Possibilities of forecasting bus average speed on city route

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Abstract. Average bus speed analysis plays a key role in transit operations planning. Such analysis makes it possible to perform forecasting more accurately, especially taking into account the possibility of automated monitoring of a large database. The paper offers a new approach to forecasting the average bus speed on the city route, taking into account the “skip-stop” method. For the convenience of data processing and comparison, four main time periods were selected. The corresponding array of data was organized for each of time periods in the software environment “Statistica”. The conducted analysis characterizes a significant difference in the values of the speed indicators. It has been established that the change in speed leads to non-compliance with traffic schedules and indicates difficult traffic conditions during peak hours. It was studied and compared the deviation of the speed from the average value during the day. It is proposed a new scenario for the operation of buses with skipping stops in the hour when the speed on the route is lower than the average value. According to the results of speed modeling in peak years, it shows the possibility of reducing the negative effects of speed on the schedule. This forecasting of the average buses speed will enable system operators to more accurately design traffic schedules and minimize disruptions in them.

1 Introduction

One of the important factors that significantly affects the quality of passenger service in the city's public transport system is compliance with bus schedules. First of all, this is relevant for long public transport routes that pass through various functional zones. Especially when the city has a historical part, where it is not possible to implement measures to re-plan the street-road network. Therefore, it becomes obvious that ensuring compliance with the same operating speed of buses along such a route is not an easy task [1].

This is a long-standing problem affecting the reliability of public transport services and can be considered a behavioral property of the network. This affects regularity and disrupts bus service and leaves users with a frustrated travel experience. Although public transport is encouraged as the most environmentally friendly mass transport.

Advances in information and communication technologies are opening up new opportunities for transit operators to limit this impact and provide more reliable service. The procedure is applied to a real test case with encouraging results. It opens up the possibility of its inclusion in a decision support system to help operators (drivers) take corrective actions during the day, improving the operation of the bus service [2].

In this work, the goal was to investigate the speed of communication on the route on working days from the starting point (on the periphery) to the final point (city center).

It was chosen for research radial route # 3A in Lviv: Terminal A - shopping center “King Cross Leopolis” (southern city); Terminal B - square “Rizni” (city center). The length of the route is 9.26 km in the forward direction and 9.28 km in the reverse direction with 17 stops in both directions. According to the route passport, the duration of the connection is regulated for both directions - 30-60 minutes. The route is served by 14 M3 class buses.

This work is organized as follows. Chapter 2 provides a brief review of the literature on the subject of research. In section 3, it is analyzed the average speed of buses on the route and it is proposed an option to increase the average speed in peak periods. Chapter 4 provides conclusions and further research development.

2 Literature Review

The speed of connection on city bus routes affects the quality of service provision in the public transport network. A decrease in traffic speed leads to non-compliance with traffic schedules and a decrease in the productivity of public transport.

Thus, in work [3], three approaches are proposed to increase the productivity of the public transport system: “skip-stop”, “deadgading” and “short-turn”. As a result, it was found that using the “skip-stop” method, it is possible to reduce the average length of a passenger's journey by 22% and the average length of a passenger's wait by 33%. The “short-turn” method allows reducing the average travel time by 21%, and the average waiting time by 33%. The lowest data is for the “deadgading” method, which allows reducing the average duration of a passenger's journey and his wait-ing time by 5% and 9% in accordance.

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The use of the “skip-stop” method can also be found in works [4-9], where the corresponding results of the research of the sought indicators are presented (depending on the specific traffic conditions).

With the use of machine learning algorithms, the problems of reducing the undesirable effect of bus grouping at public transport stops [10] and predicting bus trips [11] are solved.

The approach proposed in [10] combining two strategies (maintaining control and adjusted cruising speed) makes it possible to minimize grouping of buses at stops. It is established that each bus uses the cruise control strategy approximately 7% of the time on average. Differences in the operation of city routes occur with a certain periodicity. In particular, it is related to the days of the week and is quite relevant for different hours of the day [12]. It is affected by various traffic flows (buses share lanes with other road users) and this affects the time of the bus trip. This is especially typical for routes “to” or “from” the city center due to the high concentration of trips to work or study [13].

