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POTENTIAL FOR ESTABLISHING BUS RAPID TRANSIT (METRO-BUS SYSTEM) IN BELGRADE

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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.

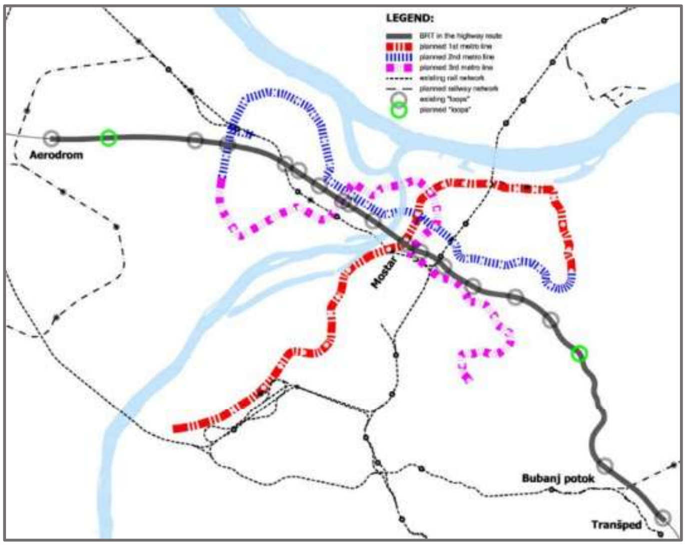
7. POSSIBILITIES OF ESTABLISHING BRT SYSTEM IN BELGRADE

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.



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.

Figure 4. Highway and planned metro lines in Belgrade

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,

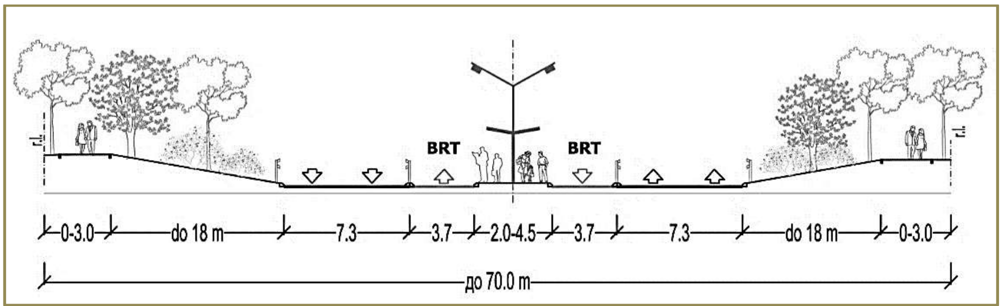


Figure 5. Highway profile with "bus lanes" in the far left lane

- 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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