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REVIEW

The role of the BRT system in the function of sustainable public passenger transport

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Abstract: Bus rapid transit (BRT) is a system of public urban passenger transport (PUPT), based on the bus subsystem, designed to improve capacity and reliability compared to the classic bus system. Typically, a BRT system includes bus lanes and gives priority to buses at intersections where buses can interact with other traffic. Public transport is crucial to the future of a nation. Strengthens the economy, conserves energy and resources, reduces congestion, reduces global warming and improves air quality and health, critical emergency and disaster relief, increases real estate value and development, mobility in small urban and rural communities. As an instrument of transport policy, transport demand management measures generally do not require large material investments, which gives them additional attractiveness. The paper was conceived on the strategy of sustainable development of cities as a function of quality of life, and the basic characteristics of the BRT system and its role in urban mobility are presented in the work. Also, an insight into their potential is given based on past experiences of application in the world's developed cities.

Keywords: Bus rapid transit, sustainable transport, public passenger transport, mobility

INTRODUCTION

According to the definitions of sustainable transport, the basis of the implementation of the strategy of sustainable development in transport is the balanced development of economic, ecological and sociological goals. Negative transport impacts are numerous and varied and require continuous monitoring. Current trends point to the biggest environmental problems of transport in the past two decades: an increase in greenhouse gas emissions and energy consumption, with the sector's high dependence on fossil fuels; problems of exceeding the permissible concentration of air pollutants in many European cities are still present, despite the overall progress in reducing harmful emissions; over one hundred million urban and suburban population are exposed to the harmful effects of noise; the number of victims in traffic accidents in road transport is decreasing, but the desired safety levels have not yet been achieved; the effects of congestion in road transport are present to a greater or lesser extent in the entire European area and impair the overall European economic potential. (1)

Because the PUPT system is such an important part of any city, it should be accessible to everyone regardless of social group or physical ability. However, in many European cities this system is still inaccessible to some citizens and visitors. Meanwhile, other groups choose not to use the PUPT, as it does not meet their needs. Providing access to efficient public transit for all types of users requires striking a balance between installing enough stops to reduce walking distance and travel time (10). Using new solutions and technology, access to mobility can be made available to people who were previously unable to take full advantage of the PUPT system. In the meantime, the efficiency of the system can be increased. The problems that arise in PUPT are primarily those problems that affect mobility, i.e. free, fast and efficient movement, as well as accessibility to all users who want to use this system.

Today, the BRT concept is increasingly used by cities that are looking for economical transit solutions. As new experiments in BRT appear, the condition of engineering in BRT will undoubtedly continue to improve. Regardless, BRT user orientation is likely to remain its defining characteristic. Developers of high-quality BRT systems in cities such as Bogota, Brisbane, Curitiba, Ottawa, Guayaquil and Rouen noted that the ultimate goal was to move people quickly, efficiently and economically, not cars.

The starting point of this paper is that, based on the past experiences of implementing the BRT system, it is possible to gain insight into the potential of sustainable development strategies in the function of "quality of life" and mobility measures for sustainable urban public transport of passengers.

IMPROVEMENT OF BUS SERVICE

In addition to the bus line, there is another category of bus services that deserves special attention. In order for a system to be designated as a BRT system, there must be a separate road alignment. However, there are several systems that possess many of the other qualities of BRT, but they do not have a significant component. In some cases these systems may use bus lanes or even mixed traffic lanes. These types of systems are called "Enhanced Bus Services". Some authors call such systems "BRT Light". Most of these "Enhanced Bus Services" are located in developed countries, especially in Europe and North America. In cities with low urban public transport (UPT) use and low-density development, the difficulty of obtaining exclusive right-of-way for UPT vehicles can be significant. However, systems in Europe, North America, and other parts of the world have added similar improvements as in to BRT on classic bus lines and during the process they achieved significant improvements in travel time and safety.

Figure 1. Corridor of Los Angeles Metro Rapid service on Wilshire Boulevard

London's bus network handles 5.4 million journeys every day, far outstripping the city's underground tube system. London is one of the few cities in the world where bus travel has steadily increased over the past ten years. London's success is based on four broad service quality objectives:

1. frequency ("show up and go" service with a wait of 12 minutes or less);
2. reliability (forced bus lanes);
3. comprehensiveness and
4. simplicity.

Figure 2. London's use of camera-based bus lanes

To achieve these goals, London has implemented many of the features of BRT within a conventional bus service:

- accessible low-floor vehicles for quick entry and exit;
- ticket collection before boarding in central areas;
- information about departure times at stations;
- quality incentive contracts with concessionaires;
- improved driver training and
- measure priority lanes.

