting room (source: photo author)

4.4. Petrovaradin station

In the area of the station, there are parking spaces for people with disabilities, figure 13-14. Access to the platforms is via traffic roads to inclined fixed ramps, underpasses and moving staircase. The platforms are set at a height of 0.55 m, through which it is possible to enter in vehicle in the level, figure 15.

Access to another platform is via underpass that further lead to stairs and moving staircase. Tickets are purchased at ticket office and ticket machines, figure 16. Station toilet is also open for people with disabilities.

Figure 13. Station building main entrance (source: photo author)

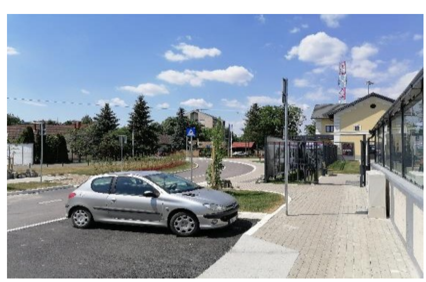

Figure 14. Parking space in front of station (source: photo author)

Figure 15. Platform with stairs to underpass (source: photo author)

Figure 16. Station building main entrance (source: photo author)

5. CONCLUSION

Some reconstructed and modernized sections, despite a great effort to improve accessibility, did not meet all the criteria for providing access to all facilities and platforms for people in wheelchairs [12]. The results of the research on the section Stara Pazova - (Novi Sad) indicate that a great advance has been made in the arrangement of accessibility for all users, especially for people in wheelchairs. In order to ensure smooth movement and complete accessibility for people in wheelchairs smaller corrections, i.e. additions, can be carried out in the stations in connection with the arrangement of curbs on the approaches, from main square and parking places, in the stations. In all stations, it is necessary to consider the possibility of installing elevator structures for communication with all platforms. The main problem is the use of moving staircase, for people in wheelchairs, and so far it has proven that they are not easy to use, the sensors that should recognize the user on the equipment do not work well enough and in most cases it is not possible to move. As an additional aggravating circumstance, it is necessary to have additional personnel to handle it as an operator because this equipment is not regularly in operation. The next step should be in the direction of a larger survey of users in order to collect more information and monitor the state of the infrastructure [13-14], as well about the service provided for people in wheelchairs, as well as other people with disabilities. It is considered that the partial observation and solution of railway lines or stations cannot bring significant results and improvements, but it must be observed on the entire railway network and expanded in interaction with other modes of traffic. Also, the problem of the need to support associations of people with disabilities, from the wider and professional public, to solve individual problems in the execution of works and the education of supervisory bodies at construction sites should be emphasized.

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Stefan Đorđević[1]
E-mail: stefan.djordjevic@naisrobotics.com
Milan Simeunović[2]
E-mail: milansim@uns.ac.rs
[1] NAIS ROBOTICS DOO, Science and Technology Park
Aleksandra Medvedeva bb, Niš, Serbia
[2] Faculty of Technical Sciences, University of Novi Sad
Trg Dositeja Obradovića 6, 21000 Novi Sad

MODEL OF THE INTEGRATED REGIONAL PUBLIC TRANSIT SYSTEM BETWEEN THE TERRITORIES OF THE MUNICIPALITIES OF NIŠ, PIROT, TOPLICA AND JABLANICA DISTRICTS IN THE REPUBLIC OF SERBIA

Keywords
Integration
Public Transit
Regional Transit
Quality

Abstract

Regional public transit between the municipalities of Niš, Pirot, Toplica and Jablanica districts connects the surrounding municipalities and cities with the territory of the city of Niš. It has a significant socio-economic function because it serves residents who live in smaller municipalities, i.e., cities, and work and study in the city of Niš. As such, regional public transit in this region is very present and has the same character as suburban public passenger transport that connects settlements with the inner-city area. In practice, Niš, Pirot, Toplica and Jablanica districts represent a unique socio-economic entity. Daily migrations of citizens between these four districts are carried out using intercity bus lines operated by several public transit companies. The tariff system and the ticket system differ between operators and even among departures of the same operator. Transfer points offer different, inconsistent information and services due to varying ownership structures and contractual agreements with transit companies. Therefore, market of public transit system between districts is unregulated and it can be characterized as defensive and unsustainable because citizens are unable to use the entire offer due to the complicated system. To address these challenges, it is necessary to develop an integrated model for the regional public transit system, connecting the four districts into a cohesive unit and improving the quality of public transport services. Integration can be achieved at four different levels: physical, tariff, informational, and wide planning integration.

1. INTRODUCTION

From the political and socio-economic point of view, City of Niš is a regional center in a wider geographical area in which gravitates different population. As a modern university city, it is simultaneously the natural, social, economic, educational, health, cultural and sports center of Southeast Serbia [5]. According to the 2022 census, 249,501 inhabitants live in the area of the City of Niš, while 178,976 live in the town itself. It covers an area of 596 km^2 [4].

Therefore, it can be said that Niš, Jablanica, Toplica and Pirot administrative districts represent the gravity area of the City of Niš (Figure 1).

It covers an area of 10,490 km^2. According to the 2022 census, 682,493 inhabitants live in four cities and 22 municipalities (5 of which belong to the City of Niš), of which 56% live in urban settlements (382,284 inhabitants). Compared to the data from 2011, there is a decrease in the number of inhabitants of 12.1% [4].

Figure 1. Geographical position of the city of Niš in relation to its gravity area

By population, second largest is the City of Leskovac, which is the seat and main center of the Jablanica administrative district. It is located in the Leskovac basin and covers an area of 1025 km^2. It includes 144 settlements, three of which are city-type (Leskovac, Vučje and Grdelica), which makes this territory the most sparsely populated in the Republic of Serbia. It is 50 km from City of Niš.

The City of Pirot is the seat of the Pirot administrative district. According to data from the 2022 census, Pirot has 49,601 inhabitants, which ranks it as the third largest city in the territory of the Niš gravity area, in terms of population. It is 75 km from City of Niš. The state road of the first "A" class passes through the Pirot district, which is part of the European E80 and the pan-European road corridor 10.

The City of Prokuplje is the seat of the Toplica administrative district. According to data from the 2022 census, Prokuplje has 34,942 inhabitants. It is 50 km from Niš. An important highway passes through the Prokuplje district, already mentioned road E80, which leads from the Adriatic Sea and Pristina to Dimitrovgrad, Sofia and Istanbul and further to the Middle East. Also, from the aspect of tourism, within the Toplica district there are three extremely visited spa centers, namely Lukovo, Kuršumlija and Prolom Spa center.

2. REGIONAL (LOCAL) TRANSIT SYSTEM IN THE NIŠ GRAVITY AREA

According to market conditions, the basic factors that influence the quality of regional (local) bus public transit between the municipalities of Niš, Pirot, Toplica, and Jablanica districts can be classified into seven categories that are circularly dependent, it is:

1. Natural migrations and devastation of the area;
2. Extremely competitive relations between transport companies/operators;
3. Illegal modes of passenger transportation (line taxi service, illegal van transport service, etc.) and individual motorization;
4. "Dedicated bus shuttle service" - special form of regular line passenger transportation which is organized for specific category of customers;
5. The tariff system and the ticket system - different tariffs between private operators and even among departures of the same operator;
6. Real operating costs of the private transport companies - fuel consumption, fleet maintenance, employee salaries;
7. Non-coordinated services - timetables, networks, stations and transfer points, system information's, etc.;

2.1. Natural migrations and devastation of the area

The development of urban systems in the observed area has an extremely monocentric character. One or a few larger cities within the region dominate their size, functions and content, while other smaller municipalities and cities have a slow development or even decline. This smaller local governments can be characterized as devastated areas. Regional (local) transit in these settlements has a significant socio-economic function as it serves residents who work and study in Niš or other larger cities such as City of Leskovac, Pirot and Prokuplje. However, the budgets of these local governments are not able to finance or subsidize public transit services.

The devastation of these areas and the constant population decrease also affects the decrease in the number of users of public transit service. In such conditions, private carriers that do not have the public transport obligation are forced to reduce their bus departure and constantly raise the prices of tickets in order to ensure economic security.

2.2. Extremely competitive relations between transport companies

Competitive relations between transport companies that operate on gravity area of the city of Niš can be reviewed from several different aspects:

- Competition between private transport companies whit similar financial power;
- Competition between smaller and larger private transport companies;
- Competition between state and private companies (Railway and bus operators);
- Competition established by bus station managers favoring certain bus operators;
- On route competition – present on corridors with a high flow of passengers;

In the literature, when it comes to deregulated public transit systems, one of the main problems is identified as unfair competition, where companies with stronger financial resources eliminate competition in their zone with a price policy, and then use their monopoly positions to increase profits.

In practice, competitive relations in the observed area are established differently. Smaller bus operators, with smaller and simpler organizations, have significantly lower operating costs. Consequently, they are able to offer lower quality services at a lower price. On the other hand, large companies, despite being financially stronger, often struggle to meet the conditions imposed by several smaller operators. This extremely competitive relations, established through price policies, are often reinforced by bus station managers favoring certain bus operators.

2.3. Illegal modes of passenger transportation and individual motorization

Problem of illegal transportation was recognized by a new “Law on passenger transport in road traffic” from 2017, but the complete suspension of regular transit and its gradual recovery in the post-Covid 19 period influenced the increased occurrence of illegal passenger transportation by cars and vans.

In March 2021, legal transport companies, through the road transport business association "Srbijatransport", drew the attention of the Ministry of Construction, Transport and Infrastructure of Republic of Serbia, to the increasingly frequent occurrence of illegal business in the field of passenger transport and, in this regard, demanded increased inspection controls on the ground [3].

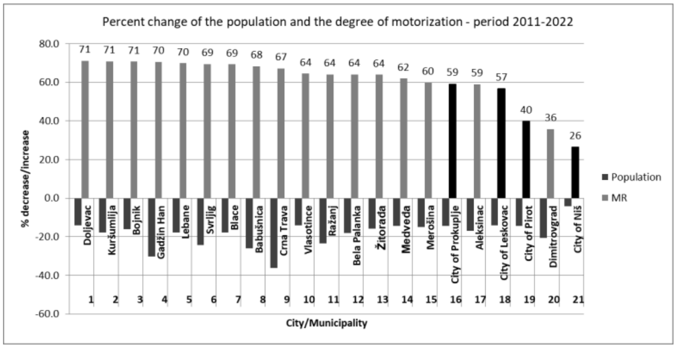

Figure 2. Percent increase of motorization rate in period 2011-2022 according to population decrease.

Within the four observed districts, in the last ten years, the number of registered passenger cars increased by 30.8%, while the population decreased by 12.1% [4]. It is characteristic that the most devastated areas have the greatest motorization rate increase (Figure 2). It can be concluded that the traffic policy is still oriented towards favoring the passenger cars.

2.4. Dedicated bus shuttle service

This form of public transport is organized as transport of employees from their place of residence to work and from work, as well as students from their place of residence to school and from school. Therefore, it is contracted for a certain category of passengers (a certain business entity, organization, institution, etc.), with the exclusion of other passengers, according to the agreed frequency and on the agreed transport route [6].

While there are numerous advantages to this form of organizing scheduled transport, it is necessary to further enhance organization in this area to overcome its existing disadvantage, such us overlapping with existing scheduled public transit.

2.5. The tariff system and the ticket system

Planning and designing tariff model is one of the most sensitive business processes faced by private carriers.

The tickets price is directly related to the quality of the transport service and is the main factor that affects the user's decision. When we talk about decisions, it also refers to the choice of which mode of transportation the passenger will fulfill his need for travel and with which operator. On the other hand, the tariff politic affects the financial stability of the carrier and ensures its competitiveness on the market.

