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Research of Downtime of Urban Passenger Transport Waiting for Additional Passengers at Stop Points

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Abstract. This article explores a new factor affecting the operation of urban passenger transport stopping points: "downtime." The study investigates the reasons contributing to the downtime experienced by urban passenger transport at stopping points while waiting for additional passengers to board. Observations of downtime were conducted at the busiest bus stops in Osh. By taking this factor into account, the research aims to provide a more accurate assessment of the capacity of urban passenger transport stops.

INTRODUCTION

Modern urban passenger transport (UPT), on the quality and stable operation of which many aspects of urban life depend, ensures the economic development of cities and the formation of comfortable living conditions for the population. The accessibility and quality of urban passenger transport largely determine the real standard of living of the population and the social climate, and a decrease in its attractiveness leads to the use of personal cars by passengers, which hurts the environmental situation of cities.

The main goal of organizing the urban transport system is to minimize transport costs, save time, and increase safety and comfort when transporting passengers. The real situation of the city, where passengers are transported mainly by trolleybuses and minibusses, shows that the level and quality of public transport services are still unsatisfactory and do not meet the needs of the urban population. This discrepancy is primarily due to non-compliance with traffic intervals, illegal parking of vehicles in prohibited places, overcrowding of vehicles, non-compliance with standard stopping times at intermediate and final stops, and violation of traffic safety rules. All of these are very serious problems for urban transport and require immediate solutions. Effective use of working time, compliance with schedules and traffic modes, travel distances, speed of passenger transportation, optimization of costs while ensuring minimal transportation time, proper use of buses, high quality of service, and regularity of vehicle traffic on the route are feasible with the proper organization and use of passenger public transport [1].

Osh is the second largest city, which is located in the south of Kyrgyzstan. The city's population is 302,100 thousand people. The population density is 4935 people/km². To date, a system of passenger public transport has developed in Osh, which includes a municipal transport organization (vehicles - buses, trolleybuses) and numerous private entrepreneurs - owners of vehicles (mainly minibusses).

A large transport hub has been formed in the city of Osh, in which all major types of transport operate, including the urban passenger transport system. The municipal enterprise Trolleybus Management owns 31 trolleybuses, of which 23 are TrolZa-5275.03 Optima, which can accommodate 100 people, with 27 seats, 8 ZIU-682GO, which can accommodate 100 people, and have 30 seats. There are 31 trolleybuses on the city routes on two lines (No. 1, No. 2). The Osh City Municipal Motor Transport Enterprise operates 30 medium-capacity buses made in China, which run on two routes (No. 12, No. 13). Also, more than 20 limited liability companies are connected to the city's routes. The

number of minibuses operating on 52 routes exceeds 1000, owned by the Passenger Transport Agency. Minibuses serve city residents, including isolated new buildings and residential areas, where the operation of buses and trolleybuses is impossible due to specific conditions.

MATERIALS AND METHODS

The city route network is characterized by a high degree of duplication, when up to 30 or more different routes can pass through one section of the road network. Vehicles of the Passenger Transport Agency use, as a rule, a large number of low-capacity rolling stock (in the city of Osh this is most often Mercedes-Benz-207 (capacity 13 seats) Mercedes-Benz (Dolphin) brands (18 seats)) and operate without a schedule (instead, the so-called “interval” strategy is used). Under these conditions, both the route network itself and the UPT stopping points experience additional load. It is expressed in the insufficient capacity of stopping points (SP), which are overloaded due to high traffic intensity. For example, at the Ramazan Shopping Center stop point, you can observe up to 10-15 minibuses simultaneously serving at the same time during rush hour. As a result, at such stopping points there are constant traffic accidents, traffic stops in the second and even third row, and other violations that negatively affect both the efficiency of organizing passenger transportation and traffic safety and road capacity. Thus, research aimed at improving the efficiency of stopping points appears to be very relevant. In the course of a comprehensive study of stopping points in the city of Osh [2], a factor that had not previously been studied in the passenger transport system of Kyrgyzstan was identified, affecting the capacity of stopping points - idle time of route vehicles at stopping points with open doors to wait for additional passengers - “downtime while waiting”.

