DATA COLLECTION METHOD ANALYSIS FOR EVALUATION OF PUBLIC TRANSPORT SYSTEM PERFORMANCES

Niko Jelušić, D.Sc.
Lecturer, Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
TEL: +385 1 2457 921; FAX: +385 1 2314 415; niko.jelusic@fpz.hr
Štefica Mrvelj, D.Sc.
Assistant Professor, Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
TEL: +385 1 2457 923; FAX: +385 1 2314 415; mrveljs@fpz.hr
Marko Matulin, B.Sc.
Research Assistant, Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
TEL: +385 1 2457 923; FAX: +385 1 2314 415; marko.matulin@fpz.hr

ABSTRACT

There is an ongoing research on the implementation of public transport (PT) priority system in City of Zagreb within CiViTAS ELAN project, co-funded by the European Union. Within the project framework, specific objectives are defined and on that basis the evaluation activities are set up by defining evaluation indicators. For this purpose, a special group of performance indicators is used for the evaluation of PT priority system. A segmentation of vehicle operation time is introduced, where each time segment of PT vehicle operation time is measured and evaluated separately in order to detect the changes, even in the small time segments. In this paper four data collection methods for the performance indicators are analyzed: manual time recording, GPS vehicle tracking, PDA computer system and manual video data processing. After the comparative analysis of those methods, several use-case scenarios are defined in order to point out preferable combination of methods for this type of measurements. Use-case scenarios describe different traffic situations in PT vehicle itinerary which are in close relation to PT station location and PT vehicle occupancy.

INTRODUCTION

Several conducted studies show that one of the most important indicators for PT system performances is the average PT vehicle travel time, (1), (2) and (3). Authors in (4) elaborate the importance of vehicle delays and relation between average delay and type of priority function used. As a complementary analysis often cost and benefit analysis is included in the evaluation of PT priority system, (2), (5) and (6). Each of those studies evaluates the effects of a priority system on the larger scale, detecting the overall impacts on PT performances.

In order to detect the all critical points in the transport network, in which PT system performances deteriorate, it is important to determine the average vehicle travel time and its speed on each segment of the line. One public transport line has two terminals and finite number of PT stations in-between, thus vehicle operation time can be segmented in relation to the possible events in the vehicle itinerary. Operation time segmentation enables the data analysis on the very small scale (conclusions can be made for a specific intersection, if so desired) so it is purposeful for the evaluation of PT priority system.

This paper represents the initial step towards defining the appropriate method for data collection for the transport indicators related to the PT system performances. As the first step, four data collection methods were applied and analyzed: manual time recording, GPS (Global Positioning System) vehicle tracking, PDA computer system and manual video data processing. In order to compare each of those four methods used for data collection, we analyzed them by a set of criteria and use-case scenarios which are described below.

DEFINING PT PERFORMANCE INDICATORS

In case, when transport infrastructure is shared between different transport modes (e.g. PT and individual transport), PT system performances highly depend on the overall level of service of the transport system due to the congestion levels and transport demand characteristics. Moreover, PT system performances are in close relation with the number of patrons, because that quantity affects the number of PT vehicles in operation, energy consumption, operating revenues, etc. For the purpose of determining PT system performances and identifying different influences, in this paper the segmentation of operation time is proposed (Figure 1). Under the term *operation time*, the time interval between departures from one terminal to the arrival at the other terminal on the line is considered.

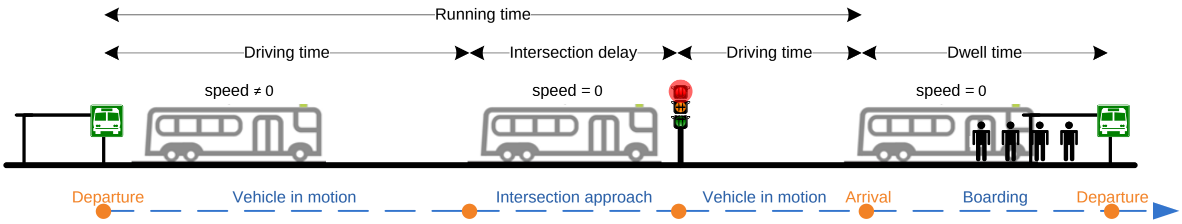

Figure 1. Different segments of the operation time

The description of the evaluation indicators depicted in the Figure 1 is listed in the Table 1.

