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INFLUENCE OF INTERVAL DISTURBANCE ON EXTENDED PASSENGER WAITING TIME

Keywords
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Abstract

Modern vehicle tracking technologies have created the possibility for a positive action of the transport organizer on the user, in order to mitigate the estimated times with accurate information about the actual arrival of the vehicle. As previous research has shown, the waiting time at the stop, as the only static part of the journey, has the greatest importance for the user. Determining the interdependence of interval disruption and waiting time estimation would allow quantifying the importance of the measures needed to maintain the interval, and then also on user behavior and the effects of that behavior. In the paper, on the chosen corridor, on the example of the observed bus stop in Nis, research was carried out based on the recording of vehicle tracking in order to obtain data on the size of the average achieved interval of vehicle tracking, as a basis for determining the disturbance of the interval that affects the extended waiting time of passengers, as and recording the accumulation of passengers, to determine the unevenness of the accumulation.

1. INTRODUCTION

In practice, the realization of the movement of vehicles along the line often does not coincide with the planned one, that is, there are deviations in the realization of the projected timetable. Depending on the size of the deviation, the unreliability of the service occurs. In public urban passenger transport systems, deviations of the realized vehicle tracking interval from the designed are the main parameter of service unreliability.

Traffic accessibility as a function of public transport strengthens the economy, deals with the conservation of energy and resources, reduces congestion, improves the quality of air and our health, provides critical assistance in emergency situations and catastrophes, increases the development and value of real estate, increases mobility in small urban and rural communities, and reduces health costs. All of this contributes to a better quality of life [1].

The user's experience of the quality of the public transport system is subjective, so the user actually behaves according to his assessment of the suitability of the transport, which is usually not objective [2].

The tracking interval represents one of the most significant dynamic elements of the line, both from the point of view of the organization of transport, and from the point of view of the quality of transport important for passengers.

Under ideal conditions, the public urban passenger transport system functions with an even interval of vehicle tracking. Interval disturbances occur due to the negative influence of certain factors on certain time components of the planned turnaround time. Then the vehicle moving on the line is in a hurry or late compared to the designed interval of the vehicle.

After the introductory part, the paper presents an analysis of waiting time and its components, as one of the elements of travel time. In the third part, the methodology used during the research is explained. After that, the analysis of the results and the obtained data was started based on the recording of the accumulation of passengers and the achieved vehicle intervals. A conclusion is given at the end of the paper.

2. ANALYZING WAITING TIME

The importance of travel time variability has been the objective of much research in the past and has therefore been extensively analysed from the traveller's perspective. Many studies have concluded that although travel time is an important factor affecting the traveller's route choice behaviour, travel time variability can be even more important. Travellers are interested in how long it will take them to reach their destination, but are even more concerned with how reliable their prediction of total travel time is. A wrong travel time prediction results in either an early arrival at the destination or in a delay [3].

Poor service reliability affects both passengers waiting time and crowding. To have a small probability of arriving late at their destination, passengers must plan on waiting longer than the average platform waiting time. While passengers vary in their

willingness to accept the risk of arriving late at their destination, a reasonable working assumption is that passengers will accept a 5% risk of arriving late. Therefore, the 95th-percentile waiting time can be interpreted as budgeted waiting time.

Budgeted waiting time can be divided into two parts: the part that passengers actually spend waiting and the remainder, called "potential waiting time." For example, if a passenger budgets 10 min for waiting, but the bus arrives after only 4 min, the 6-min difference is the potential waiting time. Potential waiting time is not spent on the platform; it is spent at the destination end of the trip, where the traveler will arrive 6 min earlier than budgeted. However, because it was set aside for waiting, that time cannot be used as freely as if it had not been so encumbered; therefore, it still represents a cost to passengers. For example, passengers going to work in the morning could not spend their potential waiting time sleeping a few minutes later or staying at home with the kids a few minutes longer. Potential waiting time is a hidden cost associated with waiting, manifested in passengers having to start their trips earlier than they would otherwise have to if waiting time were certain [4].

Passenger waiting time can be divided into two parts: ideal and excess. Ideal waiting time is the average waiting time that would result from service exactly following the schedule; excess waiting time is the difference between actual and ideal waiting time and is, therefore, the component of waiting time that can be attributed to operational issues. Separating excess from ideal waiting time provides a good idea of the quality of operations and the extent to which passenger service could be improved by improving service reliability.

2.1. Waiting Time Components

Passengers can use their waiting time more productively, select which route they would want to take, or choose to select an alternative mode of transportation. Whatever the prospective passengers' choices are, providing them with real-time information reduces the uncertainty inherent to transit systems [5].

Two components of waiting time are not avoidable and are, therefore, part of ideal waiting time, not excess waiting time:

- *Schedule inconvenience*: a well-known form of hidden waiting time that arises from departures or arrivals not being scheduled when passengers want to travel. It is manifested in passengers who are going to work arriving before their work start time because the next bus would get them there too late. Likewise, after work, passengers may consistently have time to kill between leaving work and the next scheduled departure.
- *Synchronization time*: the cost, in equivalent minutes of waiting, of ensuring that one is at the station by the target arrival time. To be sure of hitting that target, many passengers will arrive early because of uncertainty in access time, the limits of human punctuality, and risk aversion. The waiting time between when passengers arrive and the ideal arrival time is part of synchronization time.

