EVALUATING THE PUBLIC TRANSPORT PRIORITY SYSTEM: IDENTIFYING BACKGROUND DATA IMPACT

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ABSTRACT

Giving priority to public transport (PT) vehicles at signalized intersections has always been an effective way to increase the overall Quality of Service (QoS) in terms of reducing travel times. The benefits of introduction of these systems are often expressed through cost and benefit analysis (CBA), where it can be seen how and how much (expressed in monetary value) specific implications affect the PT company, city authority, users, society, etc. By conducting the evaluation of PT priority system performances using just CBA, certain transport impacts can easily be omitted. In this paper the emphasis is on defining the evaluation methodology for evaluation of PT priority system. The set of evaluation indicators, which are used for the decomposition of PT vehicle operation time, is defined. This approach enables the identification of different background data impacts on the PT system performances. PT is supported by a traffic control system that will provide public transport vehicles progression through the city's traffic signals on the tram corridors. The paper emerged from an ongoing research within the European CiViTAS ELAN project, where one of the objectives is to develop, demonstrate and evaluate the impact of giving priority to public transport in City of Zagreb on modal split, traffic congestion, energy consumptions, air quality etc.

INTRODUCTION

In 2008, the City of Zagreb together with other partners accepted the participation in the collaborative CiViTAS ELAN project, co-funded by the European Union, (1). Alongside Zagreb, four other European cities are involved and in each city the project activities are divided into several work packages. Every work package consists of several thematically linked measures, each with its own objectives. One of the measures which is going to be implemented in the City of Zagreb is to introduce the public transport priority system. Two main objectives of this measure are as follows:

- Increase the average speed of public transport vehicles (buses and trams) by giving them priority at signalized intersections,
- Reach improved mobility for all vehicles in the city by creating a system of coordinated traffic lights and „intelligent crossings“.

In order to define the impact of priority system on the overall PT QoS (Public Transport Quality of Service) often a cost and benefit analysis (CBA) is applied, (2), (3), (4), (5) and (6). According to the (7) CBA rating procedure follows the simple arithmetic of placing the monetary value on each impact, but certain (indirect) transport impacts could easily be omitted. Furthermore, other (background) impacts which could also have an influence on evaluation results are often neglected; therefore, the evaluation results are compromised.

This is identified as a problem because other CiViTAS ELAN objectives (such as reducing the number of cars in the city centre, increasing the number of PT users, promoting sustainable mobility solutions, etc.) will produce different background impact which could influence on PT priority system performance. In this case, simple recording and monetising the value of user travel times, vehicle round trip times and detection of changes of average vehicle speed cannot point out other background impacts which could cancel out the positive effects of PT priority system. In order to identify the background data impact and to preserve validity of the evaluation results a new evaluation methodology has been developed. PT vehicle operation time decomposition into different segments has been introduced.

IMPACT IDENTIFICATION

BACKGROUND IMPACT

When analyzing the PT network in the City of Zagreb it can be seen that, on the most PT lines, infrastructure is shared with other transport modes (mostly with individual and freight transport). In the daily on peak periods, when transport demand is on highest levels, queues of motorised vehicles form in front of signalized intersections, often blocking the PT vehicle pathway. The number of cars on the roads depends on wide variety of factors: transport costs (i.e. fuel price, parking availability and price, congestion charging fees), availability of other transport modes (PT, cycling lanes, etc.), multimodality options (location of multimodal

terminals, interconnectivity between different transport modes), economic situation (average income, employment rate), etc. Note that introduction of PT priority system doesn't have an influence on these factors.

Furthermore, several other measures of the CiViTAS ELAN project are devoted to the promotion of PT system services. The main objective of those measures is to increase the number of PT users and to contribute to the development of sustainable urban transport system. Growth in the number of patrons could require more PT vehicles in order to satisfy increased transport demand. Presumably, with more PT users it will also take longer for people to get on/off at the PT stops. This means that PT vehicles will spend more time on the PT stops, thus their round trip times will be increased.

All of abovementioned is detected as a background impact on the PT QoS. In the analysis of possible benefits of PT priority system, this kind of impacts shouldn't be ignored. A new evaluation approach is needed in order to evaluate the real impact of such system.

