Formation of priority movement corridors of urban passenger transport

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Abstract. Principles of the formation of priority movement corridors of urban passenger transport (UPT) are considered. The definition of the corridor of UPT priority traffic flow is given, the conditions and requirements for its formation on the road network are considered. A criteria analysis for the formation of such a corridor is given, recommendations on methods of organizing traffic and separating the flow of road transport and UPT are given.

1. Introduction
Transport provides the movement of people, goods and services, movement in the city puts “life” in its infrastructure. On the other hand, the transport sector development leads to an increase in the number of vehicles and, as a result, related problems associated with congestion of the road network, traffic accidents, environmental pollution [1, 2]. These problems can be solved by significantly increasing the role of public mass transport in urban transport systems, the quality of its work. In the face of new services for mobility, such as carsharing, carpooling or ridesharing, etc. the user places high demands on the duration of the trip and the accuracy of adherence to the timetable for mass public transport. These requirements can be met through the use of special methods of organizing traffic in the priority movement corridors of public transport [3].

2. Basic principles of formation of priority movement corridors of public transport
The following arrangements are included in the set of provisional measures due to the fact that the main purpose of organizing the priority of fixed-route transport movement is increasing the speed and regularity of movement [4]:

- Determination of UPT traffic corridors as interconnected sections of SRN (street-road network), providing communication between main centers of generation and absorption of transport demand, serving this demand of routes, where planning, organizational and managerial arrangements are implemented in various combinations to ensure the speed and traffic regularity of UPT specified by the social standard of transport service.

- Estimation of UPT traffic flow and traffic of motor vehicles, their delay time during the day, the volume of transportation and possibility of UPT routes concentration in the corridor, taking into account maintaining their availability and alternative routes for motor transport.

- Determination of the need and feasibility of organizing the priority movement of fixed-route transport on SRN elements based on urban building conditions, technical capabilities and the value of achieved reduction in the total costs of all SRN users.
• Implementation of the movement organization project and, if necessary, the reconstruction of SRN elements to ensure UPT priority.
• Calculation of the capacity of UPT traffic corridor and, if necessary, the adjustment of the fixed-route network, modes of its maintenance and used types of PN.
• Determination of service regimes of enterprises, if this service is carried out from the lane for fixed-route transport movement.

In a modern urban environment saturated with road transport, the separation of transport space between private (commercial) and public passenger transport is of paramount importance. For this purpose, before designing the fixed-route network, it is necessary to select those streets and roads in SRN where space will be allocated for UPT efficient operation [5]. The choice of corridors for UPT should be guided by the following basic principles:
  - maximizing the number of served people;
  - availability of existing UPT lines, educational institutions, shopping and business centers, external transport hubs and subway and railway lines;
  - minimizing the impact on transport flows through the use of flexible measures to ensure UPT priority;
  - minimizing UPT operating costs by increasing speed, ensuring regularity of movement;
  - revenue maximization by increasing the attractiveness of UPT and growth of transportation volumes;
  - minimization of external costs due to improvement of ecology and quality of urban environment.

Taking into account the above factors, UPT corridors are usually built along the main urban highways, since they are already covered by a large number of UPT routes and the main centers of activity and population of the city are concentrated. Distinguishing the UPT corridor along secondary streets, especially in the central part of the city, usually results in the need to close them for transit traffic of motor vehicles, but often this is the best solution for creating a favorable urban environment. The greatest difficulties in this option arise with the maintenance of commercial enterprises, located on the street with a ban on automobile traffic and the need to ban the parking of private cars. Special projects are being developed with the organization of access from other streets or the adoption of a maintenance schedule outside UPT time to solve these problems. But European experience shows that enhancing the attractiveness of urban environment and improving its accessibility increase commercial revenues of enterprises and property prices in UPT corridor [6].

Special methods of organizing movement and UPT work can be grouped into the following recommendations:
• Separation of existing road space between UPT and road transport. This solution requires careful planning and efficiency evaluation, but is the cheapest solution compared to building new paths for UPT.
• To organize priority travel at regulated intersections, it is sometimes sufficient to ensure UPT trips along the nearest allowing traffic light signal, preventing it from being in the queue. A special regulation of the traffic lights work for non-stop trip may be required for high-speed routes. In this case, the reduction of losses for motor vehicles can be ensured by synchronizing the driveway of PN UPT intersections following from different directions in one phase, etc.
• Monitoring the effectiveness of implemented activities with an analysis of the increasing degree in operational speeds of UPT and the possibilities for their further growth. Adjustments of made decisions if they are necessary.
• Permanent monitoring of compliance with restrictions on the use of lanes for fixed-route transport movement by automobile transport.
• The widest possible introduction of non-cash forms of fare payment. Good efficiency is shown by the use of closed stopping points with fare pre-payment at the entrance to it on main routes with large passenger traffic.
Optimizing the location of stopping points allows reducing the total trip time by either increasing UPT operating speed at the expense of reducing the number of stopping points, or due to the optimal ratio between walking time, movement interval and distance of the trip. It is important to reduce the transfer time between routes and between different types of UPT in order to reduce the total trip time. It is necessary to strive for the same height of the landing platform and the floor level in PN cabin, which will reduce time for boarding and landing to ensure maximum safety and convenience for passengers with prams, bicycles and persons with disabilities.

