DOI 10.20544/TTS2021.1.1.21.p21
UDC••656.131.025.2:303.62(497.11)
Original scientific paper

Influence of public passenger transport reliability on users behavior

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Abstract – **Unreliable functioning of public passenger transppport (PPT) system has direct influence on different aspects of passenger's journey. Often disturbances in vehicle headway influence users in such manner that they plan their journeys accordingly (leave earlier, choose different line, transfer to another line, changes in mode of travel). This paper will analyse the influence of PPT system's reliability on decisions and behaviour of PPT system's users.**

Keywords – **Public passenger transport, reliability, user's behaviour, vehicle headway**

I. Introduction

Urban mobility in urban areas is highly dependent on the functioning of public passenger transport (PPT). The personal mobility of residents, i.e. their freedom of movement, should be a primary product of the PPT system. For a PPT to be beneficial to many residents whose transportation requirements are not mutually synchronized, the transportation service must be predictable.

The reliability of the PPT system's functioning has a direct impact on the elements of passenger travel. Any unplanned change during the operation of the PPT system forces the passenger to change and adjust the planned trip to new circumstances.

Reliability is a key aspect of public transportation services, and surveys have shown a consistently high importance attributed to various reliability aspects by travelers [1, 2]. The most significant negative experiences that drove a reduction in public transport use were delays perceived to be the fault of the transport agency, long waits at transfer points, and being prevented from boarding because of crowding [3].

This paper presents the results of a survey of passenger behavior in the PPT system in Novi Sad in the event of a system malfunction.

II. Influence of the Headway Disturbance on the Passenger

Headway disturbance adversely affects the operational functioning of the PPT system (prolonged turnaround time, vehicle delay for subsequent departure, full load vehicles, vehicle grouping, etc.). On the other hand, headway disturbance also adversely affects the following aspects of passenger travel: average passenger travel time; uncertainty of travel time for passengers; comfort of passengers in the vehicle.

The prolonged average travel time, uncertainty of passenger travel time and reduced comfort level in the vehicle lead to the following changes in passenger behavior:

a) Within the PPT system: change of departure time; changing the departure point of the trip; change of the arriving position; route change (second line, additional transfer, etc.)
b) Outside the PPT system: change in the mode of transport; changing or canceling a trip.

A. Passenger travel time

Travel time for passengers in the PPT system consists of the following time components: system access time; waiting time; on-line travel time; transfer time; walking time from the exit stop to the final destination.

System access time of the user to and the travel time of the user from the exit stop to the destination depend on the static elements of the lines, while the headway disturbance does not affect these temporal components of the passenger journey. In the structure of travel time, headway disturbance affects the waiting time of the passenger at the stop, the travel time of the passenger and and transfer time.

The waiting time for passengers at a stop is a direct function of the realized vehicle headway which is less than 10 minutes, and is a consequence of the nature of the accumulation of passengers at the stops [4].

The minimum expected waiting time for passengers at a stop in the event of constant headways is defined as a time period equal to half the headway. The waiting time defined in this way has absolute accuracy in conditions of steady accumulation of passengers at the stops. As the definition of a mathematical expectation of a waiting time implies a uniform interval, any prolongation of the headway results in prolonged waiting time relative to the minimum expected.

According to the results of a survey on a network of lines in Novi Sad, the accumulation of passengers on city lines where headways are less than 15 minutes is done randomly. The waiting time of passengers depends directly on the standard deviation of the headway disturbance, which means that the extended waiting time of the passenger is in a direct correlation to the headway disturbance. Extending the waiting time for passengers represents a waste of time and significantly affects the deterioration of the transport service quality [5].

The prolonged on-line travel time of passengers in conditions of disturbed headway is a consequence of longer vehicle delays than planned [6]. Prolonged on-line travel time

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of passengers exists in conditions disturbed headway, but is not expressed as extended waiting time for passengers at a stop and is much more difficult to quantify.

B. Uncertainty of travel time for passengers

Based on the previous analysis of the travel time of passengers in the PPT system, it can be concluded that, in the conditions of disturbed headway, the travel time of the passengers is extended. Variations in travel time depend on many factors and are not predictable for the passenger so, in the PPT travel planning process, the passenger must consider possible time losses as a buffer time in order to successfully (without delays) reached the destination.

Buffer time in the travel planning process exists in other modes of transport as well. The subjective valuation of the buffer time that the passenger must take into account in the PPT system and its comparison with other modes of transport greatly influences the choice and preference of the PPT as a mode of transport in the realization of the trip.

C. Comfort of passengers in the vehicle

The vehicle load factor expresses the capacity utilization on the most loaded section of the line, that is, on the characteristic section of the line [7].