2.6. Real operating costs of the private transport companies

High ticket prices, which are formed on the basis of the real operating costs of the operator, create conditions for an increase in illegal transportation, individual motorization and unfair competitive relations between private operators, which further leads to new consequences, namely a smaller number of passengers and, paradoxically, less financial justification of the service, despite the increase of ticket price.

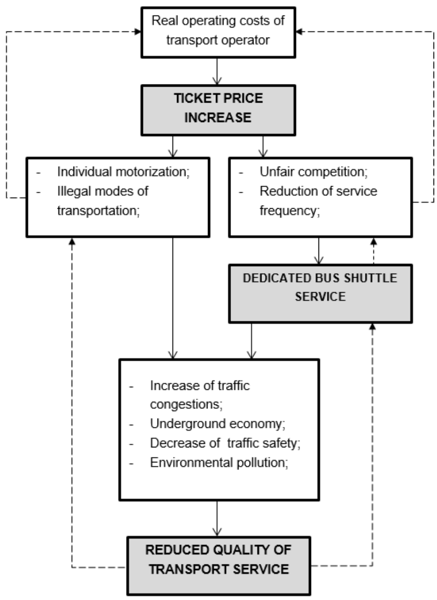

Figure 3. Influence of the formation of ticket prices based on real operating costs on the quality of transport service

2.7. Non-coordinated services

The tariff system and the ticket system differs between operators and even among departures of the same operator. Transfer points offer different, inconsistent information and services due to varying ownership structures and contractual agreements with transit companies. Uncoordinated services are the main characteristic of a deregulated regional transit system in Niš gravity area.

3. CONCEPT OF THE REGIONAL INTEGRATION OF TRANSIT SYSTEM

The integrated transit system represents a common operational environment in which interconnected transit operators (private and public) and subsystems of public transit have a unique organization of transport in a certain area.

The basic elements of the integrated system are the network of lines, the timetable, the tariff system, the billing system and the information system. Integration can be achieved at four different levels: physical, tariff, informational, and wide planning integration [2].

The physical or transport networks integration implies the synchronized planning and modeling of networks and lines that meet simultaneously or at defined time intervals, in one or more transfer points, independent of the subsystem and ownership structure of the transport operator.

A unique system of tickets, regardless of subsystems and ownership structure, allows passengers to use different modes of transportation, by purchasing only one ticket that can be valid for a short period (several hours, day ticket) or have a longer time validity (weekly, monthly, annual).

Information is a key factor in the traffic management. Important decisions are made based on the information about the state of the system and about the traffic requests. On the other hand, the information system is one of the most important parameters of the transport service quality. The availability of information that is presented to the passenger before entering the system and in the system, itself makes public transport a more convenient and attractive choice.

The concept of wider planning integration implies analyzing the mutual influence of the use of surfaces, transport system and wider social interests. It primarily refers to the consideration of the following aspects: Impact of land use and surface purpose on trip generation, social integration and environment protection.

4. LEGAL FRAMEWORK

The legal framework that governs the field of public transport in Republic of Serbia was established in such a way that it represents the first obstacle to the regional integration of the public transit system.

“The Law on Road Transport” defines the conditions for the establishment of public transport and, in this sense, prescribes the competences and responsibilities of local, regional and state administrations. The line ministry in charge of traffic, registers and verifies intercity bus lines and timetables. Bus carriers submit an application for registration of intercity lines once a year, and the proposed timetables for intercity bus passenger transportation are coordinated and approved by the commission.

Registration and verification of timetables for public urban and suburban transit is entrusted to the authority of the municipal or city administration. Local government, on the basis of the “Decision on Public Passenger Transit”, prescribes the way of organizing, the conditions of performance and the conditions of use of public transit on a certain territory, as well as all other issues of importance for public passenger transport system.

Regional public transit between the municipalities of Niš, Pirot, Toplica and Jablanica districts, forms a system of bus lines of various private carriers.

These scheduled bus lines, when their routes pass through two different cadastral municipalities, must be registered as intercity regardless of the social needs of the inhabitants or its travel character.

5. CONCLUSION

Regional public transit between the municipalities of Niš, Pirot, Toplica and Jablanica districts can be characterized as defensive and unsustainable because citizens are unable to use the entire offer due to the complicated system.

The price level, the ticket system, the payment methods and the way of providing information are regulated by each of the carriers independently, according to their own interests. Requests for registration of intercity timetables are submitted exclusively for those lines for which there is economic justification. The moment the line is no longer profitable, the carrier withdraws. On the other hand, registered timetables, which are not maintained, are often kept "in a drawer" because in this way the market is protected from competition.

Larger cities, such as Niš and Prokuplje, have organized public urban and suburban passenger transport based on a public-private partnership model. Smaller municipalities, such as Merošina and Bojnik, organize the transportation of students according to the model of “dedicated bus shuttle service”. However, the majority of local governments still do not have settled public transit, but it is organized on a completely commercial basis, that is, by approving municipal timetables for local carriers who apply for them.

To address all these challenges, regionalization of public transit and concept of regional integration is necessary. According to that, there are number of obstacles that needs to overcome related to legal framework, political environment, business models of companies, as well as the way revenue are distributed.

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Snežana Dimitrijević[1]
E-mail: dimitris@cep.rs
Goran Zimonjić[1]
E-mail: goran@cep.rs
[1] CEP – Center for urban development planning
Zahumska 34, Belgrade

POTENTIAL FOR ESTABLISHING BUS RAPID TRANSIT (METRO-BUS SYSTEM) IN BELGRADE

Keywords
Metro-BUS
Bus rapid transit – BRT
Traffic
Public transport
Planning

Abstract:
The basic feature of Belgrades street network system is that it is a street network with inherited physical traffic restrictions, where the dominant routes of the system are primary traffic routes, which upon entering the city area become elements of the primary street network. For a long time, several decades ago, the lack of a high-capacity public passenger transport system in Belgrade has been evident. After several decades of efforts, the construction of the first metro line was formally started last year. The planned metro lines are not in competition with the route of the existing highway, i.e. the route of the potential metro-bus, but will complement and in interaction provide a higher level of service in the system of public urban passenger transport. The diametrical direction of the highway in the concept of the street network, according to all previously conducted analyses, will be the backbone of the city's street network and in that sense will represent a great challenge for both, decision-makers and traffic planners and designers, to use the potential of the highway primarily for solutions that will cover the public urban passenger transport sector. High-capacity passenger transport can also be provided in road traffic, so the route of the highway through Belgrade represents a resource and potential that in this sense needs to be studiously analyzed, through various research, given that it is a very complex area and an extremely demanding system (public city passenger transport).

1. GENERAL ABOUT BUS RAPID TRANSIT

Access to safe, modern public transportation provides a unique alternative to the use of individual passenger cars, which are a major source of socioeconomic inequality and have a major impact on climate change in cities around the world. Bus rapid transit (BRT) or metro-bus - is a public passenger transport system based on the bus system, but designed as more capacitative and reliable than the conventional bus system. A characteristic of the BRT system is that it takes place in the parts of the street network intended for buses, but if it intersects with other types of traffic, it has priority at intersections. BRT aims to combine the metro capacity and speed with the flexibility, lower cost of establishing and system operating with the bus system simplicity. The first major BRT system in the world was established in 1971. in the city of Runcorn, England. To this day, a total of 166 cities on six continents have implemented bus rapid transit systems - which represents 4,906 km of the BRT network, about 35 million passengers transported every day, of which approximately 20 million passengers are transported only in South America, where there are 54 cities with established bus rapid transit systems. The daily volume magnitude of transported passengers by country is: Brazil - 10.7 million, Colombia - 3 million, Mexico - 2.5 million, China - 4.3 million, Iran - 2.1 million, etc. Currently, "Trans Jakarta" in Jakarta (Indonesia) is the largest BRT network in the world with about 251.2 km of bus rapid transit bus transport network. The Istanbul Metrobus is the only intercontinental system of its kind in the world. The term "bus rapid transit" is mainly used in America and China, in Mexico and Turkey the term "metrobus" is used, in Indonesia - "busway", in Great Britain - "quality bus", and the term "transitway" was created in 1981 in Canada.

2. GENERAL CHARACTERISTICS AND STANDARD OF THE BRT SYSTEM

Bus rapid transit is a system that can be quantified by a number of factors. In 2012, the Institute for Transportation and Development Policy - ITDP developed the "BRT standard" to quantify BRT corridors, thereby forming a list of corridors worldwide that meet the minimum definition of bus rapid transit. The indicators used to evaluate the performance of the BRT system are:

- Average time interval between vehicles on the same line - buses can run for 10 seconds or less (bus "platoons" to ensure high capacity).
- Vehicle capacity - can range from 50 for a conventional bus to some 200 places for an articulated vehicle that has room for standing passengers.
- Transfer efficiency of the bus stop – the passenger demands and transfer demands should be met.
- Efficiency of the "supply system" i.e. of parts of the Public Transport System that "fills" the BRT system - can they deliver passengers to the BRT stop at the required speed.
- Local passenger’s demand for using the BRT system lines - without local demand for travel, the capacity of the BRT system lines will not be used.

Figure 1. Buses in separated lanes and stop with pedestrian connection - Metrobus Istanbul

Applying the mentioned indicators, the minimum route and the maximum vehicle capacity, the theoretical maximum flow measured in passengers per hour per direction (Peak passengers per hour per direction - PPHPD) for one traffic lane is about 90,000 passengers per hour (250 passengers per vehicle, one vehicle every 10 seconds). In real terms, Bogotas TransMilenio holds the world record, with 35,000 to 40,000 PPHPD compared to other systems operating in the 15,000 to 25,000 range. The Bus Rapid Transit Standard is a worldwide bus rapid transit corridor assessment tool based on international best practices. The standard establishes a common definition for BRT i.e. metro-bus and identifies BRT best practice, through an established scoring system that allows BRT corridors to be evaluated and recognized for their superior performance and management aspects. The standard was created to ensure that BRT corridors around the world meet a minimum standard of quality and provide consistent travelling, economic and environmental benefits. The latest edition of the Standard was published in 2016. The standard was developed in response to a lack of agreement among planners and engineers on what constitutes a true BRT corridor.

3. BRT VS LIGHT RAIL (LRT)

Following the opening of the first BRT system in 1971, cities were slowly adopting BRT, as BRT capacity was believed to be limited to around 12,000 passengers per hour traveling in one direction during peak demand. When TransMilenio opened in 2000 in Bogotá, it changed the paradigm by providing a through lane for buses at every stop and introducing express service within the BRT infrastructure.

Figure 2. Transmetro Guatemala City, 30 m long vehicle

Figure 3. Guangzhou Bus Rapid Transit

These innovations increased the maximum transport volume of the BRT system to 35,000 pass./h, while the light rail system (LRT) achieved a transportation volume of 3,500 to 19,000 pass./h. In order to meet these conditions, a corridor with only one free lane in each direction is required, as well as 16,000 to 20,000 transported passengers per direction per hour, and a sufficient length of stops so that the bus does not block intersections.

4. BRT VS CONVENTIONAL BUS LINES

Conventional bus lines have large time losses and delays due to traffic congestion on the street network. The conventional bus subsystem uses shared/general traffic lanes, which can be slow due to traffic congestion, and bus speed is further reduced by long dwell times. Conventional buses almost always take longer to travel compared to a passenger car traveling the same route, due to a number of factors:
- If there is no bus-only lane, the bus cannot go faster than other road traffic, which is especially evident during peak hours or other periods of heavy traffic;
- During stopping at a stop to change passengers, the bus leaves the traffic flow in its lane and cannot continue moving until safe conditions are created to return to its lane;
- Slow boarding of passengers cause slow passenger boarding.

