Increasing the efficiency of urban public transport (UPT) services through the use of multimodal transport technologies

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Abstract: The present paper investigates the problem of providing integrated transport services to passengers traveling from suburbs to the city center. Options for the organization of the route "From the resort of healing waters - Tashkent railway station" will be studied. By using the multimodal transportation technology, and by taking an account the following demands like the timetable, comfort, the price of transportation of passengers, the possibility of independent mobility to the different destinations will be organized. The article proposes a set of measures of improving public transport services on the routes in suburbs or from suburbs to the city center.

1. Introduction
The uninterrupted operation of the transport system is an important factor in the sustainable socio-economic development of the city, the suburbs in general. Passenger transportation is the main task of urban public transport (UPT), which determines the living standards of the urban population and an unhindered environment for the development of society.

As it was stated by researcher Safronov [1] “... the city’s transport network is part of the life support system of this area and has infrastructural significance”.

One of the ways to improve the quality of transport services to the population is to create modern conveniences by reducing the total time and cost of long-distance trips through the integrated use of all available modes of transport and the creation of an integrated transport system [2, 3].

The expansion of urban areas and the increase of their influence, employment, education and cultural recreation are leading to an increase of intercity passengers.

Therefore, there is a need to integrate the transport system, which serves the transportation of passengers in the suburbs and areas close to the city, into the UPT system.

By this, it will be possible to raise the efficiency of urban public transport. It should be noted that passengers are often transported from the suburbs by long-distance bus, minibuses and cars to the city center or vice versa to the last destinations located around the city. This also has a negative impact on the complexity of the problem, such as grows of traffic-jam in the city center, air-pollution and increase of CO₂ emission, and the lack of parking spaces [4, 5, 6].

In large agglomerations, on suburban roads the organization of regular passenger traffic is an important tool in combating "congestion", which helps to reduce inefficient costs for the development of private transport infrastructure and increases population GDP’s productive time [7].

4.75 million passengers move in Tashkent and around Tashkent per day. 1.45 million (30%) of them uses UPT, while the remaining 3.3 million passengers use the service of illegal taxis. (there are about 10-20 thousand illegal taxis) [8].
In Tashkent, cars are socially important mode of transport, but due to the rise of the amount of cars in the city centers, traffic jams are also increasing. Traffic congestion can be alleviated through the establishment of modern road infrastructure. However, the amount of toxic gases emitted by cars in the city center equal to 411.59 thousand tons per year, from which 383.08 thousand tons are belong to exhaust gases. This figure has increased by 37% in the last 10 years, negatively affecting the urban ecosystem [8].

This situation can be resolved by reducing the number of cars in the city and attracting the population to the use of the UPT system.

The efficiency of “Toshshahartransportxizmat”, the largest passenger transport company in Tashkent, is declining due to insufficient government subsidies and inefficient use of modern equipment and technologies. By the end of 2019, a total of 155 regular passenger routes were attached to the community, and 1249 buses of various capacities served passengers, distributed in 8 palaces. The coefficient of technical readiness is 0.76, while the average age of vehicles in bus depots is 6.1 (average norm - 5 years) years. 19.2 per cent of the vehicles in the community returned to the stations from the routes due to technical failure. Due to these negative factors, the coefficient of use of stations in the society is 0.72, which leads to a decrease in the quality of transportation [9].

It is possible to increase the flow of passengers by attracting new equipment and technologies. To do this, there is a need to ensure the competitiveness of the UPT, taking into account the changing needs of passengers.

The decrease in the share of passenger transport in buses in the market of UPT services is primarily due to the lack of quality of passengers’ services and absence of a single transport system in coordination with other private carriers (direct taxis) or other modes of transport (metro, railway).

2. Methods

Assessing the advantages and disadvantages of different modes of transport, we will consider the issue of providing the urban area with UPT. This can be achieved by studying the existing transport infrastructure in the urban area, determining which transport is preferable to use, and developing a strategy that prioritizes it. We will look at all possible options for moving around the city from the city center to different types of transport routes (Figure 1).

