MEASUREMENT OF PUBLIC TRANSPORT PERFORMANCE INDICATORS BY PDA COMPUTER SYSTEM

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Abstract

Public transport (PT) performance indicators are quantitative attributes that are related to the quality of public transport service. The performance indicators are not unambiguously and universally defined, instead their selection depends on the specific study or project. The most frequent performance indicators that are currently used are, for instance: commercial speed in the corridor, delay time, accuracy of timekeeping, etc. For the calculation of values of these indicators, the required data includes the time positions of vehicles on the defined points of the traffic network. The past measurement practice included the measurer who used a stopwatch to record the times at the control points into tables which were prepared prior to the measurement. The data was then imported into a computer and along with other data, the indicator values were calculated. This paper shows a new method of measuring values of performance indicators by the means of PDA (Personal Digital Assistant) device which uses "Windows Mobile" operating system. For this purpose a software application was developed in the "Visual studio" programming environment, using "C#" programming language. The application was named "TRAM FPZ". The developed application was tested on the *Savska cesta* Street corridor on tramway network. From the measurer perspective the implementation of such application requires less effort with a very user-friendly application interface. The measured data is more accurate and more reliable, and indicator values are obtained immediately. The main purpose of the developed application is to serve as a system which may be used to evaluate the accuracy of end results when different measurement techniques are deployed, i.e. fully automatic system which integrates the capabilities of GPS and PDA devices.

Keywords: public transport performance indicators, software support, mobile application, tramway traffic, UML

1. INTRODUCTION

Evaluation of public transport (PT) system performance requires a set of performance indicators or merits which may be used for quantitative evaluation of current state of PT system. Performance indicators define the set of data that must be collected or calculated in order to determine the level of delivered performance or to detect a critical spots in PT network where performances deteriorate. If the same data set is collected before and after the implementation of new systems or services (e.g. priority system), any difference in values of performance indicators can lead to evaluation conclusions about the impact of that system or service on the traffic environment.

Various projects and research studies define PT performance indicators differently. In the available literature on this topic, there is a distinct lack of universal approach when defining PT performance, PT quality of service, PT performance indicators and possible analysis approaches. Authors in **[1]** define four levels of PT system performances: external, strategic, tactical and operational. In **[2]** evaluation of PT system performances considers only economic performance indicators, while in **[3]** authors dedicate more attention to the user perspective of PT performances.

This paper is based on the work undertaken within CiViTAS ELAN project (FP7 project, co-financed by the EC), where performance indicators are defined as different quantitative time variables which can be measured on the field or calculated. During the project implementation the first measurements of performance indicators were conducted manually. That technique included students equipped with stop watches. They were sent to ride in PT vehicles and record the exact time when vehicle reaches the predefined control points (PT stations and intersections). After the measurements the data had to be manually imported into computer for data analysis. In order to create a sufficiently big data source, the measurements lasted for one full week on different PT lines. Therefore, a large amount of data had to be recorded and manually inserted which increased a possibility of an error.

In order to decrease the margin of an error of manual measurement and to efficiently use available resources, a Personal Digital Assistant device (PDA) was used and mobile application was developed (TRAM FPZ). In the work which followed after the application development the intention was to investigate the possibility of fully automatic measurements which could be achieved by PDA-GPS integration. The market is full of mobile devices which may be used for data collection and they can be installed into PT vehicles. However, fully automatic measurement system has to meet several criteria such as: price, availability of spare parts, interoperability with other systems and devices, flexibility (in terms of defining different measurements), measurement resolution and accuracy, efficient data analysis, **[4]**. By integrating the PDA device and GPS receivers the aforementioned requirements can be met.

2. PT PERFOMANCE INDICATORS

Performance indicators represent a quantitative attributes which describe the state of public transport system and processes in traffic network which are related to public transport. As mentioned before, performance indicators may also be used for evaluation of impacts which new systems or services can produce in the environment. Different sets of performance indicators may be defined depending on which system is the subject of evaluation (e.g. tramway network, bus network etc.). In this paper the same performance indicators were used as they were in the research of CiViTAS ELAN project. Specifically, the indicators are quantitative attributes which represent different time intervals in the tramway itinerary. This approach is depicted in Figure 1, where operation time segmentation is introduced. That segmentation enables the detection of critical spots in the PT network where PT performances deteriorate, **[5], [6]**.

