A REVIEW OF NEW TECHNOLOGIES IN URBAN MASS PASSENGER TRANSPORT

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Abstract: *Modern urban mass passenger transport cannot be imagined without the use of information and communication technologies. Information technologies become irreplaceable in general informing of users, system of tickets and billing and other systems of public passenger transport. They also provide the ability for introducing uninterrupted and reliable services, in order to satisfy users for an affordable level of quality of service. The paper first provides a brief overview about some of the most important events in the history of the development of urban mass passenger transport on a world level, with a special focus on the city of Belgrade. The system of urban mass passenger transport represents one of the most important elements of the transport policy from the point of view of sustainable development and raising the quality of life of residents in cities. The perspectives of all stakeholders according to the system of urban mass passenger transport are presented in the paper. Hereinafter, new trends in the system of payment of transport services and system of tickets are presented. In addition, a brief overview of alternative technologies is provided for vehicles and fuels and especially for charging technologies of electric vehicles.*
Key words: *public transport, passenger transport, new technologies, vehicles*

1. Introduction

In accordance with (Gladovic, 1995), the function of the mass transit public passenger transport system (JMTP) as a transport activity is to provide transport services in a particular area. This activity should encourage the socio-economic development of cities and municipalities in the implementation of complex spatial planning programs. At the same time, it would have to reduce the level of environmental pollution through noise and pollution, contribute to the economic exploitation of material resources and increase the mobility of the population. JMTP has a dual function: it is a spatially economical form of transport, which on the one hand relieves congested roads and on the other hand provides transportation for those who do not have any other means of transport.

In most world and European countries, JMTP is understood as a general social interest, not as a simple utility, whose benefits are not only measured by the number of passengers carried and the cost of transportation, but also by factors such as:

- reduction of traffic congestion,
- increasing traffic safety,
- improving the environment,
- increasing the mobility of the population, etc.

Today, it is no longer necessary to prove the importance and role of public transport of passengers, as it is widely accepted that it is an irreplaceable function in the life of all citizens, the economy and all activities in the city. The importance of the public mass transit system is reflected in:

1. The JMTP system enables a large number of residents to fulfill one of their basic needs, the need for movement,
2. The quality of the transportation service of this system affects the efficiency and effectiveness of all production, supporting processes and other activities of people in the city.
3. Indirectly, it affects the rational use of urban areas, traffic congestion, speed and capacity, safety and environmental pollution in the overall urban transport system,
4. For a large number of residents, given their financial capabilities, as well as certain social groups (students, students, people with disabilities, retirees, the elderly, the unemployed, etc.), the JMTP is often the only option to meet transportation needs.

The public transport system is also an activity that engages large funds invested in resources: vehicles, employees, facilities and equipment, energy, etc. so for the economy of cities, it is of interest for every JMTP enterprise to function effectively.

According to several papers (ISOTOPE, 1997; Veselinovic, 2008; Gladovic & Deretic, 2014), goals and requirements for the public mass transit system can be formulated on the basis of goals and requirements of three interest groups: 1) city administration, 2) transport organizers-carriers and 3) users. In line with (Tica, 2016), besides the three interest groups mentioned, industry should be included as the fourth interest group. According to this source (Tica, 2016), there is a direct link between all stakeholders except the industry and users. JMTP, as a business, is faced with a number of challenges and opportunities arising from the transport area itself, as well as from external influences that originate from the socio-economic environment.

According to a report by UITP (2015), there are six major issues that are important for public mass transit of passengers: 1) demographic trends and increasing

mobility in urban areas; 2) managing and ensuring mobility in urban areas; 3) financing of mass transit of passengers; 4) globalization of the market and merger of companies whose activity is the transport of passengers; 5) climate change, air pollution and energy; 6) Human resources and employees. The JMTP system monitors the development of modern technologies, and in traffic and transport, new technologies are in the narrow sense of the term Intelligent Transport Systems (ITS), which make the necessary information available at all times. According to (Jovanovic, 2014), the World Bank has been advocating for decades for the construction of city highways and the use of motor vehicles. Before the same source, stated the position of Vukic Vucic (2000), the position of a well-known world expert on public transport: "The World Bank has long had a hostile attitude to public urban transport."