EXPECTED IMPACTS

After determining the objectives, several possible impacts of PT priority system implementation emerged. There is a significant difference between background impacts and expected impacts. As it was discussed earlier, background impacts are present because of wide variety of factors; while expected impacts are present only because of PT priority system implementation. Some of those expected (direct and indirect) impacts are listed below:

- Increased Quality of Service of public transport
  By improving the PT system performances the level of Quality of Service in public transport should be increased.
- More PT users
  Giving priority to PT vehicles should lead towards an increased use of public transport services due to better performances of PT system i.e. service level for the end user.
- Decrease of individual car use, thus decreasing congestion levels
  Giving priority at intersections to public transport vehicles destimulates the use of individual cars because travelling by means of PT should become faster, especially for the trips around and inside city centre.
- Improved satisfaction level
  Public perception about the quality of the service should be increased due to the overall improvements of performances.

QoS can be related with the subjective feelings of users about certain aspects of service (i.e. comfort, accuracy, reliability), but in this paper the focus is on determination of transport system performances.

THE EVALUATION APPROACH

DEFINING THE EVALUATION INDICATORS

Knowing the possible background and expected impacts, it is evident that PT vehicle operation time is highly influenced by those impacts. For instance, one public transport line (in our case tram line) has two terminals (A and B) and finite number of PT stops in-between. If PT vehicle gets the absolute priority at every signalised intersection between Terminal A and Terminal B, that gain of time can be easily cancelled out because of increase of time needed for patrons to get on/off vehicle. Thus, in order to detect an actual change of PT system performances in an objective manner, several evaluation indicators needed to be defined, that is, the operation time needs to be decomposed (Figure 1).

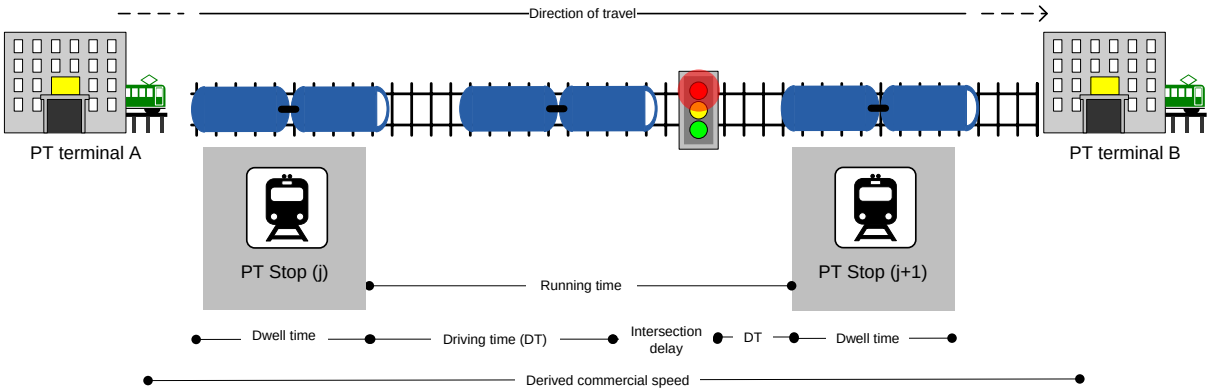

Figure 1. Operation time decomposition

Operation time decomposition enables detection of both background and expected impacts. Indicators descriptions from the Figure 1 are listed in the Table 1.

Indicator	*Description*
Operation time	The time that elapses from the departure of a vehicle/tram from a terminal to the arrival of a vehicle/tram at the other terminal on the line.
Running time	The time that elapses from the departure of a vehicle/tram from a stop to the arrival of a vehicle/tram at the adjacent stop.
Intersection delay	The time that elapses from the arrival of a vehicle/tram at an intersection approach to its passing through the intersection.
Dwell time	The time which a vehicle spends on PT stops.
Driving time	The time that a vehicle spends in motion.
Commercial speed	The average journey speed of public transport vehicles between an origin and a destination terminal, including any delay arisen in the course of the journey, (7).

Table 1. Indicator description

With the data collection process for these indicators and with known distances between PT stops, a commercial vehicle speed, as valuable performance indicator, can easily be derived, even for different segments if so desired.

PERFORMANCE EVALUATION

We are now able to present the mathematical formulation for the group of indicators defined in the Table 1. According to definition the total vehicle operation time (T_{op}) is given by:

$$T_{op} = T_{dw} + T_{rt} \tag{1}$$

where T_{dw} is the total time spent on PT stops and T_{rt} is the total time spent on running between PT stops by the PT vehicle on a journey between two terminals.

The amount of time which PT vehicle spends on specific PT stop is affected by the PT stop location and can vary during the day. Depending on location of PT stop more or less passengers will be attracted. As an example of those fluctuations we present the results of the measurement of different dwell times (t_{dw_i}) for several PT stops in one PT vehicle journey (Table 2). Note that the measurement took place on a specified corridor on a typical working day in two time intervals: between 14:00:00 and 15:00:00 CET (e.g. 2-3 PM) and between 16:00:00 and 17:00:00 CET (e.g. 4-5 PM).