The vehicle load factor, as defined in the literature, gives the average hourly utilization of the number of seats offered on the most heavily loaded section of the line. It is realistic to expect that the utilization of seats on the most heavily loaded line will be different for each individual vehicle and in each half-cycle.

Differences in peak flow values within peak hours observed by vehicles on the same line are conditioned by many factors such as headway disturbances, uneven accumulation of passengers, conditions of other surface traffic, etc. Factors that condition the realization of different values of maximum passenger flow rates on vehicles of the same line lead to the realization of different values of the vehicle load factor per vehicle and even change the characteristic inter-station distance for individual vehicles of the same line at peak time [5]. The diversity of comfort parameters is mainly conditioned by headway irregularity and passenger flow characteristics[8].

In conditions of headway disturbance passenger comfort is reduced, while in extreme situations the passenger demands for transport are often not realized (full load vehicle – passengers cannot enter the vehicle).

III. RESEARCH METHODOLOGY

Novi Sad is the second largest city in Serbia, with population of 277,522 inhabitants. The population of the administrative area of the city totals 341,625 people [9].

In Novi Sad public passenger transport system is realized by using the bus transportation subsystem, which is organized by lines. Network consists of 17 city lines. Total length of city lines is around 260 kilometers. If lines connectiong certain parts of the city with industrial zones, the average headway on city lines is around 13 minutes.

Survey of passengers in the PPT system in Novi Sad was conducted in order to identify changes in passenger behavior caused by transport reliability. The survey was performed on 17-th December 2017. Research has been done inside the vehicle, manually, by the interviewers. Preliminary phase of the research included preparation of materials for survey and training of interviewers.

The survey has been performed by directly interviewing the users of PPT, according to the predefined questions within the framework of questioner. Survey of users has had three groups of questions for users. The first group contains data on user. The second group contains data on characteristics of the trips. The third group of questions contains data on changes in passenger behavior caused by transport reliability.

The survey was conducted on 663 passengers. Interviewees have been randomly chosen.

IV. RESULTS ANALYSIS

Disruptions in the functioning of the PPT system create problems for users while traveling. The results of the survey, i.e. passenger characteristics, journey characteristics and passenger behavior during disturbances in the PPT system are given in the next section.

The main characteristics of passengers are given in Table I. The largest number of users surveyed is between 19 and 30 years old (52.64%), while the smallest number of passengers surveyed is older than 65 years (7.39%). Students and pupils have the largest share in the occupational status structure, 51.73%, while the unemployed have the lowest share, 2.87%. The largest number of passengers surveyed uses PPT daily (74.51%).

TABLE I
OVERVIEW OF THE BASIC CHARACTERISTICS OF PPT USERS

Characteristics of PPT users		*Number*	*percent*
Gender	Male	320	48.27
	Female	343	51.73
Age	< 18	64	9.65
	19-30	349	52.64
	31-40	86	12.97
	41-50	52	7.84
	51-65	63	9.50
	> 65	49	7.39
Occupational status	Employed	221	33.33
	Unemployed	19	2.87
	Pupil, Student	343	51.73
	Retired	78	11.76
	Other	2	0.30
Scope of Journey	Daily	494	74.51
	Several times a week	122	18.40
	Several times a month	40	6.03
	Several times a year	7	1.06

Passenger subjective senses of on-line travel time, as well as waiting time at the stop are given in Fig. 1. The largest number of users at the stop waits for transportation up to 5 minutes (45.10%), while 36.05% of the respondents are waiting on transportation 5 to 10 minutes. The travel time of the largest number of passengers is realized in the interval from 15 to 20 minutes (27.00%). The average passenger ride time is 18.9 minutes.

Table II provides information on user responses to what they do most when the vehicle waited is late. The results of a survey of passenger behavior in the PPT system in Novi Sad showed that when a vehicle is late most passengers (69.08%) seek a solution within the PPT system, that is, 42.99% of passengers wait for the next vehicle, while 26.09% the passenger changes the line/using the second route they reach the destination.

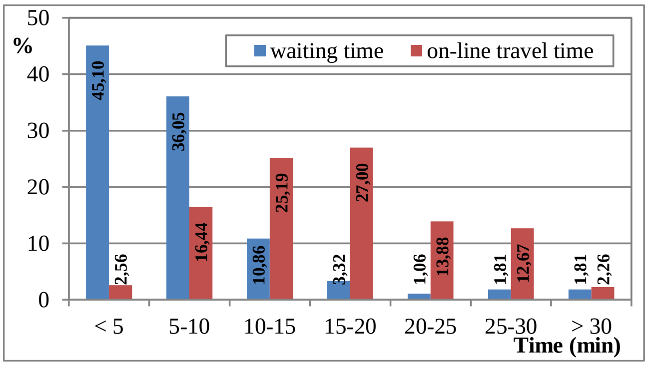

Fig. 1. Passenger waiting and on-line travel time

TABLE II
USER ANSWERS TO THE QUESTION "WHAT DO YOU MOST COMMONLY DO WHEN THE VEHICLE IS LATE?"