These are some of the reasons why traveling by bus is less comfortable for users who have the choice to travel by car - either due to the need for a shorter travel time or because of large crowds on buses.

5. CONSTRUCTION AND OPERATION COSTS

The investment value of BRT implementation is lower than the costs of building the light rail infrastructure (LRT). Studies conducted in the US up to year 2000 found that the average cost per kilometer for independent bus routes was $13.5 million, while the average cost of light rail was $34.8 million. However, the total investment varies significantly due to factors such as the cost of construction works, the structure of the stop, the traffic signal system, the cost of the vehicle, etc. For the same number of transported passengers and demand. In developing countries, the operating cost advantages of BRT over light rail or tram are much greater due to lower labor costs. BRT systems also have lower costs based on "operating costs per vehicle hour", "operating costs per revenue mile" and "operating costs per passenger trip", mainly due to lower vehicle prices and lower infrastructure costs. The initial costs of a BRT with diesel vehicles are also much lower than a trolleybus system. Proponents of light rail argue that operating costs of BRT are not necessarily lower than light rail. Light rail vehicles have an operational lifespan of forty years or more, unlike buses, which often have to be replaced after twenty years. The underground BRT system was proposed back in 1954, but it is still rare and quite expensive. With most buses running on diesel, air quality can be a significant issue in tunnels, but the downtown Seattle traffic tunnel is an example of the hybrid buses usage, which switch to electric power while underground, eliminating diesel emissions and reducing fuel consumption.

6. IMPACT ON THE ENVIRONMENT

Unlike the electric-powered trains commonly used in conventional metro and light rail (LRT) systems, vehicles in the BRT system often use diesel or gasoline engines. A typical diesel bus engine causes noticeable levels of air pollution, noise and vibration. However, it is evident that BRT can still provide significant environmental advantages over passenger cars. BRT systems can replace the inefficient conventional bus network with more efficient, faster and less polluting BRT buses. For example, Bogotá previously used 2,700 conventional buses carrying 1.6 million passengers a day, while TransMilenio carried 1.9 million passengers in 2013 using only 630 BRT buses. To reduce direct emissions, some systems use alternative forms of traction such as electric or hybrid motors. BRT systems can use trolleybuses to reduce air pollution and noise emissions as is the case in Beijing and Quito. The investment value of installing overhead lines could be compensated by the environmental benefits and potential for electricity savings, especially in cities where electricity is cheaper than other fuels. TransJakarta buses use compressed natural gas engines, while Bogotá started using hybrid buses in 2012 - these hybrid systems use regenerative braking to charge the batteries when the bus stops, as well as electric motors to start the bus up to 40 km/h, after which are automatically switched to the diesel engine for higher speeds, which allows significant savings in fuel consumption and air pollution.

7. POSSIBILITIES OF ESTABLISHING BRT SYSTEM IN BELGRADE

The basic characteristics of the street network system of Belgrade is that it is a street network with inherited physical-traffic restrictions, where the dominant routes of the system are primary transport routes, which upon entering the city area become segments of the primary street network. This configuration of the network results in an uneven volume of traffic on the primary street network, which is a consequence of the radial concept of the primary network, as well as the monocentric structure of the city and the development of residential parts of the city along the primary road and street directions.

The improvement of the existing primary street network of Belgrade is planned by the concentric elements of the network (Inner City Ring Road, Outer Main Tangent Road) and the diametrical disposition of the highway, which in all traffic studies and general urban plans is planned as a city highway after the completion of the Belgrade bypass. By establishing concentric and diametrical primary street directions, the dominantly radial conception of the network will be modified into a radial-annular one, as more favorable from the point of view of road traffic. The diametrical direction of the highway in the concept of the street network, according to all previously carried out analyses, will be the backbone of the city's street network and in this sense will represent a great challenge, both for decision makers and for traffic planners and designers, to use the potential of the highway primarily for solutions which will include the public transport sector.

Although in the modal share trips in the Belgrade area, the trip of public city transport participates with a very significant, almost 50% of the total volume of the trip, it cannot be said that this subsystem functions with a high level of service, but that this is a consequence of the state of the city's transport system (small percentage of payment for the completed transport, heavy congestion, parking spaces deficit, etc.).

In the structure of the traffic flow on the highway, in the conditions before the completion of the bypass around Belgrade, transit transport has a significant share (up to 38% in some months). The ring road completion will create conditions for dislocating transit transport from the city section, which will represent an opportunity to use the potential in the "liberated" part of the highway's capacity primarily for the public transport system.

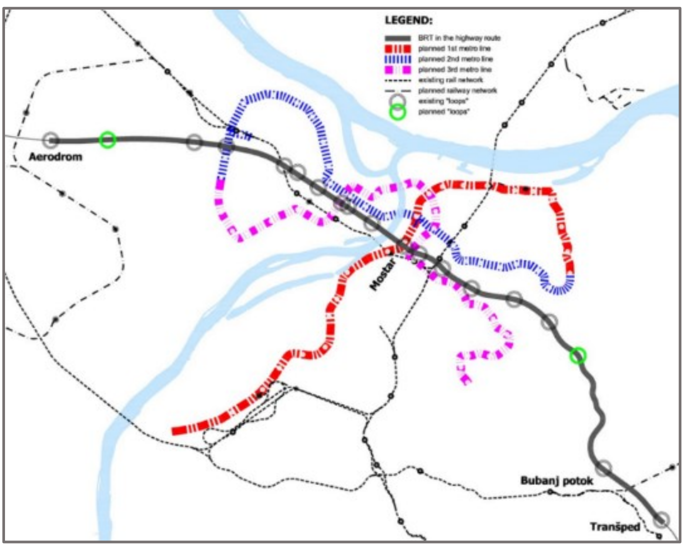

Figure 4. Highway and planned metro lines in Belgrade

For a long time, the lack of a high-capacity public transport system in Belgrade has been evident for several decades. The planned metro lines are not in competition with the route of the existing highway, i.e. with a potential metro-bus, but they will complement and in their interaction they will provide a higher level of service in the public transport system.

High-capacity passenger transport can also be provided in road traffic, so the route of the highway through Belgrade represents a resource and potential that in this sense needs to be analyzed studiously, through various researches, given that it is a very complex area and an extremely demanding system. In accordance with the characteristics and requirements of the bus rapid transit system, as well as with the established characteristics of the highway, a potential solution of the implementation of the BRT system is imposed - metro-bus in the highway corridor.

The highway profile consists of three traffic lanes, and the independence of the metro-bus route can be ensured by driving in the far left lanes, in the opposite direction to the other dynamic traffic movement - where the basic features of the established system would be as follows:

- the far left lanes are regulated in the mode of "bus lanes" and are run independently along the entire route, i.e. they have no intersection anywhere,
- in each carriageway, the far left lane is designated for metro-bus movement by physically separating it (with an elastic fence or "New Jersey" elements) from the middle traffic lane, or the purpose of the lane can only be defined by signaling,
- the proposal is to establish the route of the line on the stretch between the Airport and Tranšped interchanges (Ikea), the length of the route is 31 km,
- zones of existing (15) and planned (2) grade separated interchanges ("loops") represent the locations of potential stops along the metro-bus route,
- necessary modification of the public urban transport lines network, all conventional bus lines would be functionally relocated from the highway corridor,
- by establishing a new network of conventional lines, it is necessary to ensure the "intersection" of metro-bus lines in the zones of uneven intersections and to form transfer points from which metro-bus vehicles will be "charged",
- metro-bus vehicles are guided in the far left lanes in the opposite direction of other dynamic traffic movement in order to use the central dividing island for organizing the plateau of the bus stop,

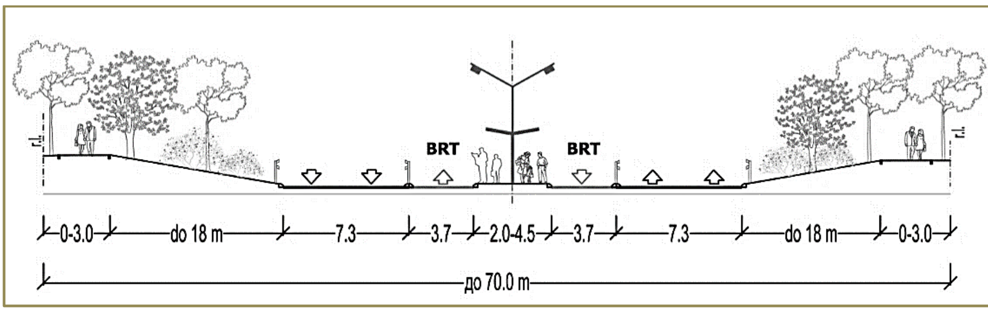

Figure 5. Highway profile with "bus lanes" in the far left lane

- plateaus of the bus stop are arranged in the dividing island, from which footbridges (or underpasses) provide pedestrian connections with the area in the highway contact zone,
- the capacity of the highway is (2+1) x 2, with the fact that the "bus lane" is available exclusively for vehicles in the metro-bus system,
- in the zones of terminal stops, as well as at stops along the route where it is determined that it is necessary, provide conditions for the implementation of "park and ride" points, etc.

For the mentioned solutions, it is necessary to carry out a pilot project and prefeazibility studies in order to look at the functionality and cost-effectiveness of the solution from all aspects, as well as the possibilities for securing the elements of the system in accordance with the BRT standard.

8. CONCLUSION OR WHY ESTABLISHING METRO-BUS SYSTEM IN BELGRADE

Compared to other traditional modes of transportation such as light rail transport (LRT) or mass rapid transport (MRT), metro-bus or bus rapid transit (BRT) service is attractive to many cities and city governments because the cost of establishing and operating BRT system is much lower: there are no infrastructure construction costs, driver trainings are simpler and cost less, there are more of them on the labor market, infrastructure maintenance costs are lower and bus maintenance is simpler and cheaper than the maintenance of railway compositions. Buses are more flexible than rail vehicles, the bus route can always be changed or adjusted, either temporarily or permanently, to meet changing demand or to circumvent unfavorable route conditions with relatively low investment. Because of the above, the bus rapid transit BRT therefore acts as a "bridge" for such routes. It is slightly more expensive and less flexible due to the infrastructure needed to mitigate the slowing effects noted above, but it is significantly cheaper than rail transport, and offers speed and capacity that, while usually unmatched by dedicated rail, can far exceed the capacity of conventional bus lines. It mostly depends on how much the BRT standard is applied, how well and on what route length. The position of the section of the Belgrade highway, in whose corridor the metro-bus route would be located, with the planned metro and railway network, can provide the city with a complete and functional high-capacity network in the public transport sector.

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Mustafa Mehanović[1]
E-mail: mustafamehanovic1@gmail.com, mustafa.mehanovic@fsk.unsa.ba
Drago Ezgeta[1]
E-mail: drago.ezgeta@fsk.unsa.ba
[1] Faculty of Traffic and Communications, University of Sarajevo
Zmaja od Bosne br. 8, 71000 Sarajevo, Bosnia and Herzegovina

CHOICE OF CARRIERS ON THE MARKET OF PUBLIC CITY PASSENGER TRANSPORT SERVICES

Keywords

Passenger transport
Market of services
Choice of carrier
Bid ranking
Carriers,
Sustainable Urban Mobility

Abstract

The passenger transport system in cities is the backbone of sustainable urban mobility. The problem faced by the city authorities is the question of choosing the carrier with the best bid in the public call. Services in charge of public transport are often able to choose carriers for one or more lines, and often for the entire area. The basic dilemmas are related to the type of procedure that should be carried out, whether the transport services market is open to competition, what methodology to apply if the transport services market is not declared open to competition, whether the selection procedure should end with the signing of the contract between the city government and the operator, and other questions for which answers are sought.