2. Development of public mass transit system for passengers

The development and advancement of public mass transit systems is directly linked to advances in vehicle technology and technology. According to (Vucic, 1987; Tica, 2016), some of the most important events in the history of the development of public mass transit systems for the city of Belgrade and in general for cities around the world are given in the following table (Table 1). The invention of the omnibus has initiated a further evolution of a new significant function in the life of cities. The advent of electric trams has made an unbreakable connection between JMTP and the city, leaving a strong influence on the way of life in modern metropolises. As stated in (Vucic, 1987), there are three basic categories of urban transport by mode of operation and use: individual, for rent (paratransit) and public and mass transportation. According to the same source (Vučić, 1987), innovations in technological and organizational sense in public transport can be divided according to their application into three basic categories: 1) technical components, 2) basic technological and organizational concepts and 3) systems and mode of transportation.

As stated in (Gladovic & Popovic, 2010), transport of passengers and goods is an integral part of the overall functioning of society and is directly related to the history of human civilization, the way and quality of life, the location and intensity of production and other activities, the volume and quality of goods and services . The introduction of new or refinement of existing transport technologies, which can also be seen from the data in Table 1, coincides spatially and temporally with important steps in the development of modern civilization.

According to (Gladovic & Popovic, 2010), the modern JMTP system cannot be imagined without the G3 system. According to this source, the G3 system integrates three modern information "system" technologies: the Geographic Information System (GIS), the Global Positioning System (GPS) and the Global System of Mobile Communications (Global System). for Mobile Communication (GSM). The aim of the G3 system is to create a highly functional and precise system, with the ability to monitor and manage vehicles (vehicles and trailers) and the process of transporting goods and passengers. The DIRD report (2014) emphasizes the importance of mass transit of passengers within the wider urban areas. Lack of reliable, efficient and affordable transportation, within or between cities, can cause social isolation and restrict access to health care, education and various services.

Table 1. Some of the important events in the history of the development of public mass transit system in Belgrade and in general for the world

Year	Town/Region	Event
1600	London	Public carriage as a taxi service
1765	London	The invention of the steam engine
1798	London	Omnibus with horse-drawn
1838	London	The first line of the suburban railway
1863	London	First subway line (city rail)
1881	Berlin	The first electric tram (Siemens & Halske)
1892	Belgrade	The first tram line in Belgrade for horse-drawn traction
1894	Belgrade	The first tram line in Belgrade on electric traction
1947	Belgrade	The first trolley line in Belgrade
2000	European Union	An era of sustainable urban mobility development
2003	European Union	Start testing buses with Fuel Cell technology
2010	European Union	Development of combined mobility services
2015	European Union	Mass application of electric buses

Source: Tica (2016), excerpt from Table 1.

The paper (Buehler & Pucher, 2012) is one of the first papers to provide a brief overview of international trends in public mass passenger transport from 1980 to 2010, which noted differences between countries. As shown in Figure 1, the number of trips per capita per year (annual mobility) in the JMTP system varies in the range of approximately 10: 1, if the number of trips in Switzerland (237 trips per year) compared to the United States is compared United States (24 trips per year). The surprising fact is that a country like the Netherlands has the second lowest number of trips per capita out of just 51 trips a year. However, the explanation can be found in the extreme importance of cycling, since in a country such as the Netherlands, cycling accounts for about 26% of all travel, which is a 2008 figure. The Netherlands has the highest share of cycling in the visual distribution of all countries in Europe. (Pucher & Buehler, 2010; Buehler & Pucher, 2012) Due to differences in research methodology, travel definitions and timetables, the results obtained by the survey are not fully comparable.

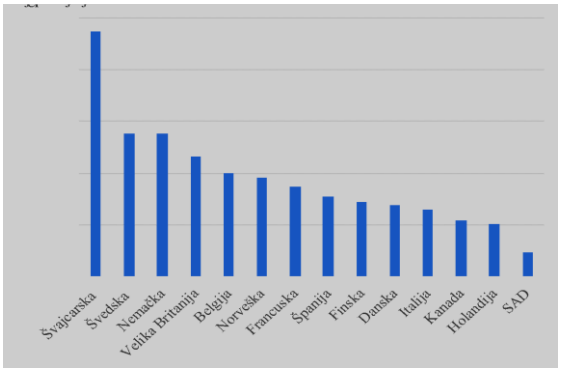

Figure 1. Number of JMTP residents' trips per year.
Source: Buehler & Pucher (2012).

In cities, there are several ways businesses operate in the transportation business. According to a study by Carroll & Walsh (2015), according to the degree of control by city authorities, these companies are divided into three groups: 1) direct control, 2) indirect control, and 3) no control.

Under the direct control, the city administration carries out the transport of passengers and procures vehicles or has direct control over the undertaking which carries out the transport of passengers. In the case of indirect control, the city administration shall announce a tender specifying the conditions to be fulfilled by the companies, which will carry out the activity of transporting passengers. In unattended conditions, the city government does not operate vehicles or contract passengers, although in some cases it may subsidize a smaller number of passenger lines. In the direct control model, the city can purchase vehicles of any technology.