What do you most commonly do when the vehicle is late?	Number of interviewees	%
1. Wait for the next vehicle	285	42.99
2. Choose another line/change your route	173	26.09
3. Change mode of transport	175	26.40
4. Give up your journey	18	2.71
5. Other	12	1.81
Total	**663**	**100.00**

The users' response to how long they are willing to wait for the longest delayed vehicle is shown in Fig. 2. The largest number of users is ready to wait for the vehicle from 10 to 15 minutes (34.7%), as many as 17.9% of users would wait for the vehicle up to 25 to 30 minutes. The maximum time a passenger agrees to wait at a stop, presented as the average for all passengers surveyed, is 18.8 minutes.

When the vehicle is delayed, 26.40% of users change the mode of transport (Table II), with the largest number of users (57.7%) changing the PPT for taxi transportation, while 31.4% decide to go on foot (Fig. 3)

Table III provides information on the users' responses to what they do most when a full load vehicle comes to the stop. Most of the passengers surveyed (31.37%) are waiting for the next PPT vehicle; 23.68% of travelers chose the answer "5. Other"; 22.32% of passengers changes the line or reaches the destination by another route; mode of transport changes 18.40% of passengers. Passengers surveyed (157 passengers) who chose "5. Other" profiled their response in more detail, with 59.87% (out of 157 passengers) stating that they still managed to get into the vehicle by pushing.

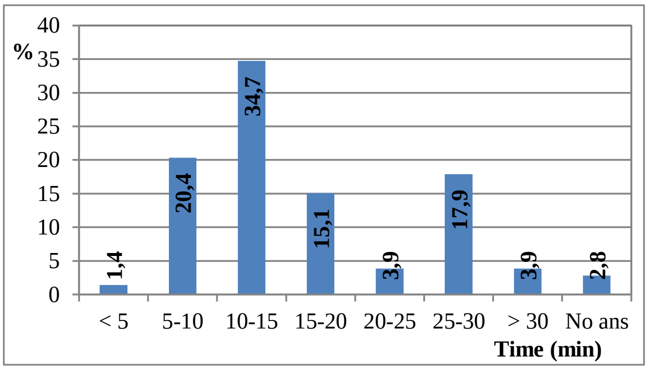

Fig. 2. Maximum passenger waiting time when vehicle is late

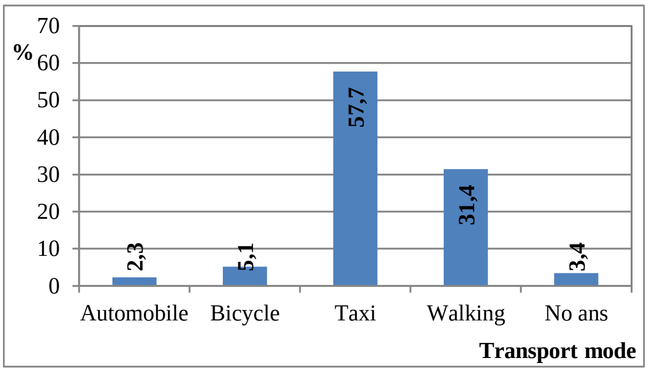

Fig. 3. Choosing an alternative mode when the bus is late

TABLE III
USER ANSWERS TO QUESTION "WHAT DO YOU DO WHEN A FULL LOAD VEHICLE ARRIVES TO THE STOP?"

What do you do when a full load vehicle arrives to the stop?	Number of interviewees	%
1. Wait for the next vehicle	208	31.37
2. Choose another line/change the route	148	22.32
3. Change the transport mode	122	18.40
4. Give up journey	28	4.22
5. Other	157	23.68
Total	**663**	**100.00**

Data on the response of users to how long they are willing to wait for the next vehicle when a full vehicle comes to a stop is shown in the following Fig. 4. The largest number of users, 30.3%, is ready to wait for a vehicle from 10 to 15 minutes, while 15.9% wait for the vehicle 25 to 30 minutes. The maximum time a passenger agrees to wait at a stop, presented as the average value for all passengers surveyed, is 19.0 minutes.

When a full load vehicle comes to the stop, 18.40% of users change the mode of transport (Table III), with the majority of users (45.1%) changing the PPT for taxi transportation, while 37.7% decide to take go on foot (Fig 5.)

