ANALYZING AND MODELING THE IMPACT OF TRANSPORT SERVICE RELIABILITY ON PASSENGERS BEHAVIOR

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Abstract: *As a result of increasing demands for mobility and high consumer expectations of society, the reliability of transport service becomes more modern, necessary and important. The reliability of transport service can be defined as the ratio between the supply (referred to in the schedule) and actually implemented public transport services. The patterns of passengers' behavior in different situations, such as early arrival or delay of vehicles express the perception of transport service reliability in different manners. This article is a study on the impact of the reliability of transport process on the passenger behavior*

Keywords: SERVICE RELIABILITY, VARIABILITY, TRANSPORT MODELS, IMPACT OF SERVICE RELIABILITY

1. Introduction

As a result of growing demands for mobility and high user expectations of society, the reliability of the transport service becomes more modern, necessary and significant. Today, the main challenge for transport operators is to provide a more reliable and quality transport services. This is so, because more reliable transport services are a prerequisite for addressing the needs of current users and an opportunity for attract new ones. The routes, characterized by unreliable transport services, experience difficulties in attracting new passengers or suffer from a reduction in passenger flows over time.

Significant are efforts, which are being made in this direction. These efforts are justified, because improving the level of reliability of transport services benefit both users (reducing the time of travel, improving the quality of the service provided, etc), and for operators (a higher level of competitiveness, more efficient use of resources, more revenue, etc.).

The reliability of the transport service can be defined as the ratio between the proposed (referred to in the schedule) and actual realized public transport services. The interaction between the supply of a transport service (consisting of order activities, the main of which are moving people and material objects in space and time) and her demand reflect the actual level of reliability relevant transport system. Unreliability of the transport service appearing in interaction of two sides. Of the supply side consists of services such as time travel and space. Of the passenger side is determined by their behavior and experience. The patterns of passengers' behavior in different situations such as before arrival time or delay of vehicles reflect different way perception of the reliability of the trip. In the current article is examining impact a reliability of the transport process on users.

2. Importance of the reliability of the public transport service

Along with growth of the economy increases and the mobility of the population. It must be recognized, that monitoring development of mobility (based on data from the National Statistics Institute), we see that the number of trips made by public transport is much smaller than those made by road (fig1).

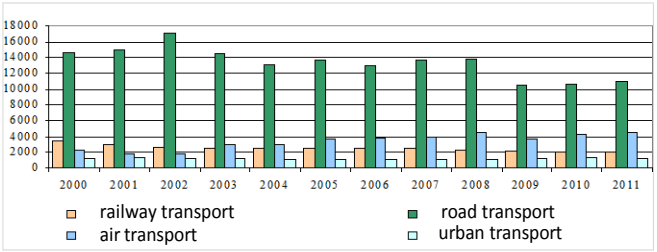

Fig.1. Work done during transport of passengers by modes of transport

To increase the role of public transport in total mobility is necessary significant improvement in quality of services, offering public transport. Enhancing the reliability of the transport service is one of the main factors for increasing hers quality.

It should be noted, that in public transport the main process is operation of the vehicles. The result of this process is vehicle journeys, including actual times of departure and arrival. The schedule in this case is of fundamental importance, because it defines the standards for time and place of travel. Ideally, the vehicles arrive and depart according to the scheduled time. In reality, large part of the trips does not coincide with those specified in the schedule. This is so, because transport system operates in an environment under the influence of a wide variety of influencing factors like: passengers and driver's behavior, weather conditions, road conditions and etc. Something more, the result of impaired functioning of the transport system is unreliable service, which itself leads to consequences for both transport operators and consumers.

The relationship between transport operators, users and reliability of service is presented in Fig. 2.

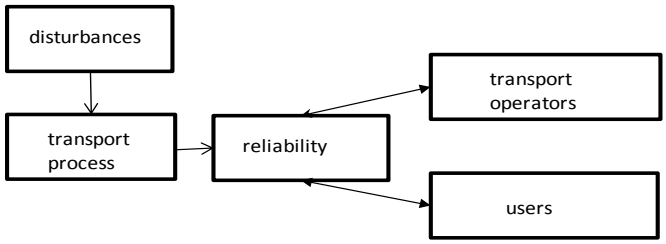

Fig. 2. Relationship between the passenger behavior, transport operators and reliability of the service.