Bus lanes are quite different in design and efficiency. Although some well-defined and well-implemented bus lane systems in developed countries are successful (eg London), in general, bus lanes alone, especially those located on the curb, do not improve the efficiency of UPT. Bus lanes are streets that are primarily reserved for UPT vehicles permanently or at certain times. Bus lanes are not physically separated from other lanes. Although the lanes are sometimes colored, demarcated and marked with a sign, it is still feasible to change bus lanes. In some cases, bus lanes may be shared with high-occupancy vehicles, taxis and/or non-motorized vehicles. Bus lanes may also be open to private vehicle use near intersections. Bus lanes are physically separated lanes that are exclusively used by UPT vehicles. Entering the bus lane can only be done at certain points. The bus lane is separated from other traffic by a wall, curb, cone or other well-defined structural features. Non-transport vehicles generally do not have access to the road, although emergency vehicles can often use the lane. Bus lanes can be on the surface, elevated or underground, but if they are located on mixed traffic lanes, they are most often located in the middle of the roadway. BRT systems usually consist of bus lane (road) infrastructure.

MODERN BRT SYSTEMS

However, the complete BRT system was not realized until the "surface metro" system was developed in Curitiba (Brazil). Construction of the first 20 kilometers of the Curitiba system was planned in 1972, completed in 1973, and the system opened for use in 1974. Combined with Curitiba's other advancements with pedestrian zones, green space and innovative social programs, the city has become a well-known urban success story around the world. Ironically, Curitiba initially gravitated toward building a rail, based on metro system.

In most of Latin America, private sector operators dominated the public transport market. However, left unchecked and unregulated such operators have not met the needs of transport in terms of comfort, convenience or safety. Disadvantage of resources to develop a rail-based or city-based UPT system, Mayor Lerner's team created a low cost but high quality alternative using bus technology. Today's modern Curitiba subways and double-articulated 270 passenger buses serve as an example to the world. The BRT system now has five radial corridors starting from the city core. The construction of the sixth corridor is underway through financing provided by the International American Development Bank (IADB). Currently, the Curitiba system has 65 kilometers of exclusive bus lanes (roads) and 340 kilometers for loading vehicles. The system annually attracts hundreds of city officials from other municipalities, who want to study the organizational and design features that have shaped Curitiba's success.

Figure 3. The main road used only by BRT vehicles

The most significant news and changes in brt systems

The BRT system must be constantly monitored and requires frequent changes in terms of its improvement, so that such a large system can be used by people correctly, quickly and safely. The most significant novelties and changes in BRT systems are:

- *Focus on safety* – To better address the issue of safety, the pedestrian section has been renamed. Pedestrian access and safety now requires more safety features, such as safe and frequent pedestrian crossings in built up areas. In addition, new work deductions were added, including a deduction for excessive pedestrian waiting time and poor maintenance of pedestrian and bicycle facilities;
- *Increased focus on operations* – To encourage high quality system performance, new elements have been added to defend operations for the many issues that have arisen on BRT corridors that significantly degrade corridor quality, even on corridors with excellent design. They include the bus crowding deduction, allowing unsafe bicycle use, lack of traffic safety data and buses running parallel to the BRT corridor;
- *Separate Design Options and Full Score (Operational Design)* – A separate design score, indicating potential performance, is now allowed for evaluating the design elements of an operational BRT corridor. This can be assessed when the corridor is launched. The complete result combines design and operational deductions and can be assessed 6 months after commercial operations have begun, allowing utilization and operations to stabilize. This gives a complete indication of performance based on design and operations;
- *Improved right-of-way definition* – The dedicated right-of-way element has been modified to create a simpler and more efficient means of evaluating exclusive bus lanes. Greater emphasis is placed on physical separation, which reduces the need for execution;
- *New bus line alignments* – The bus line alignment element has been expanded to include 4 routes out of 8 for two types of routes that are increasingly common; both alignments are for roads on boulevard streets with two separate central and express carriageways and service roads (Figure 4);

Figure 4. Middle traffic lane intended for BRT vehicles

- *Value check* – the BRT standard now assigns a certain number of points for the evaluation of tickets purchased outside the vehicle (Figure 5). This type of system is used in many cities in Europe and is also being implemented in corridors with lower demand in North America. It can provide significant time savings in conjunction with boarding.