Additionally, definitions for speed per segment and commercial speed are provided as well. These speeds can be derived based on the measurements of operation time components and known distances between adjacent PT stations.

Indicator	Description
Running time	The time that elapses from the departure of a PT vehicle from a station to the arrival of a PT vehicle at the adjacent station.
Intersection delay	The time that elapses from the arrival of a PT vehicle at an intersection approach to its passing through the intersection.
Dwell time	The time which a PT vehicle spends on PT station.
Driving time	The time that a vehicle spends in motion.
Speed per segment	Vehicle speed for predefined segments of the line.
Commercial speed	The average journey speed of PT vehicles between an origin and a destination terminal, including any delay arisen in the course of the journey, (7).

Table 1. Description of evaluation indicators

Operation time segmentation enables detection of changes (increase or decrease) of each described time interval per individual segment of the line. For example, if the increase of average dwell time is detected, a conclusion can be made that the number of passengers is higher so the time needed for patrons to get in and out of the vehicle is longer. Furthermore, if driving time increases on a specific segment and the declared vehicle speed remains the same, the increase is probably the result of an increase in the number of individual vehicles on the shared infrastructure.

APPLIED DATA COLLECTION METHODS

In order to collect the data about the operation time and its segments, four data collection methods were used:

1. Manual time recording
    - Six students equipped with stop watches traveled in trams in the time period of one week and manually recorded the time at control points (tram stations and signalized intersections).
    - Data was manually imported into Excel table.
    - During data processing, the abovementioned indicators were derived.
2. GPS vehicle tracking
    - Four GPS receivers were installed in four trams traveling on the same line.
    - Recording took place in one week period (Monday to Sunday), each day from 6 AM to 10 PM.

    - Every device recorded the vehicle position and actual speed with one second step.
    - GPS data was extracted from the devices and imported in an Excel table.
    - During data processing, the abovementioned indicators were derived.
3. Manual video data processing
    - The video track was extracted from vehicle surveillance system (for one working day).
    - While observing the recorded video, two students manually entered the data for performance indicators directly in Excel sheets.
4. PDA computer system
    - By using the application installed on a PDA device one student recorded arrival/departure times on PT stations and on intersections, as well as duration of the dwell times.
    - The application recorded and calculated the values of performance indicators. Those data from relation data base on PDA device were exported in relation data base on computer because of data processing.

While experimenting with different data collection approaches some advantages and disadvantages were detected. This experience serves as a good basis for a comparative method analysis.

ANALYSIS OF DATA COLLECTION METHODS

INTRODUCING A SET OF CRITERIA

For the purpose of conducting a comparative analysis of data collection methods, a set of criteria has been developed:

- Accuracy of the measurement
- Resolution of the measurement
- Method reliability
- Data processing
- Method execution:
    - Preparation
    - Human resources
    - Duration
    - Equipment cost
    - Simplicity.

Accuracy of measurement has been assessed based on the analysis of collected data and results. For instance, while applying manual time recording method, errors in the running time and intersection delay occurred. Depending on each individual student and their perception, errors were in range of 5 to 10 seconds for the whole tram line. PDA computer system reduces that error to about 1 to 2 seconds. While applying the GPS vehicle tracking method the source of an error is the presence of a mismatch between geographical locations of the PT stations or signalized intersections and actual vehicle position recorded by GPS receiver. This error has special significance if it is occurring at the control points, when the vehicle speed is 0 km/h (Figure 1).

Resolution of the measurement means the frequency of data input (e.g. GPS vehicle tracking method has the best resolution because vehicle position and speed is recorded in one second step, thus data is collected for the whole line, instead of just at the control points).

The method reliability criterion refers to the data and results representativeness. For example, while applying manual time recording method sometimes students did not record the exact date and time when the measurement took place. Furthermore, after the data processing it was detected that a few derived speeds per specific segment of the tramway line are simply faulty.

It can be easily concluded that for some of the applied methods, data processing is the main disadvantage (e.g. manual time recording method and GPS vehicle tracking) whilst for PDA computer system method partially processed data is exported into computer data base. This aspect is evaluated with data processing criterion.