Reliability of transport services is controlled by transport operators. By the level of reliability of the service provided, which the user perceives, supply side may affect in transport demand. Namely provided level of reliability of service determined this whether the traveler will use public transport services or would prefer another way of moving. Therefore reliability affects in passengers behavior.

The relationship between the demand side and the reliability of service is expressed in consumer behavior. They turn influence by increasing or reducing transport demand. It must be recognized, that both transport operators and users influence the reliability of the service, but without a doubt that reliability is important for both sides.

3. Analysis of the reliability on public transport service

The time is considered the most valuable resource of modern society. Today all activities in each area are focusing in attempts to be fully utilized. In the field of public transport services, this no makes exception.

Today the main task facing transport operators is to achieving compliance actual with planned service. In this sense, it is important that timely arrival and departure of vehicles from the respective stop along the route.

Taking into account the environment in which they operate there is always the probability of encounters with some of the variability. The value of this variability determines the level of reliability of the service provided. When it comes to the reliability of a transport line punctuality and regularity are the most commonly used indicators in practice. The collection and processing of real data on travel times of bus service is a good way to assess the reliability of the line. For this purpose study on the bus № 9 in Sofia has made. Used methodology proposed in the work [4], which considered approach to measuring the impact of unreliability on users:

- Analysis of transit schedule adherence.
- Calculation of passenger impacts caused by service reliability and determination of the average additional travel time.

3.1. Analysis of the punctuality of the service

Schedule trip time to the line is 26 minutes. The value of this time varies depending on the different periods of the day (Figure 3). At peak hours reaches to 35 minutes with difference between the maximum and minimum values 9 minutes. This value is more than 1/3 of the average travel time (29.5 minutes), leading to significant deviations from the schedule along the line. In non-peak hours reaches 29 minutes with a difference seven minutes, and the mean travel time 22.7 minutes.

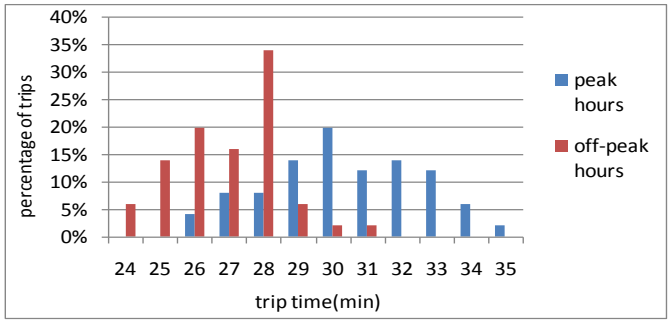

Fig.3. Distribution of travel times on a working day (made trips -50)

Reason for the variability of the provided service can be:

- Variability in the departure time - distribution of deviation from schedule (arrival before or after) at travel of the vehicle
- Vehicle travel time of variability - distribution of the travel time in the route.

Departure time's variability from the initial stop is part of the overall variability. Deviation of the vehicle departure time from the initial station determines the offset according to the schedule (fig4). The example shows that at rush hours, 4% of vehicles have deviation earlier than scheduled and 76% have departure with delay. Values in non-peak hours are respectively 46% departure before the scheduled time and 2% with delay.

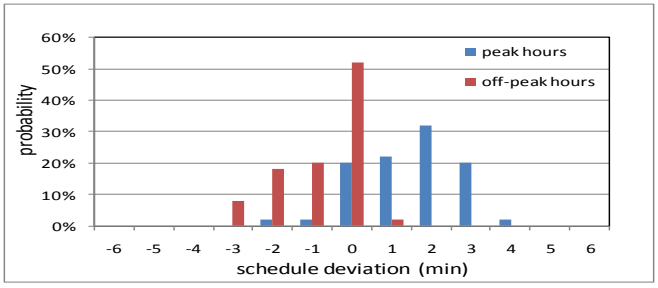

Fig.4. Variability of the departure time from the initial stop (made stop – 50)

Tracking the variability of the vehicle travel time along the line is shown in Figure 5. The focus is on the variability of travel time, so that the variability of the departure time is not taken into account. As a whole, variability increases along the route, because of the possibility of occurrence of random events (congestion, traffic accidents, road signage, weather conditions, the passengers and driver's behavior, etc.) which breaking the normal functioning of the transport system.