With the indirect control model, the city can tenderly define the characteristics of the vehicle. For the unattended model, the market is deregulated and any company, with the appropriate license, can carry passengers around the city with vehicles of any technology.

According to (Litman, 2006), travel requirements take into account both perspectives, that is, community and individual requirements when making public policies and planning assessments. The community perspective reflects on the types of travel activities that support community goals, such as reducing total traffic and congestion due to parking, traffic accidents, exhaust emissions and other pollution. Such goals tend to increase the demand on the part of the community for efficient modes of transport, such as improved cycling, ridesharing and public mass transit of passengers. According to Liftshare (2018), ridesharing is, by definition, a transportation service where a person uses a smartphone application to schedule a ride in a vehicle, which is usually privately owned, citing Uber as an example. On the other hand, community goals relate to demand management strategies that foster an efficient way of using modes of transportation.

The individual demand perspective is reflected in the travel activities that individual travelers or households choose if travel options are available. For example, an aging population, rising fuel prices and increasing concern for individuals about their own health tend to increase demand for walking, cycling, "carpooling" vehicles and mass transit of passengers. Both of these perspectives need to be considered when assessing overall transportation requirements. Consistent with (Litman, 2006), this is significant because both perspectives have multiple magnifying effects: if the demands of the community and individuals for an alternative mode of transport are doubled, then the total demands are quadrupled because the community wants the residents to use the said form and more residents are willing to use that mode of transportation.

3. Vehicle and fuel related technologies

Alternative technologies related to vehicles and fuels are presented in the following tables (Tables 1 and 2), based on the division given in Carroll & Walsh (2015), while part of the explanation is taken from Vukasovic (2005).

Table 1. Alternative vehicle technologies

Abbreviation	Description and explanation
EV	Electric vehicles.
HEV	Hybrid electric vehicles powered by a combination of internal combustion engines and one or more electric motors.
PHEV	Plug-in hybrid electric vehicles with a relatively large battery that is recharged from an external power source.
REEV	Range Extended Extended Range Electric Vehicles. These vehicles have the ability to charge the battery from a vehicle-powered generator powered by diesel or fuel cell technology.
FH	Flywheel hybrid vehicles that use flywheel to accumulate energy that is typically lost through braking and deceleration.
HH	Hydraulic hybrid vehicles that use pressurized fluids to accumulate energy that is normally lost through braking and deceleration.
FCEV	Electric vehicles with fuel cells that combine hydrogen and fuel cells to generate electricity used to start a vehicle.
AFEV	Internal combustion engine vehicles modified to run on alternative fuels such as: biofuels, natural gas and LPG.

Source: Carroll & Walsh (2015)

Up to 5 years, new technologies (eg stop-start, hybrid vehicles combined with an

internal combustion engine and flywheel hybrid vehicles) offer a relatively quick return on investment. It can be expected that by 2020, these technologies will be implemented in a large number of cities in public transport vehicles. Other technologies, such as electric vehicles, depend primarily on planning strategies, development policies and financing methods.

Tabela 2. Alternativne tehnologije goriva

Abbreviation or name	Description and explanation
High blend biofuels	A mixture of fossil fuels and biofuels above the permissible limits prescribed by current European standards for diesel (EN590) and gasoline (EN228).
Drop-in fuel	Biofuels that can mix up to 100% with fossil fuels, while maintaining current European standards for diesel (EN590) and gasoline (EN228).
PPO	100% vegetable oil.
CNG	Fossil fuel consisting mainly of methane.
Biomethane	Biomethane is chemically similar and can be exchanged with natural gas as a fuel.
LPG	Liquid petroleum gas, which is a fossil fuel, consists mainly of propane and butane.
Hydrogen	Hydrogen is a chemical element used to drive a vehicle, either through direct combustion or through fuel cells.

Source: Carroll & Walsh (2015)

With regard to biofuels, it is generally expected to use them in blending with standard fuels within the applicable EN standards. As for natural gas vehicles, their numbers will grow with the improvement of engine utilization and the reduction of CO2 emissions. The breakdown of alternative charging technologies for electric vehicles is given in Table 3. Wireless charging of vehicles, in the short term, can be expected within experimental and pilot projects.