It is known that the capacity of a stopping point is determined by the formula:

$$P_{on} = 3600 \cdot \frac{K_{sp}}{t_o}$$

where: K_{sp} – number of stopping places at the stopping point; t_o – time of occupancy of a stopping point by one downtime unit.

When calculating the occupancy time of a stopping point, we will proceed from the fact that the capacity of the stopping point will be maximum if the vehicle approaches the stopping point at speed V by the value of the safety gap $L_s=L_p$ at the moment when the previous vehicle moves away from the stopping point by the distance, equal to the length L_p . On the path L_p , the vehicle slows down and stops at a stop sign.

$$t_o = t_t + t_{od} + t_{pe} + t_{cd} + t_{vsp}$$

where: t_t – braking time; t_{od} – time spent on opening the vehicle doors (according to experimental data, $t_{od} = 1.5-2$ seconds); t_{pe} – time for passenger exchange; t_{cd} – time spent on closing the vehicle door after boarding and disembarking passengers ($t_{cd} = 2-3$ sec); t_{vsp} – time to vacate the stopping point [2].

In work [3], it is proposed to include another delay, “downtime while waiting,” that occurs when a vehicle arrives at and departs from stopping points to the busy time of a stopping point t_o .

The studied factor “downtime while waiting” is located between the time of boarding and disembarking of passengers and the time of closing the doors:

$$t_o = t_t + t_{od} + t_{pe} + t_{ewf} + t_{cd} + t_{vsp}$$

As the study showed, “downtime while waiting” is observed to one degree or another at 9.3% of all studied stopping points (or 6% of the total number of stopping points in the city of Osh). It would seem that this is a small percentage, but it includes all the key stops in the city. The reason for the appearance of this factor is high competition in the fight for passengers.

This type of delay is characteristic, first of all, of minibuses, therefore, in the following, all results are presented specifically for this type of vehicle, although it can periodically be observed in large-class municipal buses that operate on a schedule.

As the research results showed, downtime often exceeds the sum of all other delays combined.

RESULTS AND DISCUSSION

To improve the quality of service on bus routes in Osh, passenger flows were analyzed using the natural tabular method. In this case, the visual method of examining passenger flow was used, which is carried out by special observations located on the bus. Using observation data, the number of exiting and entering passengers at stopping points is determined. This method of determination allows you to obtain data on the filling of buses and the regularity of their movement, directions, and hours of the day.

To analyze the passenger flow of the city bus route, route No. 107 was chosen. This route is one of the most popular routes in the city since all the most important stops in the city are located on this route.

About 30 routes enter the line every day. Each of which carries out 4 flights. The interval time is from 4 to 5 minutes.

The histogram shows the volume of passenger traffic during the day at certain time intervals at each stop. The largest number of passengers entering and leaving is observed at the stop near the Central Market bazaar: 17% of passengers' board and 20% disembark at the stop. The busiest bus stops on the return route are stops near the Erdem mosque, bus station, and Osh district. The highest passenger flow is observed at lunchtime in 12-14 hours. Research shows that passenger pick-up and drop-off volumes always increase at stops near shopping centers, businesses, health centers, universities, and educational institutions. A similar survey of passenger flows was carried out on another 15 routes in the city.

To determine at which stopping points of downtime is possible, let's look at the results of a study of passenger flows on route No. 7 [3]. Figure 1 shows a histogram of the distribution of incoming passengers based on the results of one weekday.

As can be seen from the histogram, the Kuligova stopping point is strategically important for this route, because the number of passengers willing to use the services of this route is more than 2 times higher here than at any other stopping point. Accordingly, the probability of significantly increasing the occupancy of a vehicle by performing downtime is maximum here. A similar situation is observed on this route in the opposite direction: downtime will be observed at the "Central Market" stopping point, which is confirmed in practice.