Name of PT stop_sequence number	t_{dw_i}	Departure time	t_{dw_i}	Departure time
Frankopanska_1	0:00:33	14:40:38	0:00:29	16:40:50
Trg_marš_Tita_2	0:00:58	14:43:38	0:00:27	16:42:43
Vodnikova_3	0:00:35	14:45:13	0:00:25	16:44:03
Stud_centar_4	0:00:15	14:47:58	0:00:26	16:47:27
Zagrebčanka_5	0:00:19	14:51:29	0:00:13	16:50:23
Učit_akademija_6	0:00:17	14:52:51	0:00:20	16:51:59
Vjesnik_7	0:00:12	14:54:38	0:00:12	16:53:44
Prisavlje_8	0:00:10	14:55:43	0:00:14	16:54:59
Veslačka_9	0:00:08	14:56:25	0:00:12	16:55:50

Table 2. Result of dwell time measurements for several PT stops (departure time recorded by GPS receiver)

As it was already mentioned, the amount of time which PT vehicle spends on specific PT stop can vary during the day as it is depicted in Figure 2. For this specific case the average dwell times for PT stops "Zagrebčanka_5" and "Vjesnik_7" are $t_{dw_5} = 14\ s$; $t_{dw_7} = 16\ s$ and standard deviations are $\sigma_{dw_5} = 5\ s$; $\sigma_{dw_7} = 6\ s$. As many CiViTAS ELAN project measures have an aim to increase the number of passenger, it is expected that dwell time increases in future.

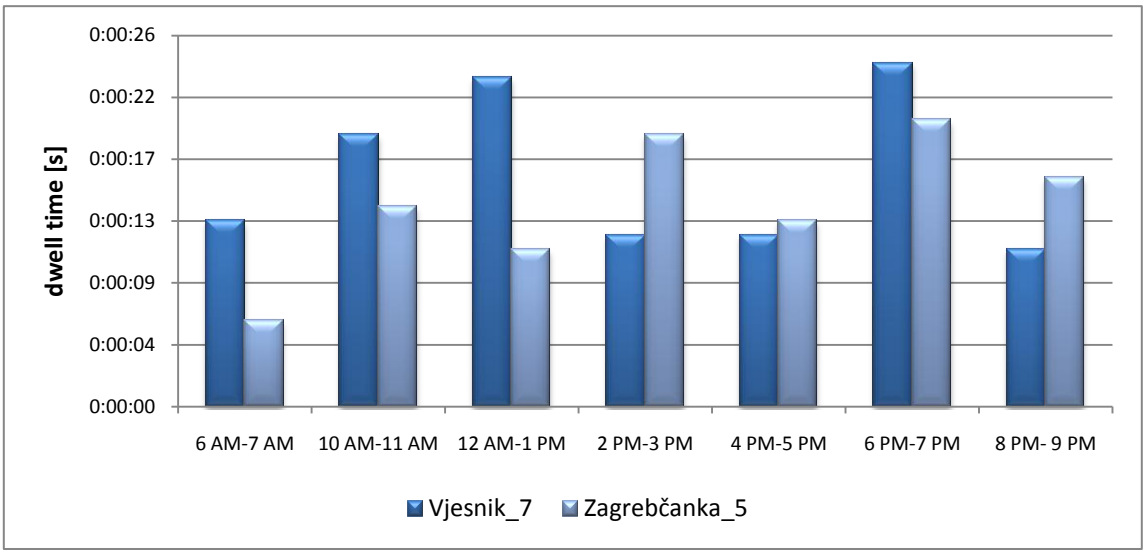

Figure 2. Daily variations of dwell times

Some PT stations in the corridor are located directly in front of signalized intersections (Figure 3). In this case it is not possible to determine which part of total time spent on this point is because of waiting for travellers to get on/off vehicle and which part is because of waiting on green period, if GPS vehicle tracking method for data collection for evaluation indicators is used. For the purpose of achieving specific objectives of CiViTAS ELAN project during the data collection process other methods (manual time recording, recording with PDA computer system, etc.) were used as well.