Figure 5. Reading a ticket for using the BRT system

Infrastructure for the operation of the brt system

Good pavement quality ensures better service and operation over a longer period, reducing the need for maintenance. Roads with poor pavement must be closed more often for repairs. Buses will also have to slow down and drive carefully on the damaged roadway. Easy ride is key to creating a high-quality service that can attract and retain customers. Regardless of the type of road, a duration of 30 years is recommended. There are several options to achieve road construction for that time period, with advantages and disadvantages to each.

Figure 6. Appearance of the infrastructure after BRT implementation

There are three such examples:

1. Properly designed and constructed, asphalt pavement can last 30 years or more with surface replacement every 10 to 15 years. This can be done without interrupting traffic, which makes for a smooth ride. At stations and intersections, it is important to use rigid pavement pads to resist potential pavement damage from vehicle braking, a problem that is most common in warm climates. Each bus should be 1.5 times the total length of the buses using it at any given time;
2. Concrete Pavement Joints, this type of pavement design can have a service life of 30 years or more. In order to ensure durability, the roadway must have round bars for indentation at the transverse joints, tied with reinforcing steel strips of appropriate thickness;
3. Permanent reinforced concrete slab, Permanent reinforced concrete slab can add additional stiffness to the pavement and may be considered under certain design conditions.

Traffic lanes for the passage of brt vehicles

Pass lanes at stations are of crucial importance for enabling express and local services. They also allow the stations to accept a large number of buses at the same time, without jamming the buses waiting to enter. On corridors with low bus frequency, it is more difficult to politically justify a specific place on the street for passing lanes, if those lanes are not occupied most of the time. Lanes are usually a good investment in the medium term, providing multiple service options and significant travel time savings and allowing flexibility as the system grows.

Figure 7. Traffic lane intended for BRT vehicles only

On high-demand corridors that require frequent service, through-lanes at stations are particularly useful for providing sufficient corridor capacity to support higher speeds. Corridors with increasing demand may not initially have large capacities, but through lanes can allow for large growth without saturating the corridor. Through lanes also allow for a variety of service options, which can be useful even on corridors with lower demand. In some cases, many of the benefits of passing lanes can be provided by allowing BRT buses to pass in the approach dedicated bus lane. However, for safety reasons, this should only be done where there is good visibility and a relatively low frequency of buses. Similarly, BRT corridors can also allow buses to pass in mixed traffic lanes. But this is mostly useful in a location with low bus frequencies and limited mixed traffic congestion.

STRATEGY AND MEASURES OF SUSTAINABLE DEVELOPMENT

From the perspective of UPT, the strategy of sustainable development implies enabling the mobility of residents while controlling the use of vehicles. In the European

Union, the achievement of the goals of "sustainable development" in the function of "quality of life" in relation to the UPT system is achieved through the conduct of a policy that takes as a principle the mobility of the population with the limited use of passenger cars. The policies and measures of European countries in "sustainable development" are shown in table 1. (7,8)

Key trends in the field of UPT today are:

- The obligation and concern of local communities to ensure the mobility of residents with limited use of passenger cars in accordance with the strategy of "sustainable development" and "quality of life",
- Opening the service market for all carriers and all types of ownership,
- The development of intermodal transport (which implies the systematic use of two or more modes of transport with the aim of increasing the overall efficiency of the transport system),
- Full integration: of transport networks (physical integration), tariff integration and logical - informational integration,
- The need to increase production efficiency and reduce the operating costs of carriers,
- Citizens' pressure on local self-government bodies to realize a higher level of quality with an acceptable price for public transport services and a single ticket for all carriers and modes of transport.

In order to realize the strategic goals of "even development of city units" and "quality of life in the city", it is necessary to know the characteristics of modern cities, the possibility of identifying strategic problems and indicators that are important for the redesign of a modern or developed city. The strategy of sustainable development as a function of the quality of life in the city is based on an urban mobility platform in which the use of individual traffic by using one's own car is reduced to the minimum. In order to achieve such goals, there is a need to intensify the capacity of UPT in terms of its availability in time and space, in order to use the capacity more massively, so that individual traffic and the use of cars are used as little as possible. The strategy involves the realization of traffic, transport and other processes in the city in which daily trips are made using the means of UPT, as well as using the possibility of transport by means of urban micro mobility (walking, bicycle,...) as well as electro mobility (electric bicycle, electric scooter). (3)

The strategy of sustainable development in the city includes the following measures:

- Mobility management
- Increasing the participation of flexible (paratransit) in UPT
- Combined mobility i
- Smart mobility