Thus, we can conclude that air defense is present at those stopping points on the route where there is a significant increase in the intensity of passenger arrivals compared to other stopping points. As a result of a comprehensive study of stopping points in the city of Osh, it was revealed that for downtime, drivers of the corresponding routes choose one, two, maximum of three key stopping points, since additional time delays at a larger number of stopping points can reduce the number of bus turns per day, which will hurt profit.

It is also worth noting that the same stopping point for different routes can be either with or without "downtime while waiting". For example, for route No. 141, the "Central Market" stop is the most important; downtime is observed there for all minibuses on this route. On the other hand, for route No. 151 the same stopping point is one of the final points of the route and mainly only passengers are disembarked there. Therefore, minibuses on route No. 151 are not observed at the "Central Market" stop point of the downtime.

One of the most important factors influencing the downtime is the occupancy of the rolling stock. When monitoring the air defense, it was noted that with low occupancy of the cabin, the minibus sits at the stopping point for a noticeably longer time than with a high degree of occupancy.

Preliminary observations confirmed the factors influencing the value under consideration, i.e. for "waiting downtime" specified in [3]:

1. Intensity of passenger arrivals at the stopping point. The higher the intensity, the higher the likelihood that additional passengers will board within a certain period.
2. Vehicle movement interval. Limiting factor for downtime. Minibuses try to leave the stopping point before the arrival of the next minibus on the same route.
3. Human factors associated with the individual characteristics of minibus drivers.
4. The number of passengers who boarded the minibus during the downtime. If the driver picks up a certain number of passengers, he can immediately leave the stopping point.
5. Drivers often stand idle at bus stops under the pretext of collecting money for travel from passengers. The presence of a conductor in the cabin can affect the faster departure of the bus from the stopping point since payment for the fare will be collected while it is moving.
6. Arrival of a bus duplicating the social route. In this case, the minibus can immediately leave the stopping point to "collect" paying passengers for the rest of the route.
7. "Displacement" of an idle minibus by other buses. A situation when a minibus arriving at a stopping point again cannot find a place to pick up and disembark passengers and begins to sound a departure signal for those minibuses that are idle at the stopping point.
8. "Alignment" of the interval between minibuses of the same route at key stopping points. A proposal has been put forward that minibus drivers could "even out" the headway between minibuses on their routes by allowing extra idling at key stopping points.

9. Other random factors: lack of space at the stopping point for additional downtime, inability to leave the stopping point due to its congestion, passengers' dissatisfaction with long downtime, the driver's desire to quickly reach the final stop, for example, for lunch or at the end of a shift, etc.

Based on the above, we can conclude that air defense is a random variable since it is influenced by many factors, including the great role of the "human" factor [4]. To identify the most important factors influencing the value under consideration and the patterns of its change, a full-scale experiment was conducted.

During the experiment, the entire process of functioning of stopping points was recorded: the arrival of a minibus, the opening, and closing of doors, the moment the air defense began, the number of passengers entering and leaving, the occupancy of the cabin, etc.

In this experiment, the most important issue was determining the moment of the start of air defense, because it is closely related to the time of boarding and disembarking passengers and is not always explicit. The start of air defense was recorded at the moment of completion of boarding of those passengers who were already at the stopping point waiting for a minibus on the corresponding route. As soon as the last of these passengers entered the bus, the moment the air defense began was noted and the occupancy of the minibus was recorded. The end of air defense is the moment the doors close or the minibus begins to depart from the stopping point [5-8].

The experiment was carried out at six bus stops in the city. The stop point "Ramazan Shopping Center" was most fully explored, from 7 a.m. to 10 p.m. At other stopping points, the experiment was carried out during rush hours.

TABLE 1. Statistics of researched stopping points.