![Figure 1. Types of transport and connections available in and around Tashkent](image)

In the formation and implementation of any system of multimodal transport technologies in long-distance and suburban passenger communications, it is necessary to take into account the basic
principles of its organization. Firstly, the applied innovative technologies should be aimed at increasing the efficiency of transportation, fully meeting the needs of passengers in transport, reducing the total travel time and providing quality service. Secondly, it should cover the economic, social, organizational and structural interests of all carriers [10]. This can be achieved by integrating (connecting) subway or rail transport (electric) to a single network, covering the remaining areas of directional taxis, cars (taxis) and buses if other carriers are available in certain limited areas of the city. In this case, the coordination of the work of all carriers on the basis of multimodal transport technology is highly effective. In the scheme of integration of all modes of transport, passengers will be able to choose the mode of transport to their destination, which will increase the popularity of UPT and create the basis for efficiency.

In passenger transport, multimodal transportation technology means using multiple modes of transport to travel to a destination with one ticket, under the responsibility of one carrier. This transportation technology allows passengers to take advantage of all modes of transport. With the help of multimodal transportation technology, passengers can organize a trip from one destination to another, depending on their needs and capabilities. You can choose one of the following methods:

- minimum travel time;
- the cheapest price;
- convenient and comfortable conditions of transport;
- the optimal ratio of indicators.

As an example, we took the “Healing waters resort” 10 km far from Tashkent, as the “point A” and “Tashkent Railway Station” which is located in the center of Tashkent as the “B-point”. The scheme of multimodal transportation technology for travel from the city to the city center using various mode of transport is as follows (Figure 2).

For convenience, taking into account the existing infrastructure, we have divided the route into three segments (sections).

1-st segment- Out of town
2-segment- City edge
3-segment- City center.

The main features of all possible ways of organizing passenger traffic in each segment are given in Tables 1-4.
Table 1. Description of methods of organizing traffic on the 1st segment

| Travel method | Cost, sum | Time spent on the road, minutes | Levels of comfort, points |
|---------------|-----------|--------------------------------|---------------------------|
| 1             | 7000      | 15                             | 5                         |
| 2             | 2000      | 25                             | 4                         |
| 3             | 1500      | 35                             | 3                         |
| 4             | 2000      | 55                             | 1                         |
| 5             | 30        | 30                             | 3                         |

Levels of comfort, conditional unity in points: 1-badly, 2-lower, 3-satisfactory, 4-middle, 5-higher.

Table 2. Description of the methods of organizing traffic on the 2nd segment outside the city

| Travel method | Cost, sum | Time spent on the road, minutes | Levels of comfort, points |
|---------------|-----------|--------------------------------|---------------------------|
| 1             | 7000+5000 | 25                             | 4                         |
| 2             | 2000      | 30                             | 4                         |
| 3             | 1500      | 45                             | 3                         |
| 4             | 2000      | 65                             | 1                         |
| 5             | 30+15     | 35                             | 4                         |

Table 3. Description of the methods of organizing traffic on the segment outside the city

| Travel method | Cost, sum | Time spent on the road, minutes | Levels of comfort, points |
|---------------|-----------|--------------------------------|---------------------------|
| 1             | 12000+10000 | 25+35                          | 60                        |
| 2             | 2000+1500   | 30+25                          | 55                        |
| 3             | 1500+1500   | 45+25                          | 70                        |
| 4             | 1500+1500   | 45+45                          | 90                        |
| 5             | 15000      | 25+25                          | 50                        |
| 6             | 2000       | 15+45+15                       | 75                        |

3. Results and Discussions
By analyzing the obtained tables, we will be able to choose the transportation options that meet the different requirements of passengers.
Table 4. A description of all selected routes

| Travel method                                                                 | Cost, sum | Time spent on the road, minutes | Levels of comfort, points |
|-------------------------------------------------------------------------------|----------|-------------------------------|--------------------------|
| 1. Construction of a multimodal transportation route on the criterion of "Price" | 1500+1500| 3000                          | 45+25                    | 70                       | 4                           |
| Description of the alternative route.                                        | 1500+1500| 3000                          | 45+45                    | 90                       | 3                           |
| 2. Constructing an optimal route according to the “Convenience” criterion.    | 15000    | 15000                         | 25+25                    | 50                       | 4                           |
| Description of the alternative route.                                        | 12000+1000| 22000                        | 25+35                    | 60                       | 3                           |
| 3. Selection of multimodal transport routes on the criterion of "travel time". | 2000+1500| 3500                          | 30+25                    | 55                       | 4                           |
| Description of the alternative route.                                        | 2000+2000| 4000                          | 30+25                    | 55                       | 4                           |
| 4. Construction of a balanced route                                           | 2000+1500| 3500                          | 30+25                    | 55                       | 5                           |

a) As the best option for the "Price" criterion, passengers are advised to choose the following route (Figure 3).