Urbanization of settlements from public transport locations

Urbanization has been one of the dominant modern processes because an increasing proportion of the world's population lives in cities. Considering this trend, urban transport issues are of utmost importance for the passenger transport and freight mobility requirements of large urban areas. Traffic in urban areas is very complex due to the modes of transportation, the multitude of departures and destinations, the amount and variety of traffic. In general, the focus of urban transport was on passenger transport, as cities were seen as locations of the greatest human interactions with intriguing transport forms associated with commuting, commercial transactions and leisure/cultural activities. However, cities are also locations of production, consumption and distribution, activities related to the movement of goods. Theoretically, the urban transport system is closely related to the urban form and spatial structure. Urban transit is an important dimension of mobility, especially in high density areas.

The process of urbanization, or "urban transition", describes the change of the population from one that is

Table 1. The policy of European countries in the development of livable cities

Sustainable development of cities (mobility with controlled use of a passenger car)	
Resource management (car usage management)	- Pedestrian zones, - Zones protected from motor traffic, - Restriction of access for passenger cars to certain zones or at certain times, - Traffic calming (slowing down), - Management and charging of parking, - Traffic management.
Development and management of the public transport system (system building, development, integration and quality)	- Allocation and Priorities, - Operational system management, - Information systems for users, - Integration of different subsystems, tariffs and information, - Development of paratransit.
Planning and mechanisms of taxation (development management, restrictions on the use of passenger cars, financing of development)	- Land planning and use (reservation of locations for rail subsystems of public transport), - Taxes (sale of real estate, valuation of location and commercial value), - Center entrance control, - Collection of tolls (toll booths, collection according to the length of the journey, etc.).
Organization and financing	

Figure 8. The impact of urbanization on public passenger transport

distributed through small rural settlements where agriculture is the dominant economic activity to a population concentrated in larger, dense urban settlements characterized by industrial and service activities. (11)

Today's cities are growing twice as fast in terms of land as in population. Accordingly, projections show that future trends in urbanization could produce an almost three-fold increase in global urban land between 2000. and 2030., as hundreds of thousands of additional square kilometers are developed into urban density levels. Such urban expansion threatens to destroy habitats in key biodiversity hotspots and contributes to carbon emissions linked to tropical deforestation and land use.

Mobility management

Mobility Management (MM) implies the reform of the transport market whenever it is cost-effective, taking into account all costs and benefits, and applies the capacity expansion measure as the last. In the context of sustainable transport development policy, mobility management is an important instrument of transport policy that aims to facilitate mobility and at the same time influence the reduction of negative environmental, economic and sociological impacts of transport. The core of this concept is the management of mobility requirements - the most important feature of the concept is its orientation towards demand instead of supply, so in the USA and some other countries, it is known as the concept Transport Demand Management (TDM).

Transport demand management measures aimed at reforming the transport market can be divided into "soft" and "hard" transport policy measures. Hard transport policy measures, sometimes called coercive, represent the "old branch" of TDM and include physical infrastructure improvements, but also increasing the cost of using cars, for example, through congestion charges or road space management. Although these measures are sometimes necessary, they are difficult to implement due to public opposition and political ineptitude (4,6).

Soft measures of transport policy, which are sometimes called non-coercive measures (9), psychological and behavioral strategies (5), measures of smarter, i.e. smart choice or mobility management tools (2), are defined in such a way as to encourage individuals to voluntarily change their behavior related to transport, in order to choose sustainable modes of transport. This approach is, for example, known in Australia as mobility management in a way to achieve "voluntary change in passenger behavior when planning a trip". The most famous MM tools in Japan, Travel Feedback Programs (TFP), inform and educate users about ways and habits in travel (daily migrations). This leads to a reduction in the use of single-passenger cars and an increase in the use of less harmful and more efficient modes of transport, through the provision of detailed information on public transport, the provision of incentives, feedback on user behavior, as well as through marketing techniques aimed at individual behavior together with by choosing the mode of transportation. (2)

Smart mobility

Smart Mobility is a concept and tool that enables efficient, flexible and environmentally friendly travel by various modes of transport in space and time using smart transport systems, smart infrastructure and smart technologies (new methods that increase mobility in the UPT system).

Figure 9. Presentation of the functioning of the smart mobility system

"Smart Mobility" is a new revolutionary approach to the realization of the mobility of residents in urban areas and implies an integrated approach to the planning and design of transport systems, mutual cooperation and interconnection (networking) of all available modes of transport and infrastructure, rapid exchange of information and data and complete orientation towards the user (Figure 9). Smart mobility creates and shapes transport systems "customized by the user", i.e. creates the conditions for the realization of mobility through flexible packages of services that the user chooses according to his needs.