- Eliminating duplication of routes can significantly improve the economic efficiency of UPT system.
- It is necessary to use PN, the design of which provides the most convenient conditions for passengers to enter and exit: wide doors, low floor level in the cabin, etc.

An analysis of the conditions and criteria for the expediency of organizing UPT priority, proposed by Russian specialists, is given in Table 1.

As can be seen from Table 1, most specialists as a criterion for the need to organize priority conditions suggest using the amount of time reduction for all people moving along SRN site. At the same time, various algorithms for calculating the value of reducing the time cost are used.

When forming the corridors of UPT priority traffic, it should be taken into account that the criteria listed in Table 1 may not meet the requirement of providing UPT priority throughout the corridor. Their use is advisable only to identify the main directions for the formation of UPT priority movement corridor.

Foreign experts pay little attention to the traffic conditions if the flow of passengers using UPT is significant. For example, in the UK, it is recommended to organize the UPT priority with a stream of more than 50 units of PN UPT per hour or 2 thousand passengers per hour. [7]. Concretization of measures depending on the intensity of passenger traffic is given in Table 2.

The criteria for organizing the priority of UPT movement adopted in South Korea are listed in Table 3. [8].

An effective method of accelerating the passage of route vehicles is the allocation of transport space, which is prohibited from driving other vehicles. It is possible to allocate one or several lanes to do this, in order to ensure the smooth movement of UPT by means of ETS or to prohibit the movement of cars on the street depending on the specific conditions. Comparison of different lanes placement for route vehicles is given in Table 4.

As a rule, a street or its section for only UPT movement is allocated in the central part of cities, park zones, etc., where it is necessary to increase the urban environment comfort or is impossible to combine the lane for fixed-route vehicles movement with the movement of cars, for instance, due to a limited street width. Measures are taken to improve the movement of pedestrians and cyclists in such streets.
### Table 1. Criteria for priority need of UPT

| Author                          | Criteria                                                                 | Source Name                                                                 |
|--------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------|
| S I Smirnov                     | Reducing the total cost of delays for various types of PN and passengers | Smirnov S I 1984 Improving the priority movement organization of means of fixed-route passenger transport in cities: abstract, Dissertation, Moscow, 1984 |
| V I Shleikov, A M Kostin, Iu V Ignatev | Traffic intensity of PN UPT 30-40 units/h in one direction               | Shleikov V I, Kostin A M, Ignatev Iu V 1991 On the relationship between the modes of movement of mass passenger transport and traffic flows. Schemes and projects of the movement organization in cities in the conditions of territories self-government, reports theses of scientific pract. seminar, (Sverdlovsk: Komvaks) p. 73 |
| Iu D Shchelkov                  | The intensity of the PN UPT movement is more than 40 (the right-most designated lane) and more than 80 (the left-most) and the intensity of vehicles movement is not more than 800 units/h per lane. | Shchelkov Iu D 1995 Organization of traffic in cities: method. allowance (Moscow: SRC SAI MIA of Russia) p. 143 |
| O V Popova                      | Reduction of the total time spent by road users and passengers in SRN site under consideration | Popova O V 2003 Development of a planning methodology for priority public terrestrial transport movement, Dissertation, SPb., |
| A A Antonova                    | Reduction of losses from the total delay of vehicles                     | Antonova A A, Mikhailov A Iu 2007 Criteria for identifying the lanes for priority movement of fixed-route passenger transport Scientific materials of the XIII Int. Sci.-Pract. Conf.: “Socio-economic problems of the transport system development of cities and zones of their influence” (Ekaterinburg: AMB Publishing House) pp. 79-86 |
| M R Iakimov                     | Depending on the value of difference in total delay time for all traffic participants when organizing a dedicated lane for UPT and without selecting a lane | Iakimov M R 2011 Methodology for justifying the expediency of isolating separate lanes for public transport on street-road network of a large city Bulletin of MADI 2(25) 90–95 |
| A M Belova                      | Total loss of UPT time passengers                                       | Belova A M 2012 Fundamentals of planning methodology for the organization of dedicated lanes for public transport Bulletin of civil engineers 6(35)123–129 |
| F V Akopov                      | Reduction of the total time spent on movement participants               | Akopov F V 2012 Problems of dedicated lanes organization for the movement of terrestrial urban passenger transport Problems and main directions of modernization of Moscow region transport complex: col. of sci. papers of MADI 83–89 |
| A. V. Kostsov                   | Amount of passenger traffic in UPT, taking into account the level of street load during the day | Kostsov A V 2012 Design of urban main streets, taking into account the priority movement of terrestrial public transport along separate lanes, Dissertation |
Table 2. Recommendations on measures composition to ensure UPT priority