This paper presents an analysis of practices and proposed guidelines for the development and application of the bed operator ranking model in the public selection process.

1. INTRODUCTION

In many cities, due to the poor quality of public transportation services, a large number of residents have stopped using these services, which results in an increase in the use of private cars and the emergence of major traffic problems. The increase in the number of private cars has resulted in an increase in traffic jams and parking problems in all parts of the city, and the worst situation in this regard is in the city centers. The insufficient legal regulation of this area and the impossibility of better organization of traffic is one of the important factors that cause traffic problems in cities.

In an effort to improve the service of public urban transport, many cities have tried to find answers and acceptable solutions through studies (Sustainable Urban Mobility Plan, Restructuring of public carriers, Inclusion of private carriers in transport, Drafting and harmonization of legal regulations, Defining models for pricing services [1], Selection of carriers, Regulation of rights and obligations between authorities and carriers through contracts and others).
As one of the very current issues, especially in the countries of the Western Balkans and other countries that have noticed the need to improve public urban transport, the choice of a carrier that will transport passengers on a specific line or on several lines is considered.
This paper presents the methodology for ranking carriers' bids on a public call for certain lines with reference to the need to define input data and the existing regulatory framework.

2. OBJECTIVES OF THE WORK

The main goal of this task is to look at aspects of the development of a new methodology for evaluating operator offers according to regulatory frameworks in the transport sector, with the aim of improving the organization and selection of operators on certain lines of public passenger transport, all in accordance with the good practice of the transport sector and EU recommendations. It should be borne in mind that the methodology for evaluating the operator's offer must take into account the recommendations and instructions of the city authorities, as well as all plans and strategies for the improvement of the transport sector adopted by the city authorities.

3. CARRIER SELECTION PROCEDURE

City authorities are often in a situation where they need to choose a carrier that will transport passengers on one or more lines or in a certain area in a certain period.
According to EC Regulation No. 1370/2007, if a public authority decides to entrust a service of general interest to a third party, it must select a public service operator in accordance with EC law on public contracts and concessions, and the principles of transparency and equal treatment. In particular, the provisions of this Regulation may not call into question the obligations applied to public authorities based on the directives on the conclusion of public contracts, if public service contracts are covered by them [2].
Public tender calls for carriers require competent authorities to define and describe complex systems, i.e. requirements and criteria, and when they enter into contracts in such cases, they should have the authority to negotiate details with some or all possible public service operators after the bids have been submitted.
According to the Directive, invitations to tender for the conclusion of public service contracts should not be mandatory if the contract concerns small amounts. Competent authorities should not be allowed to unbundle a contract or network to avoid a public tender.

The fact that the transport services market in the area is open to competition is important for the procedure of choosing a carrier (defined by the Law on Competition, and the procedure is defined by the Law on Public Procurement of Goods and Services). This is a very important item because if the transport services market is open to competition in the public call for operator selection, the price of transport services is included in the operator selection criteria, otherwise the price is defined by the authority that announces the public call for operator selection.
The selection of the carrier according to the public call should end with the signing of the contract between the authorities and the selected operator. The content of the contract should, among other things, include: - Rights and obligations of the carrier (Vehicles, Safety, Service Quality, Tariffs, Ticket Sales, Information, Marketing Activities, Billing Control); - General provisions; - Obligations of authorities (Payments for transport services; Control of legal and contractual obligations; Traffic infrastructure and traffic control measures; Quality of service); - Contract execution. In the legal regulations of some countries, there is no obligation to conclude a contract, which will certainly need to be changed.
If the competent authority plans to enter into a public service contract without subjecting it to a competitive tendering process, it must also follow detailed rules to ensure that the amount of compensation, in order to cover the costs incurred in fulfilling the public service obligation, is appropriate and reflects efforts directed towards efficiency and service quality
The competent authority that conducts the public procedure for the selection of carriers should be notified of the intention at least one year in advance so that interested operators can prepare for participation.
Since countries that are not members of the EU have different practices for selecting operators or assigning transport rights on certain lines, the procedure for selecting carriers will need to be changed in the coming period. Accordingly, it will be necessary to improve the methodology for evaluating the offers of operators who apply to the public call.

4. OPERATOR EVALUATION METHODOLOGY

The operator evaluation methodology regulates the conditions, method and procedure of operator evaluation in the selection process.

4.1. Multi-criteria evaluation method

Evaluation and ranking of bids and selection of operators on the lines in question will be carried out using a multi-criteria evaluation method.

All criteria in the public call for evaluation will be evaluated using the SAW (Simple Additive Weighting) model [3], which contains the following steps:

1. Defining the criteria matrix for evaluation, the number of offers and values according to all criteria;
2. Determination of weighting coefficients of criteria (w_j) ;
   It can be done by the Delphi method, the rating method, the Satie method, etc.;

3. Normalization of the input matrix of values (x_{ij}) of *the i* -th offer according to *the j* -th criterion is performed by calculating the value (r_{ij}) in the following way for criteria:

   that are maximized: $r_{ij} = \frac{x_{ij}}{x_{\max}}$; to be minimized: $r_{ij} = \frac{x_{\min}}{x_{ij}}$

   where: x_{ij} - value of the ith offer according to *the jth* criterion; x_{maxj} – the highest value of offers according to *the jth* criterion, x_{minj} – the lowest bid value according to *the jth* criterion
4. Calculation of the total number of points for each offer (*i*)
   The values of one offer for all criteria are multiplied by the corresponding weight coefficients of the given criteria and these products are added:

   $V_i = \sum r_{ij} \cdot w_j$, that is

   $V_i = \sum \frac{x_{ij}}{x_{\max}} \cdot w_j$ for *x* tends to the maximum value (if it is favorable that the criterion tends to the maximum)

   $V_i = \sum \frac{x_{\min}}{x_{ij}} \cdot w_j$ for *x* tends to the minimum value (if it is favorable that the criterion tends to the minimum)

   The weighting coefficients (w_j) should be determined in such a way that their sum is 100.

The methodology makes it possible to evaluate the offer according to criteria that do not have the same unit of measure. It is also important to emphasize that the result is not only which carrier is the best, but also the number of points won in relation to the maximum number of points 100, i.e. how much the best offer is less than the best possible offer which is 100 points.

4.2. Criteria for evaluating

The elements that are evaluated in the operator's offers are:

- The number and quality of the operator's fleet,
- Operator infrastructure i
- Operator references.

The criteria for evaluating the number and quality of the fleet are: the number of available vehicles, the age of the vehicle, the capacity of the vehicle, the type of fuel, the convenience of exhaust gas emissions (according to the EURO characteristics of the engine), the height of the floor in the vehicle, the degree of accessibility of the vehicle to people with mobility difficulties, external and internal appearance of the vehicle, having air conditioning in the vehicle, and the number and area of doors on the vehicle.

In order to carry out regular passenger transport, the operator needs to have the appropriate infrastructure that affects the quality of passenger transport services, so the infrastructure will be evaluated for each operator. Operator infrastructure: Technical and personnel equipment; Vehicle maintenance capacities; Parking area and car wash area; Towing vehicle and service vehicle.

Operator references are: Past experience and success in performing public line passenger transportation; Business creditworthiness of the operator; Professional and qualified staff for the organization of public transport of passengers, maintenance and repair of vehicles; Favorability of the offer for the implementation of measures for the preservation and protection of the environment; Adaptability to the existing passenger information system on and in the vehicle; Transportation management system (radio connection, satellite monitoring of work); Other circumstances that may affect the quality of public passenger transport.

The evaluation of the offer according to several criteria is described below.

<u>The evaluation of the number of vehicles</u> will be done by determining the number of points for each operator according to the route:

$$B_{V\,op} = \frac{V_{op}}{V_{\max}} \cdot w_V$$

where is:

B_{Vop} - the number of operator points for the number of available vehicles

V_r- broj vozila predviđen redom vožnje

V_{op} - the number of available vehicles of the operator that awill be engaged in the execution of the timetable (Note: this number of vehicles cannot be less than the number of vehicles provided for in the timetable specified in the public invitation , and it cannot be greater than the maximum number of vehicles specified in the public coll. The offered vehicles must have the minimum number of seats required in the public invitation)

V_{maxV} - the largest number of vehicleskoji može ponuditi operater je broj vozila predviđen redom vožnje uvećan za broj vozila u rezervi, a koji će biti određen u javnom pozivu

w_V - weight coefficient for the criterion number of available vehicles.

<u>The evaluation of the technical and personnel equipment of the operato</u>r will be carried out by determining the number of points for each operator according to the relationship:

$$B_{TKop} = \left(0{,}5 \cdot k_{dnj} + 0{,}5 \cdot k_{pos}\right) \cdot w_{TK}$$

where is:

B_{TKop} - number of points of the operator's offer according to the criterion " Technical and personnel equipment of the operator "

V_{op} - number of available vehicles offered by the operator

k_{dnj} - daily care coefficient (k_{dnj} =1 if the operator owns an organizational unit for daily vehicle care, k_{dnj} *=0* if the operator does not own an organizational unit for daily vehicle care)

k_{pos} - transport planning and organization coefficient ($k_{pos} = 1$ if the operator has an organizational unit for planning and organizing transport, $k_{posj} = 0$ if the operator does not have an organizational unit for planning and organizing transport)
w_k - weight coefficient for the criterion "Technical and personnel equipment of the operator" .

The evaluation of the suitability of the offer for the implementation of measures for the preservation and protection of the environment will be carried out by determining the number of points for each operator according to the relationship:

$$B_{ZOop} = \frac{0{,}5 \cdot n_P + 0{,}75 \cdot n_h + n_e}{V_{op}} \cdot w_{ZO}$$

where is:
B_{ZOop} - number of points of the operator's offer according to the criterion " Advantage of the offer for the implementation of measures for the preservation and protection of the environment "
V_{op} - number of available vehicles offered by the operator
w_{ZO} - the weight coefficient of the offer's favorability for the implementation of measures for the preservation and protection of the environment
n_P - number of gas-powered vehicles
n_h - number of vehicles with hybrid drive (vehicle with two or more energy sources, necessarily with an electric motor)
n_e - number of vehicles with an electric motor.

4.3. Example of the application of the bid evaluation model

On the example of the offers of three operators, the application of the described model is presented. Podaci iz ponuda operatera su uneseni u model (Excel forma) i pfema opisanom modelu određene su ocjene po svakom kriteriju, Table 1.

Table 1 Results of evaluation of operator bid

Weight	Favorable min/max	The name of the criteria	Rating of the operator's bid		
			1	2	3
70	**Criteria for evaluating the number and quality of the rolling stock**				
15	max	Number of available vehicles	9,00	7,50	9,00
20	min	The criterion is the age of the vehicle	20,00	13,33	10,00
5	max	Vehicle capacity	3,57	4,29	4,17
5	max	Types of fuel	1,92	1,20	1,08
5	max	Suitability of exhaust gas emissions (according to EURO characteristics)	1,25	3,25	5,00
5	max	Vehicle floor height	0,00	1,25	5,00
3	max	Degree of vehicle accessibility for people with mobility difficulties	2,00	3,00	1,00
2	max	Exterior and interior appearance of the vehicle	1,17	0,60	2,00

Weight	Favorable min/max	The name of the criteria	Rating of the operator's bid		
			1	2	3
5	max	Air conditioning	5	2	0
5	max	Number and area (width) of doors	5,00	2,50	3,75
10	**Operator infrastructure**				
4	max	Technical and personnel equipment of the operator	4	2	0
2	max	Vehicle maintenance capacities	2	0	2
2	max	Parking area and car wash area	2	1	0
2	max	Towing vehicles and service vehicles	0	2	1
20	**Operator references**				
3	max	Previous experience and success in performing public passenger transportation	3	0	3
4	max	Business creditworthiness of the operator	0	4	0
4	max	Expertise and qualification of staff for the organization of public transport of passengers, maintenance and repair of vehicles	4	4	0
3	max	Advantages of the offer for the implementation of measures for the preservation and protection of the environment	2,5	3	3
2	max	Adaptability to the existing passenger information system on and in the vehicle	2,00	2,00	0,00
2	max	Passenger transportation management system	0	0	2
2	max	Other circumstances that may affect the quality of public passenger transport	2	0,6	0
100			**70,40**	**57,52**	**52,00**

The most favorable offer is the offer of operator 1 with 70.40 points.