Stopping points	Int. passenger entry person/hour.	Int. RV movements units/hour	Average occupancy of a route vehicle, persons	Average downtime, sec.	Those who entered the SP for air downtime, people/hour	Average downtime for 1 additional passenger, sec
Mount Suleiman	338.0	134.0	30.2	34.52	67.0	34.5
Central Market	139.5	74.0	25.5	40.9	21.5	112.23
Ramazan Shopping Center	404.3	88.6	21.35	48.6	71.0	81.5
Kelechek	190.3	156	16.55	79.5	71.8	93.1
School named after Makarenko	132.7	90.0	27.61	30.62	33.0	61.25
Aravan	274.0	66.0	10.0	82.67	137.0	40.2
Erdem Mosque	291.0	91.2	29.45	32.57	61.4	32.57

A preliminary analysis of data from experimental studies showed that the air traffic area is significantly influenced directly or indirectly by such factors as occupancy, intensity of passenger arrivals, route vehicle traffic intensity, traffic interval, deviations from the given traffic interval, and passenger exchange of the air transport center.

According to the results of the study (Table 1), the average waiting time for one additional passenger ranged from 30 seconds to almost 2 minutes. Thus, air defense within a minute at such OPs as Erdem Mosques, school named after Makarenko, on average, will attract only two additional passengers onto the bus, which is very little, but minibus drivers still go for it [9-13].

At the Ramazan Shopping Center air defense during the morning and evening rush hour changes slightly. Thus, the passenger flow of a particular stop does not affect the air defense time, but only affects the very fact of whether there will be air defense at a given stopping point or not. Route vehicle drivers know from experience where passenger traffic is greater and plan air defense at a specific stopping point in advance, regardless of how it changes during the day.

During a decline in passenger traffic, the occupancy of the route vehicle decreases. As a result, the dependence of air defense on passenger traffic is incorrect. The fact about the influence of the traffic interval, deviation from it, the number of passengers entering during the air defense, etc. was also not confirmed.

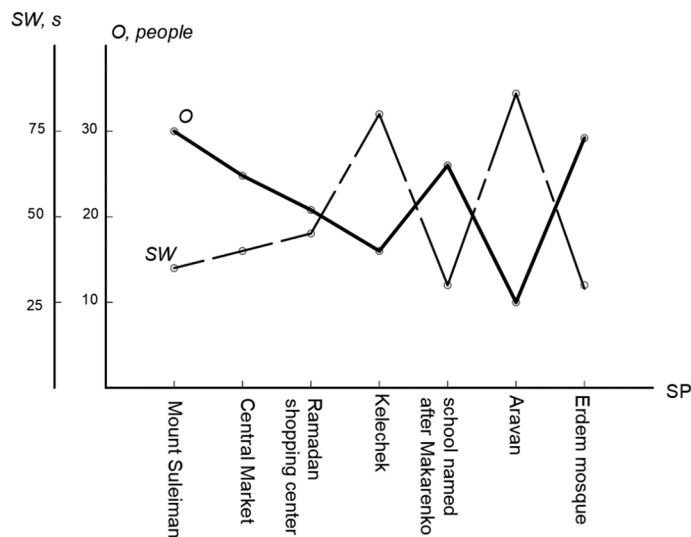


FIGURE 1. Dependence of downtime waiting for additional passengers (SW) on the average occupancy of the bus (O).

CONCLUSION

Thus, in this work, a new factor in the functioning of stopping points of urban passenger transport was investigated - “downtime while waiting”. An inverse relationship between “downtime while waiting” and the occupancy rate of route vehicle was revealed. Since air defense time most often exceeds in magnitude all other route vehicle delays at stopping points, the study of the influence of air defense on the throughput of a stopping point and, accordingly, on the efficiency of organizing passenger transportation was important.

One of the ways to improve the efficiency of organizing passenger transportation in the city of Osh is to increase the capacity of stopping points, which involves reducing such an indicator as “downtime while waiting” for passengers.

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