Table 3. Alternative charging technologies for electric vehicles

Name	Description and explanation
Conductive charge	Charging electric vehicles when vehicles are connected directly to the mains.
Static inductive charging	Wireless charging. Using an electromagnetic field to transfer energy to a vehicle while the vehicle is parked. The vehicle does not need to be directly connected to the mains.
Dynamic inductive charging	Wireless charging. Using an electromagnetic field to transfer energy to a vehicle while the vehicle is in motion.

Source: Carroll & Walsh (2015)

4. The tariff system and the ticket system

According to (Veselinović, 2008), the characteristics and magnitude of transport demands in cities are influenced by many factors: social and demographic structure of population, population growth, inherited and acquired behaviors, housing structure, as well as the volume and quality of transport supply. One of the limiting factors of the quality of transport service may be the tariff policy.

According to (Filipović, 1995), optimization of the tariff system represents one of the most important tasks of managing the JMTP system. In transportation, the price of the service is determined according to the so-called. performance and depends on the length (distance) of transportation. According to this source, in JMTP, it is not possible to set fares for each individual ride of a certain length, as this would greatly complicate the billing system. For this reason, it is necessary for the JMTP system to replace the prices for individual rides by group prices per performance, so that one price applies to all rides whose length is within a

certain class of lengths. The newly chosen optimal tariff system, according to (Gladovic, 1995), is a compromise between desires - requirements (selection criteria) and possibilities (constraints).

As stated in (Filipović, 1995), from the point of view of passengers, the tariff system is a list of prices by type of ticket. From the carrier's point of view, compiling the above price list is a very complex job that involves:

- setting optimization criteria,
- choice of the optimal type of tariff system (unique, zone, relational, combined) of the ticket system,
- selection of the optimal ticket system (in terms of revenue and collection),
- determining the level of the basic price, etc.

In (Gladovic, 1995), it is stated that the ticket system in use on a network of JMTP lines in a city must reflect the traditional goals and functions resulting from its use:

- collection of revenue,
- development of tariff structures and levels,
- Contribution to the design of optimal transport capacities based on the creation of a database of transport service users (relation: flat - business),
- facilitating the use of public transport,
- improving the awareness of the users of the transport service (passengers), and therefore the commercial policy of the enterprise,
- assistance in better utilization of transport capacities,
- contribution to the fight against non-payment of transport.

Perspectives on the development of particular types of ticket at JMTP were discussed at the end of 1993 by the Automation Committee of the Union Internationale des Transports Publics (UITP). Based on their report (Ampeles, Blasco Gonzales, 1994; Gladovic, 1995), it is concluded that over the next ten years it was envisaged that the replacement of existing ticket types would be made through three stages of the election:

Phase I - application of paper maps,
Phase II - application of magnetic cards,
Phase III - application of contactless cards (in perspective).

Electronic billing systems and electronic billing management have been in operation for almost two decades. The division of electronic payment systems can be done according to validation or cancellation technology, according to (Tica, 2016), while examples from urban transport studies are given in several studies (GWT-TUD GmbH, 2009; VRR & KCEFM, 2014):

- **Check In - CI.** Validation of tickets by passengers only when entering vehicles, ie system (stops).
- **Check In / Check Out - CICO.** Validation of tickets by passengers when entering and leaving the vehicle or system (stop).
- **Be In / Be Out - BIBO**. Billing system for transport services in which no entry or exit activity is required from the user as it is automatically detected by the user in the vehicle / system. A special case of this technology is the **Walk-In / Walk-Out technology - WIWO**, as it captures the direction of travel of passengers when passing by a vehicle door or access points to the system.

- **Check In / Be Out - CIBO**. The user only validates the ticket when entering the vehicle (system), while leaving the vehicle (system) is automatically detected.

5. Conclusion

On the one hand, JMTP needs to function better, be more efficient, and in line with changing expectations, be more customer-oriented and take an entrepreneurial approach. On the other hand, it contributes to jobs and growth, cities are more competitive, attract investors and reduce congestion. Also, JMTP contributes to the environment and quality of life in the city. From the point of view of carriers as service providers and users of transport services, it can be concluded that the application of modern information technologies is a prerequisite for safer operation and improvement of the quality of transport service.

The JMTP system is constantly changing. From one point of view, change is conditioned by people's desire for change and progress as technology evolves. On the other hand, changes are influenced by changes in conditions and circumstances in urban agglomerations where most people live and work, that is, where there is the largest set of connections, decision-making tools and information. The JMTP system as a mode of transport can play an optimal role only in cities that have a long-term development policy. The impact of short-term actions, inadequate investment, favoring one mode of transport over another, political and various other influences can lead to a loss of citizens' confidence in the JMTP system.

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