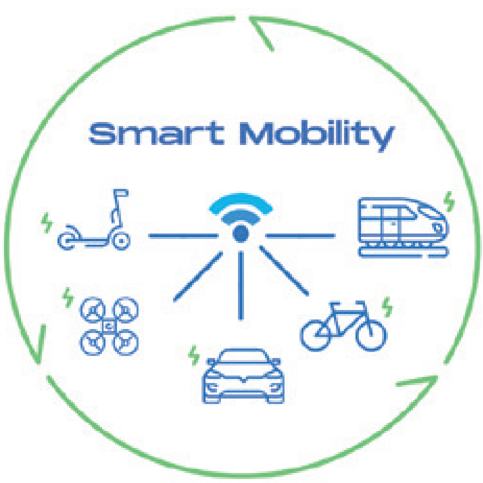

Figure 10. Mobility according to the user

CONCLUSION

BRT is a collective urban passenger transport service that operates at high levels of user performance, especially in terms of travel time and passenger capacity. Mass rapid transit can achieve reduced travel times by providing widely accessible networks, higher speed vehicles, exclusive right-of-way infrastructure, special limited or rapid transit services, efficient fare collection systems, and/or faster boarding and disembarking techniques.

Without UPT, other sustainable and innovative mobility services cannot offer an affordable alternative to car ownership. The problems that occur in cities in the region are traffic jams at peak times, and the biggest problem is the increase in the degree of motorization, which is related to the increase in the number of passenger cars, and therefore much greater congestion, taking up much more space, greater problems than the occurrence of accidents. , congestion and slow movement on important routes through the city, as well as the problem of increasing air pollution from vehicle exhaust systems. The strategy and measures for consolidating and improving the state of the UPT system stated in this paper, as a result of research by cities in the world, can realistically be applied in the cities of the Western Balkans, which will contribute to better passenger transport and increased traffic safety.

LITERATURE

[1] Bojković N., Pejčić Tarle S., Parezanović T., Gladović P., *Mere menadžmenta za održiv saobraćaj: iskustva primene i učinak*, V Međunarodno savetovanje Savremeni trendovi u saobraćaju, logistici i ekologiji u funkciji održivog razvoja, Travnik – Vlašić, BIH, 2014.

[2] Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., Goodwin, P., *Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using Soft Measures*. Transport Reviews, 2008.

[3] Drašković D., Bogdanović V., Gladović P., Davidović S., Jeličanin V., *Savremeni modeli organizovanja javnog gradskog transporta putnika*, 12 Međunarodna Konferencija "Bezbjednost saobraćaja u lokalnoj zajednici", Republika Srpska, Banja Luka, 2023.

[4] European Platform on Mobility Management, *Mobility Management: The smart way to sustainable mobility in European countries, regions and cities*, 2013.

[5] Fujii, S. and Taniguchi, A., *Determinants of the effectiveness of travel feedback programs - a review of communicative mobility management measures for changing travel behavior in Japan*, Transport Policy, 2006.

[6] Gärling, T. and Schuitema, G., *Travel demand management targeting reduced private car use: Effectiveness, public acceptability and political feasibility*", Journal of Social Issues, 2007.

[7] Gladović P., *Strategija održivog razvoja sistema javnog gradskog i prigradskog transporta putnika u Srbiji*, Konferencija „Ka održivom transportu" Zlatibor, 2019.

[8] Gladović P., *Organizacija i upravljanje sistemima za javni gradski transport putnika u gradovima Srbije*, Naučno-stručni skup sa međunarodnim učešćem „Dobra praksa u drumskom saobraćaju i transportu", Beograd, 2022.

[9] Loukopoulos, P., *A classification of travel demand management measures*, In: T.Gärling and L. Steg (Eds). Threats from car traffic to the quality of urban life: Problems, causes, and solutions, 2007.

[10] Stanković M., Gladović P., Popović V., Mišić J., *Uloga urbanog transporta putnika na održivost gradova*, Naučno-stručni skup sa međunarodnim učešćem „Dobra praksa u drumskom saobraćaju i transportu", Beograd, 2022.

[11] Tica S., *Smart Sity I Smart mobility – Od paradigme do koncepta*, Naučno-stručni skup sa međunarodnim učešćem „Dobra praksa u drumskom saobraćaju i transportu", Beograd, 2022.