5. CONCLUSION

The process of selecting an operator for the transport of passengers on public city transport lines can improve the transport service if it is aligned with the guidelines of the European Union. The choice of a carrier requires a multi-criteria evaluation where all relevant criteria that contribute to the selection of the most favorable offer of the operator should be included. The criteria should be adequately covered by the contract between the selected operator and the city government.

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Julijan Jurak[1]
E-mail: jjurak@fpz.unizg.hr
Matija Sikirić[1]
E-mail: msikiric@fpz.unizg.hr
Marko Slavulj[1]
E-mail: mslavulj@fpz.unizg.hr
Ivan Kundid[2]
E-mail: ikundid89@gmail.com
[1]Faculty of Transport and Traffic Sciences
Vukelićeva street 4, City of Zagreb
[2]Gradski parking d.o.o. Šibenik
Draga street 14, City of Šibenik

DEVELOPMENT OF NEW PUBLIC TRANSPORT SERVICES - CASE STUDY OF ŠIBENIK

Keywords

Urban mobility
Insufficient public transport
Tourism and mobility

Abstract

The goal and purpose of the research is to show a sustainable way of developing and implementing a completely new system of public passenger transportation on the example of a typical medium-sized Mediterranean city - Šibenik. The hypothesis of the study is to present a possible sustainable implementation of a new system of public passenger transportation regardless of financial, spatial, or other limitations. The research consisted of data and measures determined by the study of the development of urban passenger transport in the city of Šibenik, as well as problems that arose during the implementation phase. The results of the research and study are to confirm the hypothesis and give the possibility to other similar urban areas that sustainable public transport is the future of the transport system of Mediterranean cities.

1. INTRODUCTION

The research's objective is to demonstrate a sustainable method of creating and executing a fully new public passenger transportation system using the example of a typical medium-sized Mediterranean city - Šibenik. The study's hypothesis aims to propose a feasible long-term deployment of a new public passenger transportation system, independent of budgetary, geographical, or other constraints. The research included data and metrics derived from a study of the development of urban passenger transportation in the city of Šibenik, as well as issues encountered during the implementation phase. The findings of the research and study are expected to corroborate the theory and provide hope to other similar urban regions that sustainable public transportation is the way of the future. To improve the city of Šibenik transportation system, a new, more efficient system of public passenger transportation must be defined. Given that this Study will serve as the foundation for the creation of a new public service agreement (PSA) contract under which municipal regular bus transportation will be provided in the administrative area of the city of Šibenik, the emphasis on defining a new system of public passenger transportation is concentrated specifically on the bus subsystem. The purpose of a quality bus subsystem in the city of Šibenik must be enabling efficient and reliable transport for the purpose of compulsory travel (work and school) and for the purpose of optional travel (recreation, leisure, etc.), providing a reliable transport service for users who do not have access to an alternative mode of transport, ensuring quality transport connections, increasing the mobility of citizens and visitors of the city of Šibenik by increasing the capacity of transport services on the city corridors, increasing the energy efficiency of the transport system of the city of Šibenik, and reducing the traffic load on the road network and related adverse consequences by providing an effective alternative to private transport. As a result, by establishing high-quality municipal regular transportation, positive effects such as increased accessibility of city content to more users, reduced time loss and traffic delays, reduced negative environmental impacts of transportation, increased the attractiveness of city space and creating preconditions for its revitalization, and increased traffic safety will be realized. The primary purpose of the new public transportation system's design is to attract as many people as possible. The publication includes a literature review, study methodology, findings, and discussion, as well as conclusions and recommendations for future researchers.

2. LITERATURE OVERVIEW

In many cities, there is growing concern about reliance on automobiles and the need to clean up the environment. One strategy is to build new public transportation networks. Around the world, cities are developing and building a lot of these. The decision-making process for such systems is the subject of this essay, specifically its justification and how it affects the environment, urban development, and travel demand in the city. The analysis is based on a global survey that was conducted as part of a project to investigate how people decide which technology is best for an urban transportation system [1]. In situations where the management of public transportation is divided among several stakeholders, it can be difficult to design effective systems that draw users. As a result, topics like coordination, collaboration, and steering in settings with complex governance have received more attention in recent public transportation research. What must be done, however, is better understood than how to bring about the required adjustments. In order to better understand how to improve the conditions for public transportation, this paper presents a systematic review of the relevant literature. The reviewed articles are analyzed to better comprehend the significant obstacles to developing and putting into action policies to promote the use of public transportation, the methods used to address issues raised in the literature, and the benefits and drawbacks of various methods. Based on the analysis, an analytical framework is created that can be used to research and assess working methods for dealing with pressing issues. The framework is made up of three interrelated components: institutions (laws and regulations that control how the actors interact), work processes (phases in this interaction), and actors. Considering the findings of the systematic review, several crucial issues for developing working procedures for addressing the difficulties are emphasized for each of the factors [2]. The techniques for the development of urban transportation sustainably are described in this. In the context of modern transport, paper, are examples that lend support to the thesis policy based on the use of environmentally friendly measures, such as cycling and walking, if an alternative to the current system is one that is properly coordinated with public transportation single-person motorized transportation predominance. In order to create this kind of transportation policy it is necessary to implement suitable measures, such as raising drivers', for the system to function properly, awareness of social responsibility as it relates to being motivated by environmental preservation, increasing health as well as efficiently using the city's resources (cultural, sporting, and recreational opportunities, etc.) [3].

3. METHODOLOGY OF CONDUCTED STUDY

To begin, the current transport model of Šibenik from 2015 was used as a starting point, and that year did not represent the relevant status of the transport system. The model has several flaws, including an insufficient level of zoning in the Šibenik settlement and an insufficient level of network model in the Šibenik area, inaccuracy of certain parameters of existing roads, incorrect public transportation system data, a lack of description and a clear structure of origin-destination travel matrices for all transport subsystems, and a lack of origin-destination matrices for light and heavy goods vehicles. The model's correction, supplement, and calibration were based on primary and secondary research. A field study of manual traffic counting at important places in the city of Šibenik, as well as counting the entry/exit of passengers on public transportation lines, was undertaken as part of the main research. The secondary study comprised an examination of submitted and publicly accessible data regarding Šibenik transportation system. The field survey was conducted in February 2022 due to structural, financial, and other issues. Also, February was chosen because the focus of the study was to detected mobility patterns of inhabitants of City of Šibenik. Study covered the following tasks: counting categorized vehicles at intersections and intersections, counting passengers on public bus transport, counting passengers in the maritime port of Šibenik, and counting of parked vehicles in the parking lots "Draga", "Mulo Krke", "Pier Vrulje" and "Railway Station". By counting all forms of traffic in the wider area of the city of Šibenik, it is possible to explore the cause-and-effect relationship, as well as the mutual impact of certain types of traffic on each other, as seen in tables 1. and 2.

Table 1. Demand on city bus lines

Number	Name	Length	Travel time (min)	Departure /day	Daily demand
1	1 SI Njivice-Tržnica-Vidici-Njivice	10,8	30	27	359
2	2 SI Meterize-Tržnicar-Meterize	6,5	19	27	186
3	3 SI Šubićevac-Tržnica-Šubićevac	6,8	21	27	185
4	4 SI Ražine-Tržnica-Ražine	12,7	30	30	387
5	5 SI Brodarica-Tržnica-Brodarica	15,8	27	27	384
6	6 AK-Solaris-Zablaće	19,5	30	14	96
7	7 SI Mandalina-Bilice-Tržnica-Mandalina	17,2	37	10	26
Total		90,82	-	159	1.623

Table 2. Demand on suburban lines

Number	Name	Length	Travel time (min)	Departure/day	Daily demand
1	AK - Brnjača	43,8	105	6	30
2	AK - Lepenica	45,67	110	8	64
3	AK - Perković	50,22	121	8	84
4	AK - Lozovac	27,19	65	8	89
5	AK - Brnjica	40,44	97	5	28
6	AK - Raslina	28,83	69	14	120

The process of calibration of public transport models consists of creating an initial public transport matrix, assigning trips to the network, and calibration of model results according to actual data. Created public transport matrix in the city of Šibenik is divided into the inner-city matrix (between the zones within Šibenik), and suburban matrix (Demand on suburban bus transport, ship and rail transport).

4. RESULTS AND DISCUSSION OF STUDY

The administrative area of the city of Šibenik includes a large area with mostly sparsely populated area. For this reason, it is extremely challenging to implement the municipal system of public transport in the optimal ratio of supply and demand, so that the transport service is not financially unsustainable. Accordingly, in the dimensioning of the future transport service for the suburbs of the city of Šibenik, it is proposed to optimize transport capacities in relation to the current situation. In the proposed variant, the aim was to ensure the greatest possible connection between the administrative area of the city of Šibenik through the rationalization of operational indicators. Because of this, some suburban lines are shorter than the existing ones, because, according to the existing condition, they connected areas with insufficient transportation demand for municipal bus transport. Such remote settlements with low population density should be connected through an on-call transportation service to rationalize transport costs. The service in question would ensure a higher level of mobility of the population because the transport offer would be created exclusively according to the wishes of the user. The production and attraction of communal bus travel was estimated using data of the actual demand for passenger exchange at public transport stops, according to which the total demand of utility bus lines is 1,623 passengers/day. Then, each of the 43 internal zones of Šibenik was assigned demand depending on the bus stop belonging to the zone. Assuming that the demand at individual stops is weighted in relation to the population of the associated zones, the production and attraction generated by the existing utility bus systems by zones is known. After the production model and travel attractions were prepared, the distribution of these trips across the zones followed. To estimate the distribution of travel on city bus lines, the Fratar model was used, which distributes traffic between zones based on travel costs. The final demand for public transport in the city of Šibenik has a total amount of 2,430 trips/day, which are divided into:

- city trips (1,623 trips/day) and
- suburban travel (807 trips/day).

Accordingly, the following guidelines and theses were used when defining the new public transport system:

- Simplicity of bus lines: The new bus lines are designed to simplify the existing scheme of bus lines in the city area (Figure 1.),
- Introduction of tact timetable: Tact timetable is a timetable in which public transport vehicles have departures at equal intervals throughout the day or a larger period of the day (e.g., departures every 1 hour, 30 minutes, 20 minutes, etc.),
- Defining the system in accordance with the road infrastructure: The analysis of the organization and regulation of the road network in the city of Šibenik determined favorable corridors for tracing bus lines,
- Adapting the service to users: new timetables are aligned with the working hours of the population, school teaching times and other needs of the population, timetables are organized in such a way that from the terminal points of travel to the key points of attraction arrive at an adequate time.

Before defining the operational indicators of the new public transport system, the identification of more than 1,500 points of transport demand in the city area was carried out,

- Designing transport services depending on the spatial-demographic characteristics of the area,
- Facilitating layovers: The organization of new routes is planned with the provision of easy and efficient transfers to other utility bus lines in mind,
- Integration: As public passenger transport in the city of Šibenik develops in the future, it is necessary to ensure mutual complementarity of the transport subsystem.