Figure 3. Signalized intersection in front of PT stop

In order to carry out more detailed analysis of PT priority system performances, running time has to be decomposed and analyzed separately for each segment of a line. Reason for this can be found in the fact that by giving priority to PT vehicles at signalized intersections T_{op} can be decreased only if PT vehicles spend less time while running between two PT stops.
Running time between two adjacent PT stops ($t_{rt_{j,j+1}}$) is given by:

$$t_{rt_{j,j+1}} = t_{dt_{j,j+1}} + \sum_{i=1}^{n} t_{id_i} \tag{2}$$

where $t_{dt_{j,j+1}}$ is the time which PT vehicle spends in motion between two adjacent PT stops and $\sum_{i=1}^{n} t_{id_i}$ is the total intersection delay which is caused at finite number of intersections n between two adjacent PT stops $(j, j+1)$.
Figure 4 shows the comparison of measured PT vehicle speeds between two adjacent PT stops (Stud_centar_4 to Zagrebčanka_5) during different time periods.

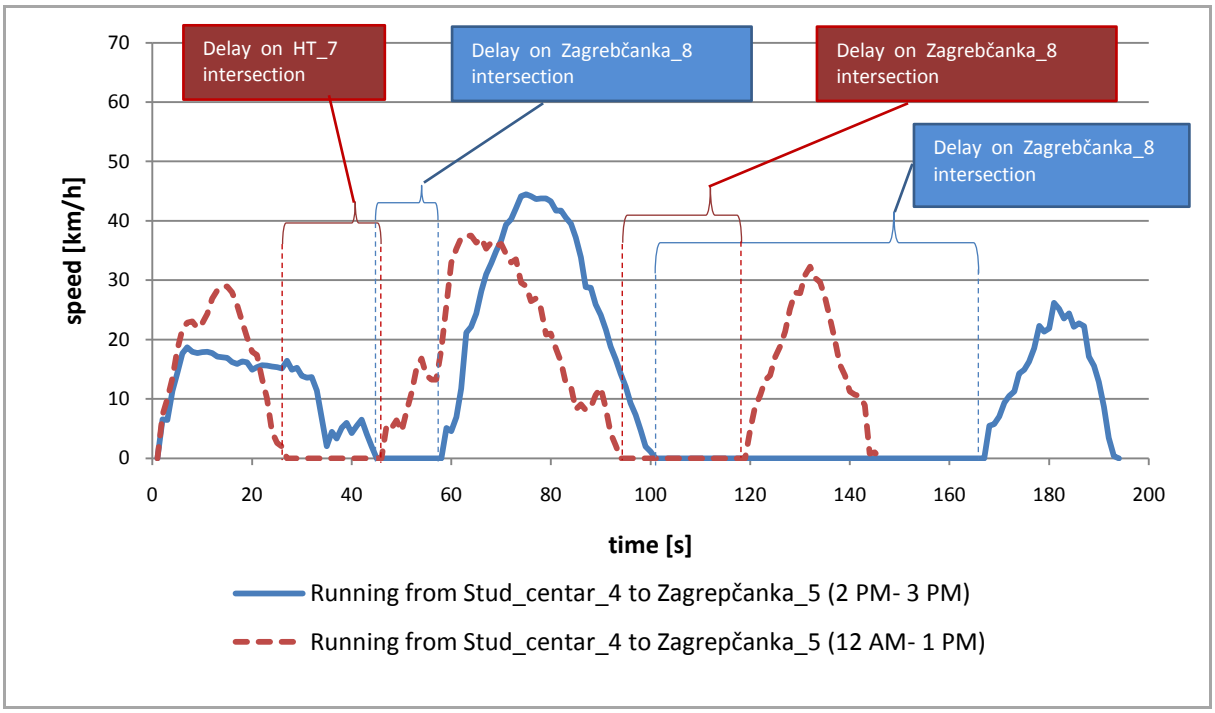

Figure 4. Comparison of measured PT vehicle speeds

Speed trajectories during running of one PT vehicle between two adjacent PT stops shown in Figure 4 examine main reasons of stopping. In this example, tracking data were not recorded for situation when PT vehicle have to stop because of cars occupy space aimed for them. Slow motion with almost constant-speed trajectory in the beginning, for monitored tram in period from 2 PM to 3 PM, could be affected by above mentioned problem. In addition, this speed trajectory shows too long delay at second intersection (Zagrebčanka_8) which is more than one minute (see Table 3). All of this abovementioned is a reason why monitored tram has

much longer running time, $t_{rt_{j,j+1}} = 191\ s$, which is 47 s more than for monitored tram in the first record period shown in this paper (see Table 3). All analyses were performed offline in Microsoft Office Excel 2007.