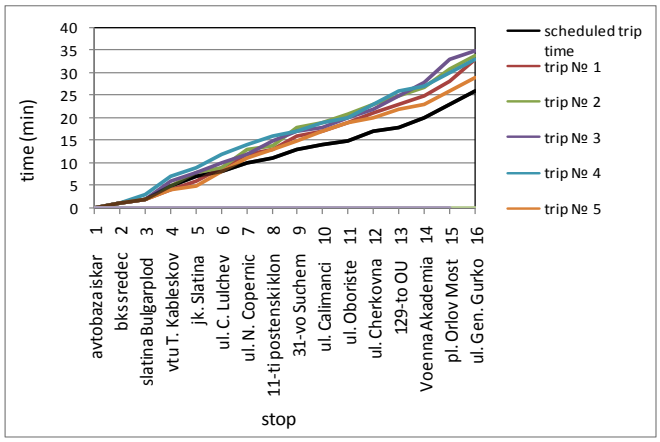

Fig.5. Pattern of individual trip times in working day that illustrates the distribution of variability along the route

Basing on data, obtained after analysis, we can determine punctuality of the line with the following equation:

$$P_l = \frac{\sum_j^{n,l,j} \sum_i^{m,l,i} |T_a - T_s|}{n_{l,j} * m_{l,i}} \quad (1)$$

where:

P_l - punctuality on line l;

T_a - actual departure time of vehicle i on stop j on line l;

T_s - scheduled departure time of vehicle i on stop j on line l;

$n_{l,j}$ - numbers of stops of line l;

$m_{l,i}$ - number of trips of line l.

The result is 2.15 minutes. This means that the delay for each stop on the line will be ± 2.15 minutes.

3.2. Analysis of the regularity of the service

The regularity of service is determined by the variability of the headways vehicles. The reason for this can be, as variable times of travel, as and time of boarding and alight of passengers, which differ depending on their characteristics and number.

One of the ways to describe the regularity of a single transport line is by using the percentage of deviation from schedule. This indicator expresses the deviation of actual headway compared with scheduled ones.

(2) $$R_j = \frac{\sum_i \left| \frac{H_{i,j} - h_{i,j}}{H_{i,j}} \right|}{k_j}$$

where:

R_j - relative regularity for stop j;

$H_{i,j}$ - scheduled headway for vehicle i at stop j;

$h_{i,j}$ - actual headway for vehicle i at stop j;

k_j - number of vehicles serving stop j.

Figure 6 presents a diagram that tracks the distribution of irregularity in all stops along the line.

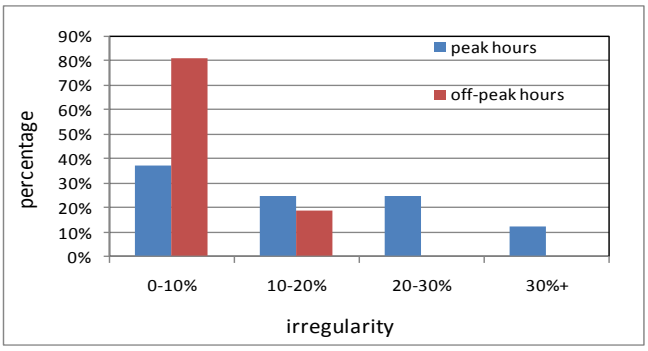

Fig. 6. Distribution of irregularity in all stops along the line.

The obtained value for the regularity of the whole line is average 27% deviation from the schedule headway in rush hour and 11% in off-peak hours. Similar to punctuality, regularity at the beginning of the line is better, decreasing with each stop. At the end in the line, regularity is much worse than average, due to increased variability.

Obtained values for the punctuality and regularity of the provided service, help to illustrate the level of reliability, but they do not completely coincide with the perception of passengers. These indicators focus on variability in terms of supply, thereby ignoring the impact on users. Using the punctuality and regularity, impact for passengers of earlier or delay is examined in the same way. In practice, however, this is not so. With the introduction of the indicator additional travel time [1] can be determined quantify the impact of unreliability on users.