Figure 1. Scheme of city lines

5. CONCLUSIONS AND RECOMMENDATIONS

The implementation of the new public transport system in Šibenik (JGP Šibenik) proved to be successful. The methodology of research and planning resulted in the development of four variants of city bus lines:

- Variant 1G: Minimal corrections of the route and stop in relation to the current situation with a significant increase in the frequencies of vehicles on the lines – test variant.
- Variant 2G: (long-term variant): Complete reorganization of bus lines with a significant increase in the frequencies of vehicles on the lines with the construction of new bus stops and turnstiles
- Variant 2.1G (medium-term variant): Complete reorganization of bus lines with increasing vehicle frequencies on lines, but with minimal corrections to existing stops and turnstiles
- Variant 2.2G (short-term variant): In agreement with the Client, the variant in question was developed, which represents a complete reorganization of bus lines, but with reduced operational indicators with minimal corrections of existing stops and turnstiles for the purposes of the transitional period of the PSO contract.

The main objective of the project was to increase the number of passengers and this goal was achieved already in the first four months since the establishment of public transport in the last year (September 2022 – December 2023) when 300.000 passengers were transported. In the first six months of 2023, 500.000 passengers were transported on public transport lines, and in July a record of 100.000 passengers was achieved. So, the goal of the project has been achieved many times over and this year it is planned to reach the figure of one million passengers. In addition to defining city lines, the organization of suburban lines has been proposed. From 01.09.2022. The new public transport system started with the 2.2G variant. The consequences of the methodology of the research and planning of the future system of JGP Šibenik proved to be excellent at the very beginning of the establishment of the service. Which implies that an expert approach based on the real state produces positive results. The new public transport system in city of Šibenik has shown a great improvement in service from what it was in the past, so to speak this in Šibenik is a renaissance of public transport, and this is precisely expertise and the correct approach, based on real data from the field. It is important to emphasize that with the renaissance of public transport in Šibenik, the job is not finished, on the contrary, it is necessary to monitor the situation from day to day / month to month, to listen to the wishes and needs of the population, and it is necessary to cooperate well with the representatives of the city of Šibenik because under their jurisdiction is the maintenance and construction of infrastructure (traffic signalization, equipment, bus stops / lay-bys...).

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Deni Krevešić[1]
E-mail: dkrevesic@glanvillegroup.com; denikrevesic@gmail.com
David Gruhonjić[2]
E-mail: davidns99@gmail.com
[1] Glanville Consultants
3 Grovelands Business Centre, Boundary Way, Hemel Hempstead, United Kingdom
[2] Independent researcher

THE BENEFITS OF AUTONOMOUS PODS FOR THE FIRST/LAST MILE AND THEIR POTENTIAL IMPACT ON TRADITIONAL MODES OF PUBLIC TRANSPORT

Keywords
Autonomous pods
Public transport
First/last trip mile
Transport modes integration
Autonomous vehicles

Abstract
The transport industry is evolving rapidly, and new technologies are emerging every day, including autonomous vehicles. Autonomous vehicles are a promising technology for bridging the gap for first/last mile connections of public transport journeys, however, their potential benefits in providing efficient and reliable transportation solutions and their impact on traditional modes of public transport still need to be explored. This paper investigates the potential benefits of autonomous vehicles and their integration with traditional public transport modes. Additionally, the paper examines the potential infrastructural elements required for their introduction from two aspects. The first aspect is the user, which considers stops and designated road surfaces, while the second aspect is the operator, which considers service stations, depots and charging stations. Moreover, the use of autonomous vehicles can also significantly impact traditional modes of public transport, such as trains and buses. While these modes of transport have their own advantages, they often need help to provide a door-to-door service, leaving the first/last mile of the journey uncovered. Autonomous vehicles can bridge this gap, reducing the reliance on traditional modes of transport and potentially leading to a more integrated and seamless transport system. Overall, this paper highlights the potential of the introduction of autonomous vehicles for the first/last mile of public transport journeys and the way it enhances the overall efficiency and convenience of the transport.

1. INTRODUCTION

Creating a sustainable transportation system is a fundamental imperative for urban areas worldwide. Such a system not only improves the quality of life but also reduces pollution and offers a multitude of significant advantages [1]. However, designing an efficient and sustainable public transport system for low-density areas has proven to be a difficult task, primarily due to the substantial operational costs involved. In many cases, public transport relies on government entities to provide financial support through subsidies. However, despite diligent efforts, accessibility remains a persistent challenge, particularly in rural areas. This persistent "poverty of access" leaves many without viable public transport options, underscoring the critical importance of addressing the first/last mile gap [2]. Autonomous pods (APs) have the potential to reshape mobility and have the potential to address some of the unique transport challenges, especially in rural areas where the first/last mile issue is prominent. This paper is dedicated to investigating the role of APs in addressing complex transportation issues, particularly in rural areas, by exploring their prospects, benefits, and associated challenges.

This paper aims to explore the integration of APs into public transport systems, focusing on mitigating the first/last mile challenge, particularly in low density areas with limited access to public transport. The significance of addressing the first/last mile transportation challenge extends beyond mere convenience and accessibility. It represents a crucial step toward constructing sustainable, efficient, and inclusive urban and rural transport systems for the future. This research assesses the feasibility and potential benefits of APs, emphasising their transformative potential in addressing this critical transportation issue. By underscoring the importance of tackling the first/last mile challenge, this study contributes to the development of sustainable, efficient, and inclusive urban and rural transport systems.

2. POTENTIAL ADVANTAGES AND IMPACTS OF AUTONOMOUS PODS

The initial reports, studies, and trials of the usage of APs, have shown that, if adequately designed, APs do have the potential to fill the gap of the first/last mile where public transport service is limited. For example, a study done in the Finnish capital of Helsinki, has shown that, if introduced, APs could increase the population living in the 30-minute travel time area from the city centre by 36% [3]. The transportation model for Singapore has shown that the introduction of fully autonomous pods, integrated with traditional public transportation modes, could increase public transportation ridership, and switch the modal split towards more sustainable modes, which, in turn, could decrease congestion by 36,9% on congested road links in peak hours [4]. A study undertaken in the USA, in Arlington, Texas has shown that, although the initial investment for APs is substantially higher than for fossil fuel-powered vans, the non-existent driver costs, as well as the lower price of electricity compared to fossil fuels, implies that, over time, the investment would pay off and that APs are a cost-effective solution over a longer period [5].

Theoretical assumptions suggest that integrating APs into the public transport system can expand coverage, enhancing accessibility and attractiveness. An improved modal split might also reduce air pollution. The lower price of electricity compared to fossil fuels, no driver costs would imply that higher frequency could be achieved without a substantial impact on operational costs [5, 6]. Also, such conditions imply that the service could be available during most of the day, or non-stop. For example, the Heathrow Pod operates 22 hours a day [7]. Moreover, autonomous services offer greater on-demand flexibility compared to traditional public transport modes, and they easily integrate with Mobility as a Service (MaaS).

In addition, the users of past/current pilots and practical examples of the system are satisfied with the system and feel safe using it. During the Sohjoa Last Mile pilot project, most users rated the quality of the service as 5 (on a scale of 1 to 5). In terms of safety during operation, the most common grade was 7 (on a scale of 1 to 7), although a lot of users also rated their safety as 5 or 6. This pilot included tests with and without a professional supervisor. Around 75-80% of users expressed feeling safe without a supervisor. Most users intended to use the service for the first/last mile of their trip, provided the pod's speed increases while still ensuring safety, and that they would use the service for distances of up to 5 kilometres [8, 9].

In addition to their potential advantages in enhancing accessibility and mobility, APs also hold promise in significantly reducing environmental impacts. As these vehicles operate on electric power, they offer an eco-friendly alternative to traditional fossil-fuel-powered vehicles. This shift towards electric drive not only reduces greenhouse gas emissions but also helps improve air quality, particularly in urban areas. APs align with sustainability goals by promoting cleaner transportation options, making them a key component of future urban mobility systems. By addressing the environmental aspect, APs can play a crucial role in mitigating the adverse effects of climate change and improving the quality of life in urban environments.

3. POTENTIAL CHALLENGES FOR IMPLEMENTATION

While the benefits of such a service are evident, addressing challenges is essential for improved efficiency and safety. To address these concerns, the GATEway project has been run in London, United Kingdom. During the project, an extensive four-week-long public trial in a real-world urban environment was conducted. The trial was strategically located in the Greenwich Peninsula, specifically along the Thames Path, due to its complex environment with frequent interactions between pedestrians, cyclists, and vehicles. Within this context, the project deployed driverless pods equipped with sophisticated technology including sensors, cameras, lasers, and cutting-edge software algorithms. These technological advancements allowed the driverless pods to navigate the complex environment safely and efficiently, showcasing their capabilities in a dynamic and demanding urban environment [10]. This implies that potential safety concerns can be dismissed if adequate technology is applied. However, an issue that is yet to be tackled is the assistance to people with disabilities. A human could easily assist people and recognise when a ramp should be lowered, while driverless vehicles cannot assist such users in an adequate way. Addressing this issue is of great importance.

Another issue which current APs are facing is the low operating speed. Citizens who used the service during the Sohjoa Last Mile pilot project said that, to start using the service daily for the first/last mile of their trip, the average speed should be higher than it is now. The average travel speed of pods used in the pilot was around 7 km/h, with the maximum speed being below 20 km/h, which was the case in another related study as well [9-11]. In comparison, buses in mixed traffic usually have travel speeds between 12 and 20 km/h [1]. However, to operate at such speed, adequate technology must be applied to ensure safe operations.

Personal safety on board is another challenge which needs to be overcome. A certain portion of users of APs have noted that the lack of presence of a driver made them feel uncomfortable in case of potential robbery, assault, or any kind of criminal activity in the vehicle. Also, both users and partners of the Sohjoa Last Mile pilot project said that additional measures must be taken for users not to press stop buttons or similar buttons, to test the technical limits of the pods. The same concerns were noted for other road users and their potential wish to test the pods, a behavior which could be dangerous for both passengers and other road users [8, 9].

Communication between the pod and other road users must be clear and easy to understand. Generally, studies have shown that other road users are wearier of autonomous pods, than those inside of them. During the Sohjoa Last Mile pilot project in Tallin, 33,3% of other road users said that a driverless pod makes them feel unsafe, while 25% said that they are not sure if they feel unsafe [8]. Also, around 24% of other road users in Tallin said that they did not completely understand that the pod has safely stopped and is planning to remain stopped until all pedestrians have safely crossed the road. Both audio and visual signals must exist, which will provide road users with information about the pod's next move [8, 9].

Additionally, there may be a need for updated regulations and legal frameworks to govern the operation of APs on public roads. Establishing clear guidelines for insurance and liability allocation is crucial to ensure the protection of passengers, pedestrians, and other road users. Additionally, regulatory agencies must develop comprehensive safety standards and certification processes specific to APs, considering their unique characteristics and autonomous operation.

4. INFRASTRUCTURE INTEGRATION AND DESIGN CONSEDIRATION

Infrastructural elements for APs can be divided into two groups: infrastructural elements from the aspect of the user (designated stops and dedicated lanes), and infrastructural elements from the aspect of the operator (service and charging stations and depots).

Regarding APs stops, two methods have been considered: a system with fixed stops and an on-demand system, with no fixed stops. Although an on-demand system is more convenient for users, it is far more complex to organise for the operator and can be confusing for elderly users and people with disabilities, who sometimes prefer fixed stops at locations which are familiar to them. If fixed stops are designed, they should include displays with key information: when a vehicle is coming, and if it is an on-demand service, and not a fixed schedule one. Also, the display should include a way to request a vehicle, while including key data, such as the trip duration, price, etc. Alternatively, a method used during the Sohjoa Last Mile pilot project can be applied – dedicated bus stops included a QR code, inviting the users to use a web application to request a vehicle [9]. If the service is on-demand location wise, some authors recommend passenger pooling – a system where a few passengers request the service at proximity from each other, and the system arranges an optimal meeting point for all these users. Additionally, regarding the construction of dedicated lanes for autonomous pods, three aspects should be considered – how much will a dedicated lane improve the travel speed of the pod, does the pod have a fixed route which it uses or is it an on-demand service location wise, and is the ridership and the frequency of pods high enough to justify such an investment.