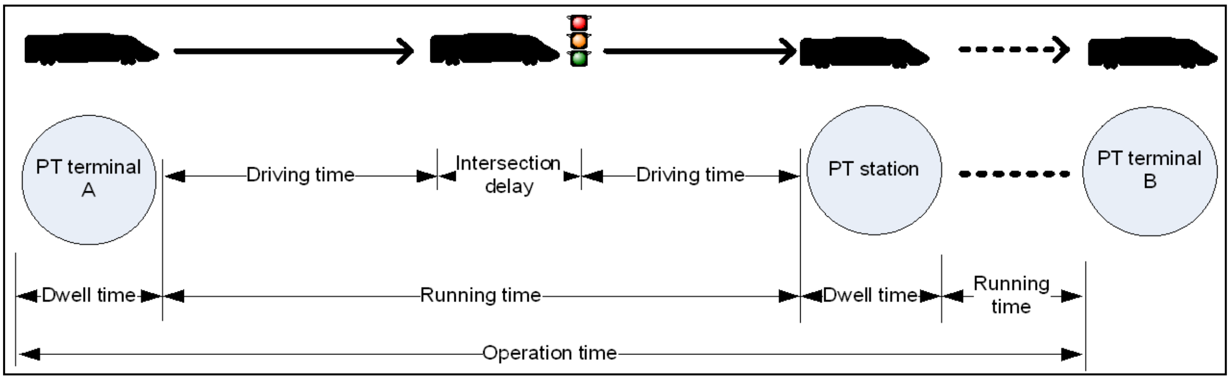

Figure 1: Operation time segmentation, **[6]**

Following the same approach as it is described in **[6]**, the public transport performance indicators are:

- Operation time
- Running time
- Intersection delay
- Dwell time
- Driving time
- Speed per segment
- Commercial speed.

Operation time represent the time that elapses from the departure of a tramway from the PT terminal to the arrival at the other terminal on the line. *Running time* is the time that elapses from the departure of a tramway from a stop to the arrival of a tramway at the adjacent stop. *Intersection delay* is the time that elapses from the arrival of a tramway at an intersection approach to its passing through the intersection. *Dwell time* is the time which a tramway spends on PT stops for boarding and alighting of passengers. *Driving time* is the time that a vehicle spends in motion. *Speed per* segment is the tramway speed on the predefined segments of the line and it is calculated based on the length of the segment and time spent on that segment. *Commercial speed* is the average journey speed of tramway between an origin and a destination terminal, including any delay arisen in course of the journey, **[6]**, **[7]**.

3. PDA MEASUREMENT SYSTEM

3.1 PDA device

The Fujitsu Siemens «Pocket Loox T830» was selected as a suitable PDA device for the development and testing "TRAM FPZ" software system. The device uses the “Windows Mobile 5 Phone Edition” operating system, which allows organization of a local database which was one of the main requirements for selection of mobile device. Since its system of data storage is harmonised with the one on personal computers, full synchronisation of local and central database is possible. It should be noted that for this type of device platforms for software development are available, thus they may be relatively simply programmed by using standard programming languages, e.g. C# programming language. Furthermore, the display of PDA device is sufficiently sized (supports the resolution of 240x240 pixels) for the developed application. The display light and contrast are also acceptable.

3.2 Software solution – “TRAM FPZ” application

The purpose of the “TRAM FPZ” application is to provide assistance while measuring time intervals on the control points of public transport and the calculation of performance indicators. Here it is necessary to make the measurer’s job maximally simple and to reduce maximally the probability of error, i.e. the software interface for the measurer should be simple and well laid-out. Furthermore, the application itself has to be flexible regarding the measurement location, i.e. it should allow upgrades of the database with data about other corridors, needing no additional changes in other parts of the software.

Because of the mentioned reasons, for the development of the application a multi-layer architecture has been selected. Individual application layers communicate with the layer below or above, which allows changes in individual layers. The advantages of a multi-layer architecture are the scalability (application that can be run on various computers), ease of maintenance, possibility of code re-usage etc. There are also drawbacks of such architecture. For example, it requires the experience and has a complicated process of defining of the location of software elements to specific layers, **[8]**.