4. Researching and modeling of the impact of reliability of provided service on the users

For the users of the transport service, travel time including waiting time on vehicle is essential.

The waiting time, is the time from the moment of the passenger's arrival at the stop until the moment of the boarding in vehicle. This time is different for passengers, depending on the model of their arrival [1].

The first model is when passengers plan their trip, taking into account the schedule. This pattern is typical of the users, which use services with low frequency. For them, adherence to the schedule is the most important measure of reliability, because the deviation influencing at waiting times. Driving ahead of schedule, leads of the user's point of view to miss the vehicle and respectively extended the waiting time i.e. waiting time is extended by the full headway before a new vehicle arrives. Figure 5 shows distribution of the punctuality of the departure of vehicles on stops along the route in non-peak hours, where the headway is 20 minutes.

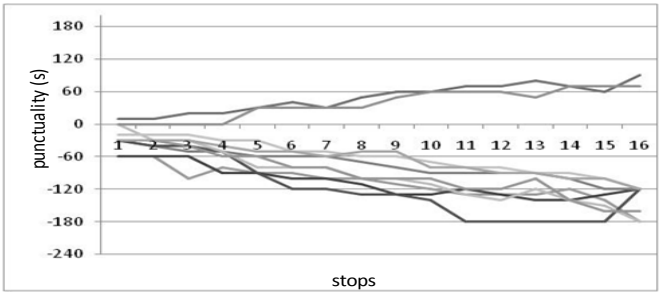

Fig.7. Measured vehicle departure punctuality per stop on bus line

It should be noted, that the majority of journeys of vehicles be carried out prior the scheduled headway. This is so, because the foreseen scheduled time of journey is in accordance with the time window, which guarantees less difference in the value traveling times in different periods. The lack of punctuality is reason to extend the travel time of passengers. For them unreliability is expressed in additional waiting time for the next vehicle.

The average additional waiting time for the passenger for each stop is calculated by determining the delay (in case of delayed vehicles) and headway (in case of untimely arrival of the vehicles).

(3) $$T_{w,l,j} = \frac{\sum_i T_{w,l,i,j}}{m_{l,i}}$$

where:

$T_{w,l,j}$ - average additional waiting time per passenger due to unreliability of line l at stop j;

$T_{w,l,i,j}$- average additional waiting time per passenger due to unreliability of vehicle i of line l at stop j;

$m_{l,i}$ - number of trips of line l.

Figure 8 shows the results about obtained average waiting additional time for the passenger for each stop on the bus line.

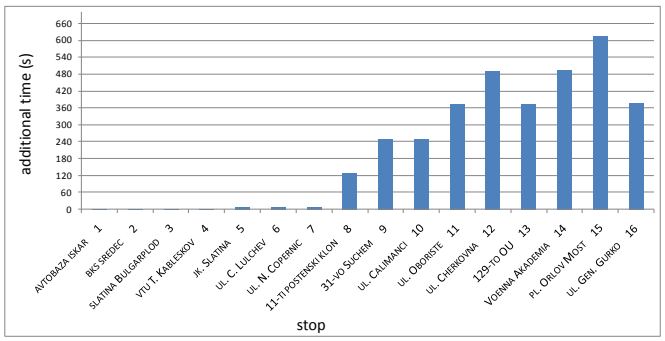

Fig.8. Average additional waiting time per passenger per stop on bus line

This graph shows effects of the arrival before the time, because on stops where it happens, waiting time, including travel time is increased.

Taking into account the pattern of arrival of passengers, average additional time per passenger for the entire line can be determined.

(4) $$T_{w,l} = \sum_j (\alpha_{l,j} * T_{w,l,j}) \quad \text{with} \sum_j \alpha_{l,j} = 1$$

where:

$T_{w,l}$ - average additional travel time per passenger on the complete line

$\alpha_{l,j}$ - proportion of passengers of line l boarding at stop j

The resulting value (2.51 min) is lower compared to the values of other stops, wherein the additional time reaches to 10 minutes per passenger. The reason for this is the pattern of demand on the line. The majority of them, beginning their journey in the first stops, where additional time is less, respectively, and the average is lower compared to the values of the rest stops

It should be noted that unreliability leads to an average increase in the total travel time by about 36%, in terms that, the average travel time of a passenger is 7 minutes.