Bus delays can cause inconvenience for passengers and reduce the competitive attractiveness of the route due to the uncertainty of the travel time. Correct time management can be achieved by considering the simulation of different scenarios and diagnostics of the travel time model. This is due to route characteristics and dual communication types for different routes. Such models are competitive [14].

The change in the bus speed and the time series with an interval of 5 minutes make it possible to determine the average value of the bus trip on each section of the line. The dynamic hierarchical spatial-temporal network model and the mechanism of analysis of fixed spatial dependences of speed (long-term and short-term) make it possible to predict the change of the bus speed in the next time interval [15].

### 3 Bus Average Speed Analysis and Forecasting

The study of the average speed of the bus was carried out on working days of the week on the route of public transport #3A, which runs in Lviv. The route connects two terminals (Fig. 1): Terminal A - shopping center “King Cross Leopolis” (southern city); Terminal B - square “Rizni” (city center). The analyses synthesized below were performed using AVM data of the bus [13]. The collected data includes the average speed of traffic on the route of all buses during the working days of the week.

![Fig. 1. Stretch of the bus route #3A.](image)

Part of the route runs through the city center, where streets with intense traffic and pedestrian traffic generally pass. The rest of the route runs along the main street, where there are no obstacles for the movement of both personal and public transport. Table 1 presents the main characteristics of bus line #3A. Data on bus speed are obtained from the “UA-GIS TREK” program and refer to working days of the week. This program is used by many Ukrainian (UA) companies to monitor bus services.

Data for bus route #3A were collected by monitoring buses on the website http://track.ua-gis.com/ for 10 weeks [13]. The collected data includes the average speed of the buses for the direction of the city center.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Font size and style</th>
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</thead>
<tbody>
<tr>
<td>operating time</td>
<td>working hours: from 6:15 to 23:00</td>
</tr>
<tr>
<td></td>
<td>headway: 7-15 min</td>
</tr>
<tr>
<td>route length of the route (for direction)</td>
<td>18.54 km (9.26 km / 9.28 km)</td>
</tr>
<tr>
<td>route time duration</td>
<td>30-60 min</td>
</tr>
<tr>
<td>number of stops</td>
<td>17/17 stops (to the city centre / from the city centre)</td>
</tr>
<tr>
<td>distance between stops</td>
<td>from 350 m to 1000 m</td>
</tr>
</tbody>
</table>

![Table 1. Main characteristics of bus line #3A.](image)
At the first stage, it was determined the average speed on the bus route #3A in the direction to the city-center. The change in average speed during the day is shown in Fig. 2. It is worth noting the high dependence of speed on the running time of buses. There are two peak periods (morning and evening) during which the average speed of buses is significantly lower.

When analyzing the average speed at the second stage, four main time periods (hours) were selected: 6.00-10.00, 10.00-14.00, 14.00-19.00, 19.00-23.00. These periods are divided into two peak periods and in accordance two inter-peak periods, which differ significantly in terms of traffic conditions on the route. It was determined the average speeds of bus traffic for working days for ten weeks in each of the time periods. The corresponding array of data was organized for each of the time periods in the “Statistica” software environment. The results of the research are presented in Fig. 3.

The results of the data analysis made it possible to determine the average speed for different time periods during 10 weeks. So, the average speed for time period 1 (6.00-10.00) is 13.37 km/h, with a minimum value of 12.57 km/h and a maximum of 14.04 km/h. At the same time, the determined speeds of movement in this period ranged from 8.62 km/h to 19.66 km/h. For period 2 (10.00-14.00) the average speed is 13.53 km/h (min 12.59 km/h, max 14.24 km/h). Determined speeds varied from 8.69 km/h to 17.07 km/h. Similarly, for period 3 (14.00-19.00), the average speed is 12.71 km/h (min 12.17 km/h, max 13.60 km/h). Determined speeds varied from 7.98 km/h to 16.56 km/h. In period 4 (19.00-23.00) the average speed is 15.25 km/h (min 14.35 km/h, max 15.94 km/h). Determined speeds varied from 8.79 km/h to 24.37 km/h.