| Passenger traffic, thou. pass./h | Priority measures |
|---------------------------------|-------------------|
| Less than 2                     | Selected measures at high traffic intersections |
| 2-8                             | Highlighted lanes and priority crossing of regulated intersections with high traffic intensity |
| 8-15                            | Highlighted or isolated lanes and priority crossing of regulated intersections |
| More than 15                    | Isolated lanes and priority crossing of regulated intersections Closed stopping points with advance fare payment |

Table 3. Minimum criteria values for organizing separate lanes for UPT traffic in South Korea

| Number of lanes in this direction | Bus traffic intensity, un./h | Passenger traffic, pass./h | Separate lane type |
|-----------------------------------|-----------------------------|---------------------------|-------------------|
| 3                                 | 60                          | 1800                      | Right lane in the direction of traffic flow |
|                                   | 100                         | 3000                      | Right lane in the direction of traffic flow |
|                                   | 150                         | 4500                      | Right lane in the direction against the general traffic flow |
| 4                                 | 100                         | 3000                      | Right lane in the direction of traffic flow |
|                                   | 150                         | 4500                      | Right lane in the direction of traffic flow |

* - in the area of stopping points, additional overtaking lanes are organized

Table 4. Features of providing UPT priority at midpoint crossing

| Method                               | Advantages                                      | Disadvantages                                                                 |
|--------------------------------------|-------------------------------------------------|-------------------------------------------------------------------------------|
| Street or its site for UPT and pedestrian movement only | Simplest organization | Need for alternative ways to drive cars |
| Isolated path for UPT traffic        | Formation of a comfortable urban environment    | The difficulty of servicing residential and commercial buildings from this street |
|                                      | Provides the highest speed and safety of the movement | Requires the allocation of space outside SRN or the construction of overpasses and crossovers (tunnels) |
| Right lane for fixed-route transport | Simplest organization | The difficulty of organizing the right turn for main stream |
|                                      | Minimum capital costs | Elimination of a stop and car parking |
|                                      | Preservation of parking | The need to introduce a special service mode of enterprises, which occurs with SRN |
| Second right lane for fixed-route transport | The ability to service enterprises with SRN | Capital expenditures need for reconstruction of the roadway to accommodate stopping points |
| Left lane for fixed-route transport  | Possibility of increased speed | Crossing of the lane for fixed-route transport by cars for arrival and departure from the parking |
|                                      | Preservation of existing conditions for access to objects along SRN | The difficulty of organizing the left turn for the main stream |
| Lane to meet the flow with one-way traffic (counter lane) | Simplest organization | Capital costs need for the organization of stopping points and access to them |
|                                      | Minimum capital costs | As a rule, the absence of the possibility of organizing a lane for fixed-route transport in the direction of main traffic flow |
An isolated way for UPT movement is realized when it is necessary to ensure message high speed. As a rule, it is combined with facilities that allow avoiding the intersection of traffic and pedestrian flows (fences, overpasses, tunnels, overpasses, elevated or underground pedestrian crossings), therefore, requiring increased investment. This method is often used in tram systems. For the movement of PN wheel, the isolated path is equipped with side stops along which the guide rollers move, stabilizing the movement of the bus or trolleybus.

As a rule, the right lane is allocated in the existing transport infrastructure on narrow roads with frequent stopping points, and, consequently, not high operational speed. Generally, such a lane is organized in existing sections of the street-road network; therefore the possibilities of its physical (constructive) separation from the general carriageway are limited. In this case, a low curbstone or flags are used. These methods of lane separation allow, if necessary, driving into the lane at any place or leave it. The use of rubber delineators showed that they are not durable in operation and are easily damaged when a motor vehicle hits or during winter street cleaning.

3. Conclusion
Colossal problems of cities associated with ensuring the population mobility and the sustainable economy functioning can only be solved through the development of urban public passenger transport. This places high demands on the quality of its work. In assessing the quality of public transport, the population gives first place to the speed and regularity of transport. These requirements can be met only by forming UPT priority traffic corridors, which should use special traffic management methods.

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