The second model is when passengers arrive randomly. This pattern is typical for passengers using services with high frequency. For them, to comply with an interval is the most important measure of reliability, because the headway between vehicles determined the waiting time.

Figure 9 shows the distribution of the irregularity of vehicles on stops from the routing line. The impact on passengers, transforming the irregularity in additional waiting time (Formula 5) is presented in Figure 10.

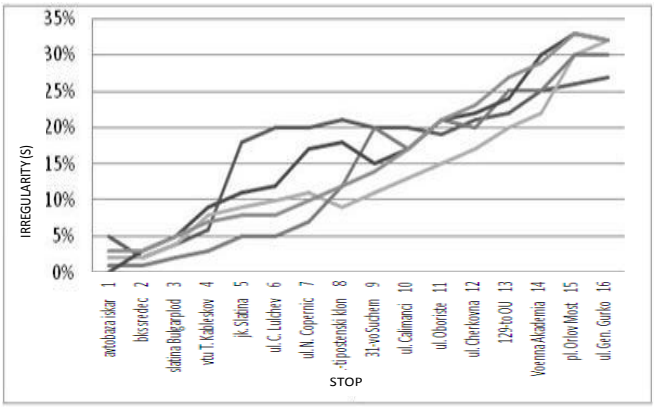

Fig.9. Irregularity of vehicles on stops

(5) $$T_{(w)j} = \frac{H_j}{2} * \left(1 + \frac{VH_j}{(H_j)^2}\right)$$

where:

$T_{(w)j}$ – passenger waiting time at stop j;

H_j – actual headway at stop j;

VH_j – the variance of the headways at stop j.

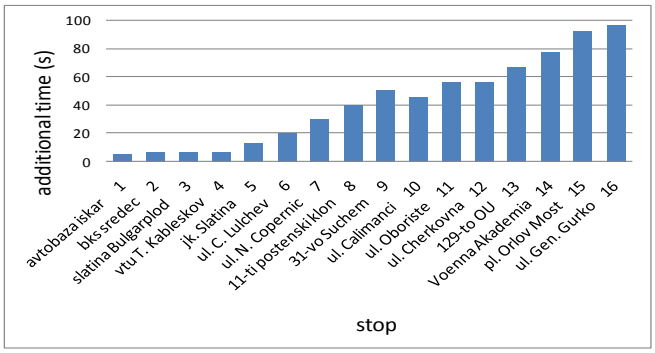

Fig.10. Average additional time per passenger per stop on bus line

The result again is that passengers at the end of the line are the most affected, because the total travel time will be extended by 10%.

In view of the results obtained, related to the effects of the reliability of provided service on users, we can conclude that the individual components of the travel time is influenced by variable headways, departure times, trip times and arrival times of vehicles (Table 1).

Types of service variability	*Main impacts on*
Variability of departure times	Waiting time
Variability of headways	Waiting time
Variability of trip times	In-vehicle time
Variability of arrival times	Arrival time

Table 1. Types of service variability

5. Conclusion

The variability of the service provided is an unwanted effect during operation of the transport system. The appearance of variability is the reason for reducing the level of reliability, which in turn has consequences for both transport operators and consumers.

In terms of the supply side, the unreliability is an expression of impaired functioning of the transport system, leading to inefficient use of resources, reduce demand, more costs and less revenue.

From consumer point of view, unreliability is expressed in extra travel time, which they could use for other more productive activities. The value of extended time (based on their experiences) the user takes into account in making process a decision. Exactly this value determines whether users will continue use the services of public transport systems, or would prefer another mode of transport.

The attention of transport operators should be directed to the analysis of reasons leading to the variability of service and focus on those of them, on which they can impact. In this way, they have able to take measures to reduce variability. This will enable them to meet the requirements of current users and the ability to attract new ones. Something more, reliability of the transport service, may affect the future use of public transport systems.

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