Running APs as a service involves several infrastructure considerations. Currently, APs operate under various schemes, some relying on segregated infrastructure while others function without fixed tracks. Notable examples include the Heathrow Pod in the UK and the Suncheon Wetlands SkyCube in South Korea, which operate on dedicated segregated infrastructure [7, 12]. In contrast, vehicles in Masdar City, Abu Dhabi, and Capelle aan den Ijssel, the Netherlands, navigate flat tracks based on virtual routes, utilising external reference points for positioning [13, 14]. All these systems are powered by batteries, ensuring emission-free operations, with recharging occurring either at maintenance facilities or dedicated stations. These systems operate on demand, 24 hours a day, backed by staffed emergency support. Each element of the system communicates with each other in real-time and is controlled through distributed telecommunication control systems.

Key infrastructural and design elements should be considered, such as data utilisation, cybersecurity measures, improved accessibility provisions, enhanced safety protocols, an operational center, charging infrastructure, and a maintenance system for vehicle servicing. The new infrastructure could explore innovative funding models, such as public-private partnerships, for infrastructure development.

5. INTEGRATION WITH PUBLIC TRANSPORT

APs have the potential to be used for the first/last mile of a trip. The International Association of Public Transport (UITP) has recognised that APs are best suited for this role [15]. UITP also claims that different types of autonomous vehicles, including APs, could reduce the usage of passenger cars by 80% [16].

Integrating APs into traditional public transport systems requires careful consideration of aspects such as geographic reach, communications systems, scheduling synchronization, and fare structure alignment. Key enablers for this integration include advanced smart ticketing systems that facilitate contactless payments and dynamic pricing models to incentivise off-peak usage. Furthermore, these systems promote multimodal integration, enabling passengers to effortlessly switch between different modes of transportation with a single ticket. Real-time data sharing is identified as essential, supporting efficient fleet allocation, proactive maintenance, and accurate demand forecasting. To optimise AP performance, data-sharing systems must prioritise user privacy, scalability, and data accuracy. By addressing these aspects, we can ensure the successful integration of autonomous pods, reshaping mobility and enhancing the overall transport experience for users.

Additionally, the authors of a study done for Helsinki, Finland, claim that, if APs are used for the first/last mile in many parts of a city and the area is well covered by the system, it can decrease the travel time of the traditional mode, which is, in this case, the trunk line, while the pod lines serve as feeder lines. The reduction of travel time can be achieved by grouping the feeder lines at one trunk line stop, instead of many feeder lines serving many different trunk line stops. Therefore, since the entire area is well served by autonomous pods, the number of stops on the trunk line can be reduced without reducing the coverage area, with feeder lines integrated with the trunk line at the same location. The lower number of stops therefore reduces travel time on the trunk line. A prerequisite for this system is the acceptable travel speed of pods [5].

6. CONCLUSION

In conclusion, the introduction of APs for first/last-mile public transport journeys present a significant opportunity to deliver efficient and sustainable transport solutions. Their potential benefits, including enhanced accessibility, improved efficiency, cost savings, and environmental advantages, position them as an attractive option for bridging gaps within traditional transport systems, thereby contributing to more sustainable and balanced urban and rural environments. However, successful integration demands careful consideration of infrastructure elements from both user and operator perspectives. Furthermore, the potential impact on traditional modes of transport should not be underestimated, as APs can serve to complement and potentially reduce reliance on these modes. Overall, APs have the potential to enhance the overall performance of public transport, creating a more integrated and efficient system accessible to everyone. The promising potential of APs in improving transport accessibility underscores the value of a flexible, on-demand, door-to-door service in addressing current barriers to transport and improving access to essential amenities and opportunities. Nevertheless, several challenges must be addressed before introducing autonomous infrastructure into the transport ecosystem, including technological and cost uncertainties, along with the need for extensive implementation research to understand the full spectrum of requirements for deploying and maintaining autonomous pods while developing workforce skills. Ensuring the safety of passengers and road users through advanced technology is of paramount importance, while maintaining travel speed.

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Pavle Pitka[1]
E-mail: pitka@uns.ac.rs
Milica Miličić[1]
E-mail: mmilica@uns.ac.rs
Tatjana Kovačević[1]
E-mail: savkovic.t@uns.ac.rs
Milja Simeunović[1]
E-mail: mlekovic@uns.ac.rs
Andrijana Jović[1]
E-mail: andrijana.jovic@uns.ac.rs
Jovan Rašković[2]
E-mail: raskovicjovan96@gmail.com
[1] University of Novi Sad, Faculty of Technical Sciences
Trg Dositeja Obradovića 6, 21102 Novi Sad
[2] Toyo Tires Serbia d.o.o.
Industrijska 3, 22320 Inđija

TRAVEL TIME ANALYSIS - CASE STUDY OF NOVI SAD

Keywords
Travel time
Dwell time
Public transport
Cycling

Abstract

Research has shown that people are more likely to choose a transport alternative that offers a shorter travel time than a passenger car. The simplest and most commonly used method for determining travel time is a survey of citizens. This method is prone to subjectivism, and the results obtained are imprecise. In Novi Sad, the travel time from the origin-destination trips was recorded using the global navigation satellite system for the following transport modes: walking, bicycle, passenger car, taxi and bus public transport. In this paper, a comparative analysis of travel time was used to assess the competitiveness of alternative modes of transportation with a special emphasis on the time that passengers spend in a state of rest.

1. INTRODUCTION

In urban areas, modern industrial society has led to a greater flow of people and information. One of the challenges of modern cities is to fit the daily migration of the population into sustainability standards, which should push the passenger car to the margins of the modal distribution [1,2,3]. In order to achieve this, alternative transport modes must be competitive with the passenger car. The choice of transport mode is influenced by a number of factors such as: price, availability of transport in space and time, comfort, travel time, reliability, safety and others [4,5,6].

Findings of Horrey [7] suggest that even though households acquire at least one car, some are more likely to keep using public transit to commute whenever it provides competitive services in terms of travel time.

One of the important factors when choosing the transport mode is, among other things, the travel time [8]. In order to improve alternative transport modes, it is necessary to analyze and improve the service quality, in the area of travel time. Two characteristics affect the complexity of determining and analyzing the travel time of citizens.

First of all, travel time is a complex parameter and consists of a number of time components. The structure of travel time also depends on transport mode. If it is taken into account that a significant number of trips are realized in a combination of two or more different transport modes, the problem becomes even more complex.

Secondly, in practice, the exact determination of the travel time of each participant is a problem. The simplest and most commonly used method for determining travel time is a citizen survey. This method is prone to subjectivism, and the results obtained are rather imprecise. A detailed analysis of the time components characteristics of the trip is almost impossible to perform based on the data from the citizen survey.

For the purposes of a detailed analysis of travel time and its time components, the movement of citizens was recorded for different transport modes in Novi Sad. Within this work, a comparative analysis of the total travel time and time components for different transport modes (passenger car - PC, bus passenger transport – PT, taxi, bicycle, walking) was carried out, with the aim of determining the current situation, problems, as well as opportunities for increasing the competitiveness of bus PT (passenger transport) and bicycles in relation to PC in Novi Sad.

2. METHODOLOGY

The travel time recording from the origin to the destination was carried out in Novi Sad for the following transport modes: walking, bicycle, passenger car, taxi and bus public transport. 5 researchers participated in the research, one for each transport mode. The researchers are residents and permanent users of the transport mode assigned in the experiment. All researchers moved from a common source on the outskirts of the city (address: Novo naselje, Ulica Braće Dronjak no.10) to the same goal in the innercity core (address: Trg slobode - monument to Svetozar Miletić). The movement routes were not defined in advance, so that the exact length of the route in question differs from the transport mode and it is about 5 km.

The survey was conducted on Wednesday, October 12 2022, between 2 and 3 p.m. during the time after the midday peak load. All researchers started moving from the source at the same moment without prior preparations for the chosen transport mode, that is:

- Researchers using bicycles and PC had to walk to their properly parked vehicles;
- The researcher who traveled by taxi should have called and waited for the arrival of the taxi;
- A researcher traveling by bus public transport should have walked to the nearest bus stop and waited for the bus.

Data collection during the research was carried out with the mobile application "GPS Logger", which recorded the time and exact passengers' location, i.e., latitude, longitude and altitude, using the Global Navigation Satellite System (GNSS). The researchers were trained in advance for application usage. The location parameters in the application are updated every second, that is, with a frequency of 1 Hz. The measurement error was ±7 m, which represents the standard deviation of a single-channel GNSS system without additional corrections.

3. RESULTS AND ANALYSIS

The comparative analysis of travel time for the researched transport modes was performed through the presentation of research results, namely: comparative analysis of movement speed by time, space-time diagram, comparative analysis of time components of travel, as well as the share of individual time components in the total travel time.

The movement route by transport mode was determined by the traffic infrastructure and arbitrary choice by the researcher. The shortest movement route was achieved by hiking and it is 4,272 m, and the longest movement route is achieved by PC and it is 5,239 m.

Movement dynamics of research participants differ by section and by transport mode (as on Figure 2). The user of Taxi transport was the first to reach the finish line, after 19.7 min. Immediately after, the cyclist and the PC driver arrived, who crossed the researched route in 20.8 min and 22.6 min observed respectively. So, the average travel speeds of bicycles, taxis and PC are close, with values of 13.1 km/h, 14.3 km/h and 13.9 km/h observed respectively (as on Table 1). The last to reach the destination was a pedestrian with a travel time of 41.4 min, with the lowest average speed of 6.2 km/h.