Schedule inconvenience and synchronization time are unavoidable; they are responsible for planning, as they are the inevitable consequence of designing a service with a long headway. In contrast, random waiting time that occurs after the ideal arrival time is due to service unreliability and is, therefore, excess waiting time.

3. METHODOLOGY OF RESEARCH

The research methodology is based on recording the waiting time of passengers at the stop, that is, their accumulation in each minute of the interval of vehicles using the observed stop.

The choice of the corridor for researching the quality of transport service was chosen on the basis of transport requirements in peak and off-peak periods in the direction of the city center, the convenience of all lines for all passengers, the importance of transporting pupils and students and the high percentage of service time during the day.

The research period during the day was chosen, so as to include the peak period (from 6 - 8 a.m.) and the off-peak period (from 9 - 11 a.m.) of the working day during the validity of the summer timetable. The direction towards the center of the city of Nis was chosen during the period of going to work or for another purpose, as the primary direction in terms of the importance of reliable transportation.

At the observed bus stop, all vehicles were registered by line, namely line 6 (Duvanište - Ž. stanica), line 11 (Duvanište - Medoševac) and line 13 (Bulevar Nemanjića - Trg K.A.), with their frequencies in the direction of the city center. Considering that the lines of this corridor have mostly the same itinerary, the choice of the line by the passengers did not affect the waiting time, but the passengers used the first bus that came along. The stop is organized at the level of the carriageway, from the canopy. The recording was made on a working day.

At the same time and on the same section of the corridor, the accumulation of passengers at the bus stop was recorded by minutes after the departure of the previous bus. The research included all passengers heading towards the center. The investigation of passengers waiting for the bus was carried out by numerical processing of the investigation of the accumulation of passengers according to the minutes of waiting in relation to the arrival time of the next bus.

4. ANALYSIS OF RESEARCH RESULTS

The unevenness of the intervals and the accumulation of passengers were recorded at the bus stop of the observed corridor (Park Sveti Sava - city center), in the peak and off-peak periods, which obtained data on the sequence of bus passes, the duration of the interval and the number of arriving passengers per minute of the interval. Figure 1 shows the relationship between timetables and passenger purchases. The congestion shown results in increased passenger waiting time, compared to the minimum expected waiting time that would occur if the intervals were even.

Different values of vehicle intervals on lines in peak and off-peak periods are shown in the following table:

Table 1. Interval of following vehicles on the lines

	Peak period	Off peak period
Line No 6	9 min	11 min
Line No 11	/	60 min
Line No 13	14 min	15 min

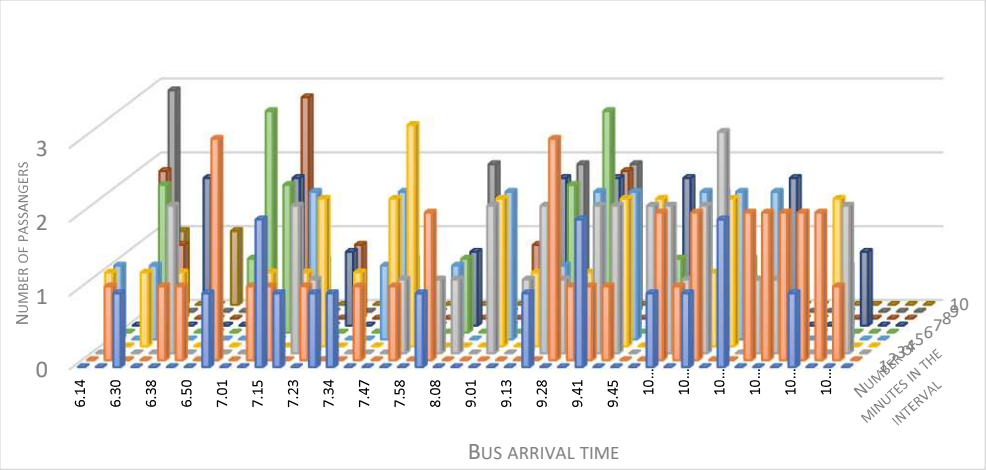

Figure 1. Display of the unevenness of the accumulation of passengers for the recording period at the observed bus stop

The results of recording the interval disturbances, on the selected characteristic section of the corridor, show that in the peak period from 6:14 to 8:10 a.m., that is, for a duration of 116 minutes, 22 intervals were realized, while in the off-peak period from 9:01 a.m. to 11:01 a.m., i.e. for a duration of 120 minutes, 22 intervals were also completed. The average achieved interval was 5.5 minutes and 5.7 minutes, respectively.