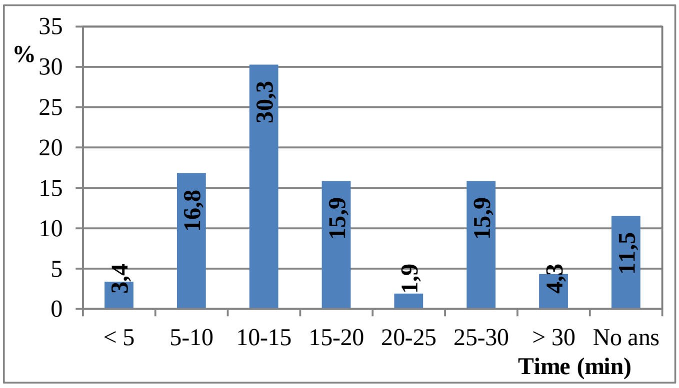

Fig. 4. Maximum passenger waiting time when full load vehicle arrives to a stop

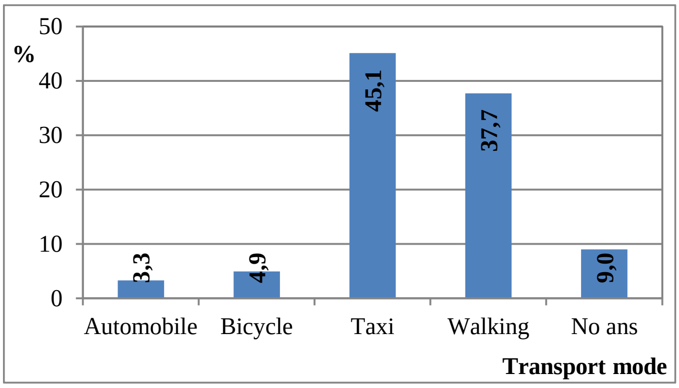

Fig. 5. Choosing an alternative mode when full bus arrives

When asked "How earlier do you have go to begin your journey for the PPT system to take you to your destination safely?” Most users (28.51%) answered 1 to 10 minutes. Also, a large number of users 26.40% leave 20 to 30 minutes earlier and 22.17% leave 10 to 20 minutes earlier (Fig. 6). The earlier leaving time, the so-called buffer time, for all surveyed passengers, averages 22.0 minutes.

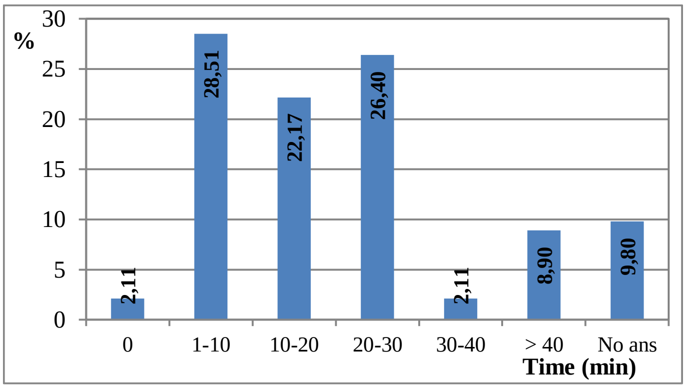

Fig. 6. Buffer time

V. Discussion and Conclusions

Disturbances in the PPT system adversely affect the passenger. In the event of a PPT disruption, the passenger is forced to change and adjust the planned trip to new circumstances. Changes made by the passenger within the journey plan can be classified as changes to journey within the PPT system and outside the PPT system.

As part of this paper, an analysis of the behavior of passengers was made based on a survey conducted on PPT users in Novi Sad for the cases when a vehicle arrives late or a full load vehicle arrives at a stop.

The results of the analysis showed that regardless of whether the vehicle is late or full at the stop, the behavior of people is similar, with the majority of users striving to stay in the PPT system, while every fourth or fifth user changes the mode of transportation. Most passengers use PPT daily (74.51%). They are aware of the reliability of the system and are prepared in for any delays. The buffer time taken by passengers when traveling with the PPT system (when they need to arrive on time) is approximately the waiting time for the next vehicle to which the passengers have agreed. This time is also close to the longest headway PPT system in Novi Sad which is about 20 minutes.

Based on the analysis, it can be concluded that the value of buffer time used by passengers in a system is a subjective assessment of the reliability of the PPT system by passengers.

Buffer time in the journey planning process exists for each mode of transport. Future research will focus on a comparative analysis of the buffer times of different transport modes in Novi Sad.

Acknowledgment

The results presented in this paper are part of the research project "Development and application of modern tools and research methods in the field of traffic and transportation", founded by the Department of Traffic Engineering, Faculty of Technical Sciences in Novi Sad, University of Novi Sad, Republic of Serbia.

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