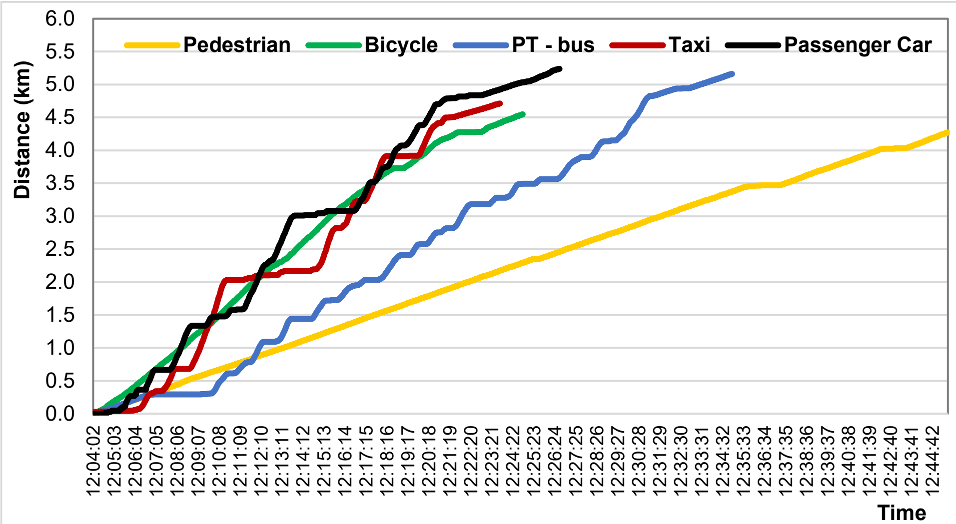


Figure 2. Spacetime diagram

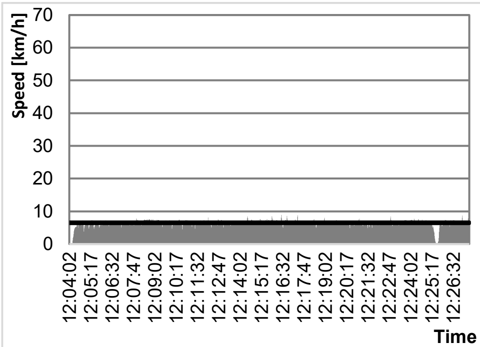
Table 1. Time components, distance and speeds

Parameters	Pedestrian	Bicycle	PT-bus	Taxi	PC
Access time [min]		0.0	3.0	0.6	0.5
Waiting time [min]			4.6	1.7	
Running time* [min]	38.8	17.4	13.8	8.8	10.0
Dwell time-intersection [min]	2.6	1.7	4.2	6.6	8.3
Dwell time-station [min]			4.2		
Finish walk time [min]		1.8	3.2	2.2	3.8
TOTAL travel time [min]	**41.4**	**20.8**	**32.8**	**19.7**	**22.6**
TOTAL lost time [min]	2.6	1.7	13.0	8.2	8.3
Distance [km]	4.272	4.548	5.163	4.712	5.239
Avg speed [km/h]	6.2	13.1	9.4	14.3	13.9
Max speed [km/h]	8.9	20.9	47.1	65.3	50.6

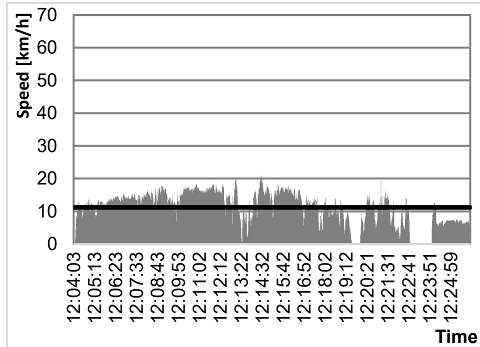
* hiking time for pedestrian

* It also includes bicycle parking time and car parking time

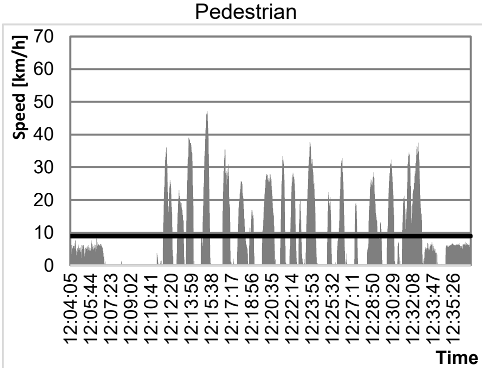
The greatest constancy in movement was achieved by pedestrians and cyclists (as on Figure 3). While the longest one-time delay, while waiting at the bus stop (dwell time-bus stop), was a PT-bus passenger. This delay of passengers amounted to 4.8 min. The taxi transport user had the greatest unevenness in movement speed. In this transport mode, the highest speed of 65.3 km/h was recorded.



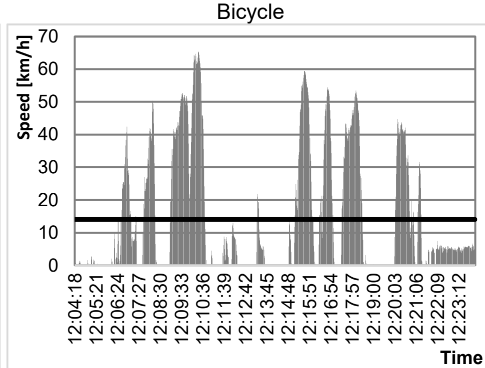
Pedestrian



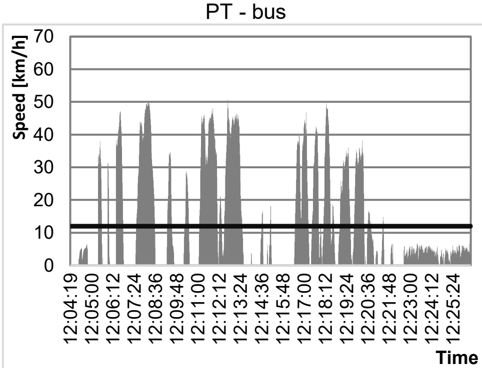
Bicycle



PT - bus



Taxi



Passenger Car

Figure 3. Comparative graph of speed by transport modes

In the case of motorized transport modes (PC, taxi, PT-bus) there is a significant difference between the median and mean speed values (as on Figure 4). A significantly lower median value than the mean shows that users of motorized transport modes spend a large part of their time at rest or moving at low speeds. This difference is created by traffic jams and delays at intersections, as well as the transportation availability in time. In Novi Sad, the transport availability in time is particularly pronounced with the PT-bus, where passengers often wait longer than 10 minutes for the vehicle.

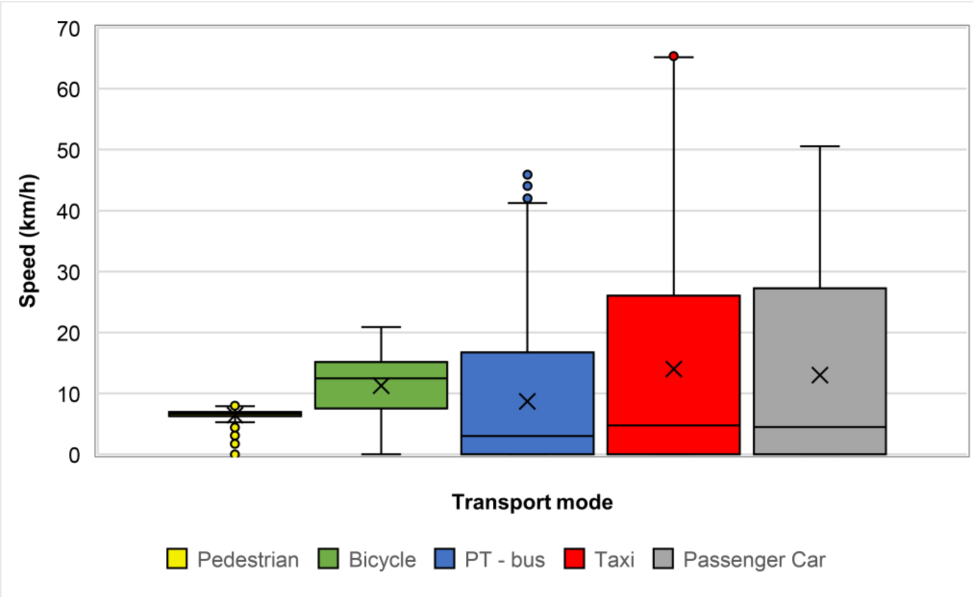


Figure 4. Box plot of speed by transport modes

The following graphic shows the structure of travel time for the researched transport modes. Special emphasis is placed on the time passengers spend in a state of rest, the so-called time losses. For this analysis, the time spent in a state of rest is significant because: it represents ineffective time that negatively affects travel time and average travel speed, mostly contributing to the unevenness of travel speed, it has a bad effect on the subjectivity of experienced travel time, etc.

Walking and cycling have the smallest share of time losses in the total travel time structure, less than 10% (as on Figure 5). Motorized transport modes account for a significantly larger share of time losses in the total travel time, amounting to around 40%. In the case of taxi and PC transport modes, the dominant time losses are waiting at intersections (dwell time- intersection), which amount to 6.6 minutes and 8.3 minutes, respectively. Compared to PC, taxi users have additional time lost waiting for a taxi (1.7 min), while PC drivers have to park their vehicle. In this research, no time losses were recorded during parking, but the parking location affected the longer walking time to the destination (3.8 min).

The structure of the time a PT-bus passenger spends at rest is significantly more complex compared to the other researched transportation modes. First of all, there is the time that the passenger spends waiting for the vehicle at the bus stop, which amounted to 4.6 minutes, or 13.96% of the total travel time. Then, while the passenger is in the vehicle, there are time losses, namely: dwell time at intersections and dwell time at bus stops to change passengers. Within the scope of this research, both of these times were 4.2 min each, or 12.96% of the total travel time. So that the PT-bus user spent 13.0 min in idle mode, which represents 39.44% of the travel time.

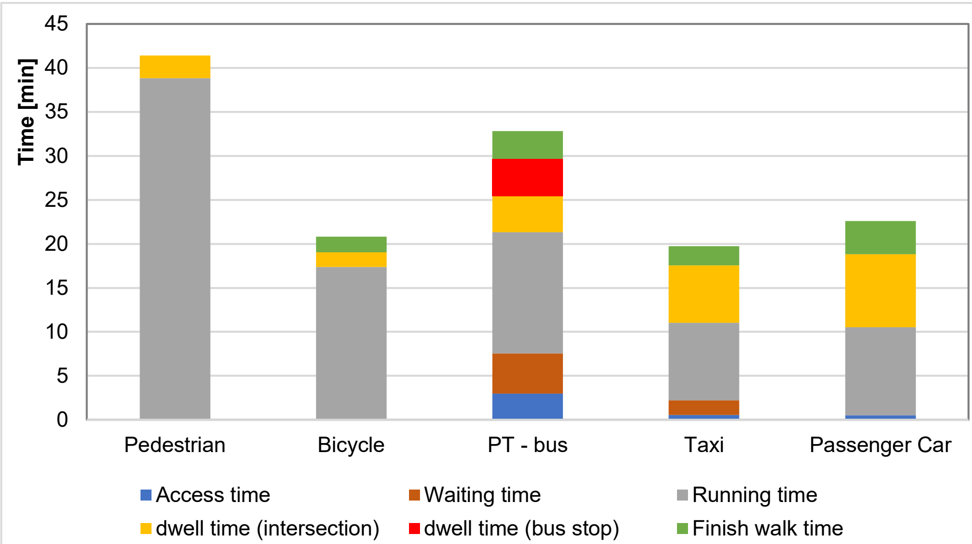


Figure 5. The structure of travel time by transport modes

4. CONCLUDING CONSIDERATIONS

Given the favorable climatic and relief characteristics of the city, the bicycle is one of the promising alternative transportation modes in Novi Sad. Based on the research, it can be concluded that if there is adequate infrastructure in Novi Sad for the chosen travel route, the bicycle is an alternative to the car, which in terms of travel time is competitive with all other transport modes.

Considering that non-motorized modes (e.g. walking and bicycle) are alternatives usually restricted to short-distance trips [9], public transport can effectively competes with passenger car for medium to long-distance trips.

In order to make the choice of public transport more attractive than the car, a high level of public transport service [10] and the high car costs are necessary [11].

The travel time structure of PT-bus users is significantly more complex compared to the other transport modes, which creates additional uncertainty in the passenger travel time. As a rule, passengers solve the problem of uncertainty by incorporating a protective time into the planned travel time and they start earlier in order to safely reach their destination on time.

According to this modest research, PT-bus travel in Novi Sad takes significantly longer time compared to other motorized transport modes. Passenger transport can be characterized as the slowest transport mode in Novi Sad because of the time losses, that is, the time the passenger spends in a state of rest during the journey.

There are three basic time components that have a negative impact on the length of the passenger's journey, namely: waiting for the vehicle arrival, dwell time at intersection at intersections, and dwell time at bus stops to change passengers. Reducing time losses within all three components of travel time is key to solving the inferior position of PT-bus in relation to other transport modes in Novi Sad.

In the following period, it is planned to repeat the research on a large number of routes in Novi Sad in order to obtain statistically valid results, as well as the development of a model for determining the dynamic elements of the lines that would provide a competitive service to the car.

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