With the method execution criterion the intention is to point out the different aspects. A preparation sub criterion is associated with necessary activities which are needed to be undertaken before measurement. For instance, manual time recording includes organizing the students and designing the layout of the data entry forms, while GPS vehicle recording requires only device instalment. The number of people needed for execution of the measurement and data processing is evaluated with human resources sub criterion. Likewise, the time interval from preparation phase to the production of results is graded by duration sub criterion. Equipment cost refers to the approximate cost of the used equipment. Last sub criterion is introduced in order to evaluate simplicity of method.

INITIAL RESULTS

The comparative analysis of data collection methods was carried out. The results are shown in the Table 2 in a scale from 1 to 5 (1 meaning worst performance and 5 meaning excellent performance).

As it can be seen from the Table 2, the manual recording method performed the worst (average grade). Slightly better method is manual video data processing method, but still it has a large number of disadvantages which makes it unattractive to use. Initial evaluation of methods shows that PDA computer system method performs very well, thanks to the user-friendly application (developed specifically for this use). The same grade would be applicable for the GPS vehicle tracking method, but first the data processing has to be improved i.e. map matching has to be used to improve accuracy of recorded tracks.

	Manual time recording	PDA computer system	GPS vehicle tracking	Manual video data processing
Accuracy	2	5	4	4
Resolution	3	3	5	4
Reliability	2	4	5	3
Data processing	2	5	1	2
Preparation	2	4	3	2
Human resources	2	3	5	4
Duration	2	5	2	3
Equipment cost	5	2	3	2
Simplicity	2	4	5	1
Average grade	**2,5**	**3,75**	**3,625**	**2,625**

Table 2: Initial method evaluation

We emphasize the fact that a complete and most accurate result of such analysis requires the application of each method in the same time and on the same public transport line. That was not the case in this research.

USE-CASE SCENARIOS

Based on the results of the initial evaluation of data collection methods, it is evident that PDA computer system method and GPS vehicle tracking method produces the best results. During the measurement some specific traffic situations occurred in which additional differences between those two methods emerged. Based on those traffic situations three use-case scenarios for one signalized intersection were synthesized.

a) b)

Figure 2. Recorded GPS track (a) and actual PT vehicle position (b)

Source of orthophoto: Croatian State Geodetic Administration

Figure 2 shows the recorded GPS track (blue line) for that specific intersection. Blue triangles on the GPS track represent PT vehicle in motion ($v \neq 0$ km/h) and rectangles on the GPS track represent that PT vehicle is stopped ($v = 0$ km/h).

In general GPS vehicle tracking method gives very accurate results for the vehicle operation time and average commercial speed. But, when the speed of PT vehicle is around 0 km/h, due to the GPS signal reflection, GPS tracks can be in offset to about 30-40 meters. Without map matching (Figure 2.b.) it is impossible to determine actual vehicle position in a specific moment of time, which is important for calculation of different operation time segments.

In case when two PT vehicles arrive on the same station in the same time, as it is depicted in Figure 3, with the GPS vehicle tracking method it is not possible to determine the exact reason why vehicle B stopped. In this specific situation, geographical location of the PT station and the position of vehicle B, when the speed v is 0 km/h, do not overlap. Knowing the GPS signal reflection problems, during the data processing it is hard to determine whether the vehicle B has reached the PT station and started to board passengers or another vehicle (PT or even individual vehicle) was occupying the PT station at the time.