	$t_{dt_{j,j+1}}$	t_{id_1}	t_{id_2}	$\sum_{i=1}^{2} t_{id_i}$	$t_{rt_{j,j+1}}$	$\bar{v}_{j,j+1}$
First running (12 AM-1 PM)	0:01:36	0:00:21	0:00:27	0:00:48	0:02:24	13.09 [km/h]
Second running (2 AM- 3 PM)	0:01:49	0:00:14	0:01:08	0:01:22	0:03:11	10.83 [km/h]

Table 3. Decomposition of running time $t_{rt_{j,j+1}}$

We have already stated that, in the City of Zagreb, transport infrastructure is often shared among different transport modes, thus $t_{dt_{j,j+1}}$ variations in the on and off peak periods of the day are significant, due to the transport demand characteristics. When demand is on its highest levels cars are blocking PT vehicle pathway, thus PT vehicles are spending more time on intersection approach. If there are more than two PT vehicles approaching the intersection $t_{dt_{j,j+1}}$ will increase. The time spent on waiting to move nearer to the intersection is included in $t_{dt_{j,j+1}}$ because the length of intersection approach lane is defined by GPS measurement. After the introduction of PT priority system it is expected that these variations will be decreased, thus improve accuracy of PT vehicle arrivals in relation to the timetables. Furthermore, by giving priority to the PT vehicles $\sum_{i=1}^{n} t_{id_i}$ will be decreased which will cause additional savings in the $t_{rt_{j,j+1}}$.

IDENTIFIED BENEFITS OF EVALUATION APPROACH

The operation time decomposition is needed because, after the introduction of PT priority system, it is very likely that there will not be any decrease in the time needed for PT vehicles to go from one terminal to another (operation time). This is due to the already identified background impacts and due to the broader CiViTAS ELAN context (different project activities have the same main objective, e.g. to increase the number of PT users, that is, to achieve modal shift in favour of cleaner modes). This will result in increased dwell time because PT vehicles will spend more time on PT stops waiting for people to get in and out. Without the operation time decomposition it would be impossible to detect the impact of PT priority system. Thus, the main benefit of using this approach is the ability to detect decrease in the PT vehicle total running time (T_{rt}) because that is the main expected improvement.

Furthermore, using the new evaluation approach critical points in the network, in which PT system performances deteriorate, can be identified. For instance, for known average PT

vehicle speed and distance between two adjacent PT stops the average time needed for departure/arrival between those stops can easily be calculated. If there is a significant difference between the results of that calculation and measured running time (between those stops), it could be concluded that on that segment of a line there are certain critical points (i.e. car drivers are driving on the dedicated transport lanes, the signal plans are not synchronized, etc.).

CONCLUSION

In this paper we studied the problem of evaluation of public transport priority system as well as defining appropriate evaluation indicators. Because of possible background impacts on benefits of giving priority to PT vehicles at intersections, we proved that PT vehicle operation time requires detailed analysis of certain components. Thus, operation time decomposition is introduced.

We described evaluation indicators and presented the mathematical formulation for the group of indicators in order to be able to calculate components of operation time and to show changes in these components.

In addition to decomposition of operation time we analysed possible background data impact which could interfere with the PT priority system performances. Our analysis is based on recorded data of possible events in the public transport vehicle itinerary (travelling between two PT terminals). This type of decomposition is needed because it is helpful for determination of priority rule and it will enable detection of all changes after the implementation of PT priority system on a very small scale (for a specific signalized intersection, if necessary).

In our future research we will focus on modelling changes that have to be made in PT system. If some background impacts have opposite effect on decreasing operation time or some of its components we will try to find activities that have to be carried out in order to conserve benefits of PT priority system.

REFERENCES

(1) "Mobilising Citizens for Vital Cities". Available at http://www.civitas-initiative.org/docs/e-CIVITAS-ELAN%20brochure.pdf

(2) "National development plan". Available at http://www.ndp.ie/documents/publications/evaluation/INDECONFINALREPORT.pdf

(3) Currie, G, Sarvi, M and Young, B, "A new approach to evaluating on-road public transport priority projects: balancing the demand for limited road-space", *Transport*, Springer Netherlands, Netherlands, July 2007, pp. 413-428

(4) Currie, G, Sarvi, M and Young, B, "Roadspace Allocation for Public Transport Priority", in *Proceedings of AITPM National Conference*, (Brisbane, Australia, 27th - 29th July, 2005)

(5) Vedagiri, P and Arasan, V, "Estimating Modal Shift of Car Travelers to Bus on Introduction of Bus Priority System", *Journal of Transportation Systems Engineering and Information Technology*, Systems Engineering Society of China, China, December 2009, pp. 120-129

(6) "Evaluation of the Public Transport Priority". Available at http://www.ndp.ie/documents/publications/evaluation/INDECONFINALREPORT.pdf

(7) Khisty, C J, Lall, B K, *Transportation Engineering: An Introduction*, Prentice Hall, New Jersey, USA, 2003