![Fig. 2. Hourly fluctuation of average speed of analyzed bus line #3A.](image)

![Fig. 3. The average speed of bus in certain periods of day.](image)
The conducted analysis characterizes a significant difference in the values of speed indicators. A sharp change in speed dynamics from 7.98 km/h to 24.37 km/h leads to non-compliance with traffic schedules and indicates difficult traffic conditions during peak hours.

The deviation of the speed from the average value during the day is shown in Fig. 4. This figure presents the results of the comparison of the determined speed during the day with the average value of ten weeks for each of the periods.

![Fig. 4. Speed deviation from the average value during the day.](image)

For example, in the morning hours before 7:00 am and in the evening hours after 10:00 pm, the specified speed is higher than the average by 19 % and 17 % in accordance. On the other hand, in the peak hours of 8:00 am and 6:00 pm, the speed is 16 % and 13 % lower than the average. Speeds are below average are observed in the morning rush hour from 7:00 am to 9:30 am and in the evening rush hour from 4:30 pm to 8:30 pm.

To increase the average speed on the route from the regulated one can be compensated by the duration of the stop. On the other hand, a decrease in speed leads to non-compliance with traffic schedules and a decrease in the quality of service provision on the route.

This route has 17 stops in each direction. Research shows that the duration of a bus stop was a maximum of 2.5 minutes, and a minimum of less than 10 seconds. The average bus stop time is 1 minute. It was also established that the duration of the bus trip at the stop varies from 40 to 100 seconds. On average, from 1 to 10 passengers were seen at each stop during the morning peak period. More than 10 passengers at stops were observed in 15% of the entire sample, significantly. The distance between stops on the route ranges from 350 to 1000 m. There are also stops with low passenger traffic.

The paper proposes a scenario for the operation of buses skipping stops (“skip-stop” model) in hours when
the speed on the route is lower than the average value. Fig. 5 shows a comparison of the deviation of the speed values from the average with the base scenario, in which no change in the traffic schedule is used. The data is based on the results of simulations that allowed us to determine the average travel time at different hours.

According to the figure, speed modeling in peak hours shows the possibility of reducing the negative effects of speed on the traffic schedule. In particular, the sharp decrease in speed during the morning rush hour (16%) as a result of the proposed approach can be changed to 10%, and the period of traffic delays is reduced by 1 hour. Regarding the evening peak (13%), the speed reduction is 6%, and the period of traffic delays is reduced to almost 0.6 hours.

4 Conclusions

The proposed approach for predicting the average speed of traffic on a route taking into account the "skip-stop" method can improve the accuracy of calculating the traffic schedule under various conditions. In this way, it is possible to determine the influence of both traffic conditions and transportation demand on the average speed of the bus in real time. The study of the average speed of the bus will provide an opportunity to improve the quality of public transport services (calculate the timetable more accurately).

This paper focuses on forecasting the average speed of the bus on the public transport route #3A. When analyzing the average speed, four main time periods (hours) were selected. The corresponding array of data was organized for each of the time periods in the “Statistica” software environment. The results of the data analysis made it possible to determine the average speed for different time periods during 10 weeks. The conducted analysis characterizes a significant difference in the values of the speed indicators. A sharp change in speed dynamics from 7.98 km/h to 24.37 km/h leads to non-compliance with traffic schedules and indicates difficult traffic conditions during peak hours.

The deviation of the speed from the average value during the day was also investigated and compared. The paper proposes a scenario of bus operation with a stop pass at hours when the speed on the route is lower than the average value. According to the results of speed modeling in peak hours, it is possible to reduce the negative effects of speed on the traffic schedule. In this way, system operators can design and adjust the data according to the estimated average speed.

References


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