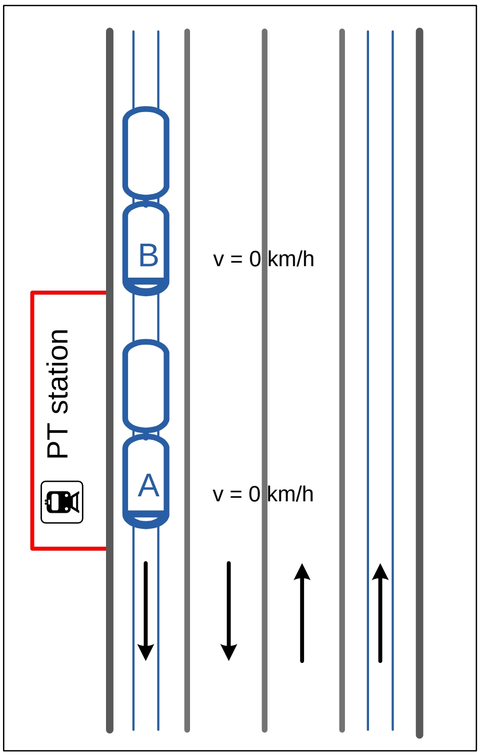

Figure 3. Arrival of two PT vehicles on the same PT station

When the PT station is located directly in front of signalized intersection and the “red” period is activated (Figure 4), intersection delay and dwell time measurements are incomplete when using GPS vehicle tracking method. This results in inaccurate calculation of driving time and speed per segment. While processing the data extracted from GPS device it can be easily detected when the vehicle speed was 0 km/h, but in this case the difference between dwell time and intersection delay cannot be recognized.

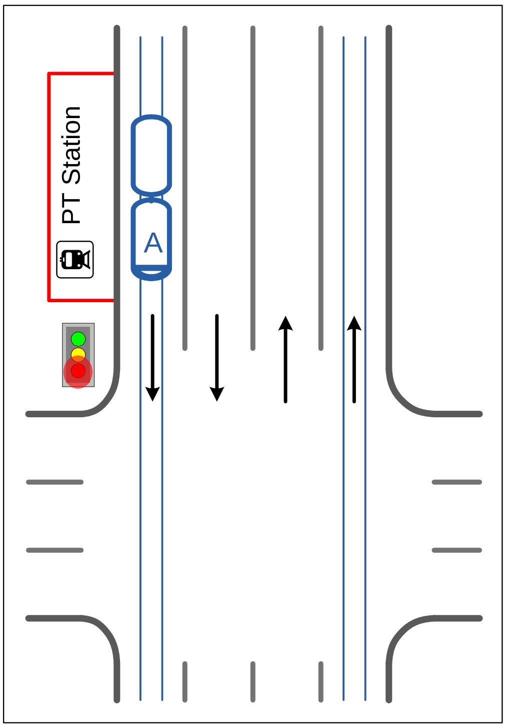

Figure 4. Specific geographical location of PT station

With the application of a PDA computer system method the abovementioned problems are avoided, because measurer can distinguish dwell time from intersection delay. Furthermore, measurer travels in PT vehicle during the measurement so he/she can initialize the dwell time measurement only when PT vehicle reaches PT station.

CONCLUSION

When transport infrastructure is shared between different transport modes the delivery of PT services can be significantly affected by road traffic. The need for evaluation of PT system performances on a smaller scale requires vehicle operation time segmentation. With that approach the impact of the priority system can be evaluated on *intersection-to-intersection* basis, if necessary.

In order to select the optimal method for data collection, four data collection methods were tested and their performances were initially evaluated. For that purpose a set of criteria and sub criteria has been developed. Based on the initial results and the average grade, two best performing methods were PDA computer system and GPS vehicle tracking method. With the help of several use-case scenarios additional differences between those two methods were detected. Even though the GPS vehicle tracking method has a several disadvantages in compare with PDA computer system method, it is still very appealing because the data is recorded in one second step which enables more detailed analysis.

A new method which could perform excellent by all criterions, thus produce most accurate results, would have to be a combination of PDA computer system and GPS vehicle tracking methods, with necessary software support.

In our future research we will focus on developing software for fully automated data processing. This software will unite two methods which have the highest average grades.

REFERENCES

(1) Sampaio, R B, Neto, O L and Sampaio, Y, "Efficiency analysis of public transport systems: Lessons for institutional planning", *Transportation Research Part A*, Elsevier, March 2008, pp. 445-454

(2) "Evaluation of the Public Transport Priority". 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) "SYVARI – BUS Priority Strategy: Easy, Effective and Independent". Available at www.hel2.fi%2Fliikenteenohjaus%2Fjenka%2Fdownload%2FSYVARI_presentation_20080416.pps&rct=j&q=A+real+example+of+the+Syvari+control&ei=q2z6S8f3IdmVOPepxZUM&usg=AFQjCNHgFC3-XYuXrJo-oEdJJKojYc5uag

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

(6) "Roadspace Allocation for Public Transport Priority". Available at http://www.aitpm.org.au/Conference_2005/Proceedings/3_3_Young_and_Currie.pdf

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