Figure 3. Construction of a multimodal transportation route on the criterion of "Price". Travel time: 5+35+5+25+5, minutes, total 70 minutes. Cost 1500+1500 sum, Average price of convenience 3000 sum. Average comfort levels 4 points.
As an alternative to the price criterion: Travel time $5+35+5+45+5$ total 90 minutes. Cost $1500+1500$ sum. Average price of convenience 3000 sums. Average comfort levels 3 points.

b) It is recommended to choose the following direction as the best option for the “convenience” criterion (Figure 4).

The cost is as follows: $12000+1500$ total 13500 sum. The average price of convenience is total 13500 sum. Travel time: $35+5+25$ total in minutes 65 minutes are spent. Average comfort levels 4 points. It promotes the use of UPT for commuters traveling around the city, making it easier for them to park their cars outside the city.

In this case, the car may be more convenient, but it will cost the passenger a total of 60 minutes and 23,000 sums. Average comfort levels 3 points.

c) The best option for the criterion of "travel time" is a taxi from this direction to the subway and from the subway to the destination (Figure 5).

It is also possible to use the subway after a car to reduce travel time, but this method can be inconvenient due to the fact that it takes time to walk to the subway after leaving the car in the parking...
At the same time, the travel time in the method is $25+5+25+25$ for a total of 55 minutes. The cost of this trip will be $2000 + 1500$ for a total of 3500 sums. Average comfort levels 4 points.

d). The cost of travel has a great importance to passengers, but observations show that the option of choosing a cheaper route leads to fatigue of passengers due to the low level of convenience. The most convenient route is very expensive. Therefore, a balanced trip can be created by following the principle of "door to door" multimodal transport technology (Figure 6).

As it can be seen from Figure 6, the efficiency of the use of route modes of transport in the UPT as the main link for passengers in the combination of addresses is high in all respects. However, the main advantages of overground and underground metro can be recognized as the main connecting rib of multimodal transport. The advantage of this type of transport is the regularity, high level of security, low prices and convenience. An important disadvantage of subway transportation to the center is the lack of capacity for door-to-door transportation [11].

At the same time, in order to give priority to the use of UPT types, it is necessary to involve bicycle transport as a mode of multimodal transport technology, with the establishment of bicycle rental outlets at all transport crossings in UPT. At the same time, it is advised to the city administration designate the city center as a special "green zone" and take measures to make it paid or restrict the entry of cars there. There is a need to establish bicycle rental offices in front of all institutions, organizations, museums, theaters in the region, as well as in front of special stations of the UPT. At the same time, cycling infrastructure will be created throughout the region. Specially equipped bicycle lanes as a "cultural route" aims to attract the city to local and foreign tourists.

In this case, trips we recommend will allow passengers to travel by using the multimodal method "door to door". Here, the total cost for the multimodal route is: $2000 + 1500 = 3500$ sums. Passengers within the green zone will be provided with a free service for up to 15 minutes if they present a ticket for UPT. Special bikes near the destination will need to be handed over to the rental office within 15 minutes. The average cost of convenience is 3,500 sums. Travel time: 50 minutes. Average comfort levels 5 points.

To speed up the door-to-door transportation of passengers, it is possible to use cars. However, their number is growing disproportionately compared to the infrastructure being built for cars in the city center. The rise the amount of cars in the city leads to traffic-jams, lack of parking spaces, excessive
noise, and inconvenience effect negatively on environment. In this situation, the role of alternative transport to light road transport in the city center can be highlighted by the development of cycling infrastructure. Through the development of cycling infrastructure, passengers will be able to go "door to door". Enriching multimodal transport technologies in the UPT with the infrastructure of bicycle transport will allow providing high convenience and speed of passage within the framework of this innovative project.

4. Conclusions

Thus, by using multimodal systems, passengers will be able to select independently the mode of transport by choosing the price of the desired route, the time spent on it, the convenience created and other features.

The future of cities depends on the living standards and culture of the city's population, adapting to it with a positive acceptance of innovative techniques and technologies. Their adaptation will determine the future state of the urban environment, the level of development of passenger transport links in all types and forms.

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