The accumulation of passengers for the same time showed that an average of 1.4 passengers/min or 1.08 passengers/min arrived per minute.. Looking at the intervals achieved, the number of passengers ranged from a minimum of zero passengers to a maximum of 14 passengers, or an average of 4.41 passengers per interval.

Comparing the maximum deviations from the average values of the intervals and the number of accumulated passengers per interval, the unevenness of the accumulation of passengers was more favorable than the unevenness of the intervals. This leads to the conclusion that the disruption of the bus following interval will have a much greater impact on the extended waiting time than the unevenness

of the accumulation of passengers. Passengers behave individually or in pairs, and rarely in smaller groups, so their accumulation cannot be significantly different from a randomly even one.

The total waiting time for the recorded intervals and the number of passenger accumulations was 579 passenger min and 747 passenger min respectively.

The percentage of passengers in the peak and off-peak periods, and according to the minutes of the interval before the departure of the bus (from the end of the waiting interval), is shown in the Figure 2:

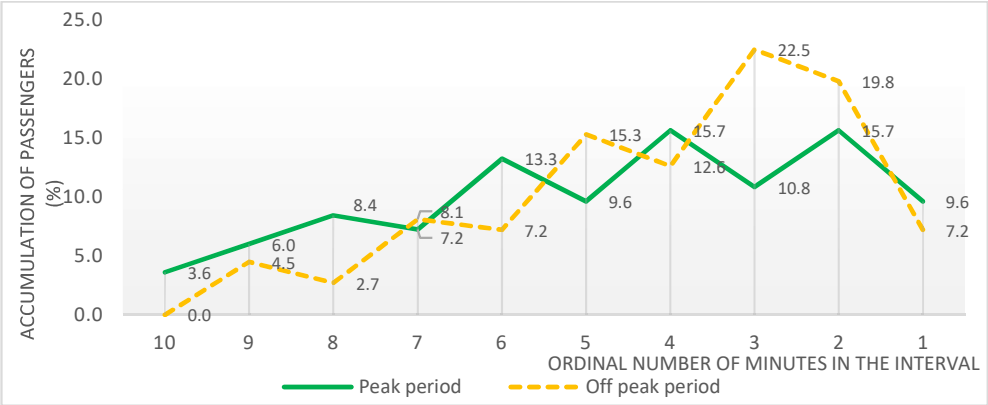

Figure 2. Accumulation of passengers by the minute

The accumulation of passengers, in the peak period, grows more slowly from the beginning of the interval, to increase sharply in the last minutes of the interval. The accumulation of passengers, in the off-peak period, is even with visible fluctuations, with a sudden drop at the end.

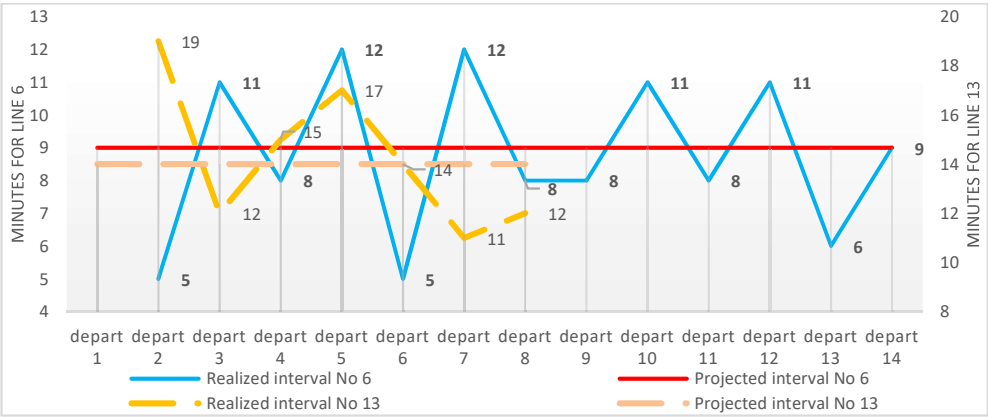

Figure 3. Presentation of unevenness of intervals on lines 6 and 13 during peak hours

Figure 3 shows the unevenness of the peak hour intervals on lines 6 and 13 at the observed bus stop. Interval deviations on line 6 ranged from 0 to 4 minutes based on the realized interval compared to the projected interval of 9 minutes. On line 13 in the same observation period, the deviations ranged from 0 to 5 minutes based on the design interval of 14 minutes.

5. CONCLUSION

High level of passenger satisfaction and competitiveness of the public transport system is achieved exclusively by high quality of service. The high quality of service in public transport implies that users experience a short waiting time at the stop and a short driving time. The main characteristic of city lines is the high frequency of vehicles, which provides users with shorter waiting times at stops and higher transport speeds. However, the operational functioning of the system in high frequency conditions is difficult. During the operational functioning of the system due to the action of various factors, there are frequent variations in the time of movement of vehicles along the line.

Based on the recording that initiated the continuation of similar and larger research, significant results were obtained that can help in understanding the accumulation of passengers and their behavior, at the expense of uneven arrivals of vehicles. Namely, this way of observing these two mutual entities can in the future help in a new way of designing and better functioning of the system.

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