Software architecture of “TRAM FPZ” application consists of three layers:

- Data Layer,
- Business Layer,
- Presentation Layer.

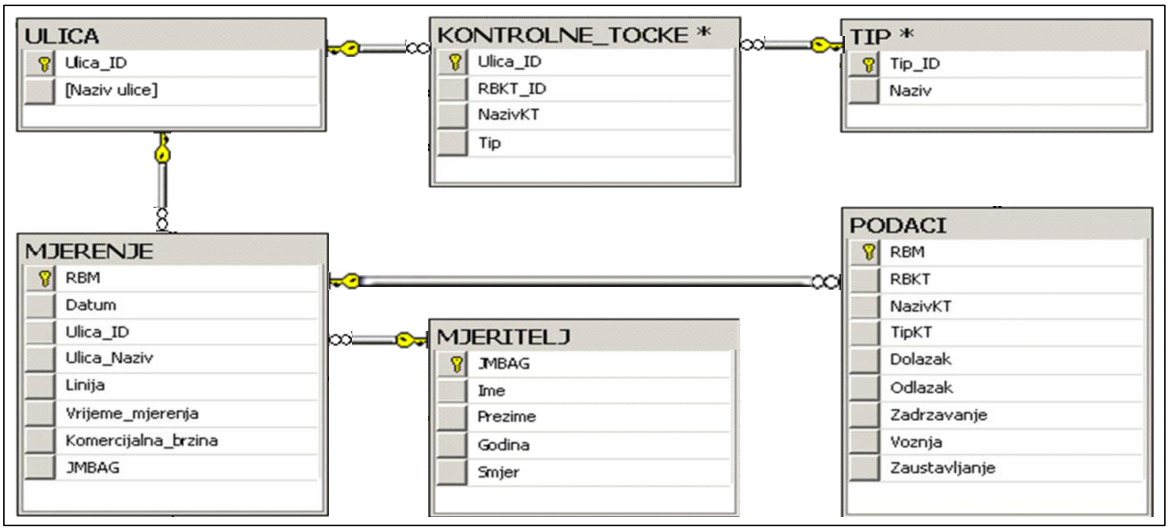

Figure 2: Data layer organization

The role of the data layer is the retrieval of data and delivery of data to the business layer. The data layer is mainly the database. Here the mobile database “SQL Server CE” was used, which has been adapted to the Pocket PC.

Figure 2 shows the database model of the “TRAM FPZ” application with connections between the tables. The table MEASURER (*MJERITELJ*) contains data about the measurer. The table STREET (*ULICA*) contains a list of corridors, with directions. The table MEASUREMENT (*MJERENJE*) contains data about the measurement and the calculated indicator of commercial speed. The table CONTROL POINTS (*KONTROLNE TOČKE*) contains data about control points, whereas the table TYPE (*TIP*) contains the description of the type of the control point (intersection or PT station). In the table DATA (*PODACI*) all of the measured and calculated time variables at control points are entered.

The role of the business layer is data processing based on the given conditions and algorithms. It also allows communication between the presentation and data layers. For instance, it makes possible for the user to retrieve the data or enter the data into the database. The presentation of the basic software elements per layers and UML collaboration diagram is given in Figure 3.

In the “TRAM FPZ” application, the business layer is divided into three functional parts: “Control object”, “Measurement results” and “Temporary memory of control points”. The task of the “Control object” in the business layer is the distribution of tasks and coordination of individual software elements. The “Temporary memory” contains the necessary data for current measurement, and they change depending on the position in the corridor. The control object in communication with the data layer is responsible for data retrieval on demand (data about the route) and recording of measurement results. The task of the block “Measurement results” is the processing of received data and the calculation of indicators.

In the presentation layer the Graphical User Interface (GUI) is defined, which makes possible for the user to exchange information (commands and data) with the system over the “Control object”. In this application there are two basic software forms of the user interface. With the form “Travel definition”, the identification data about the measurer, measurement and the measurement location are input into the system, whereas the form “Measurement” serves to perform the measurement itself. The forms of presentation layer are presented in the figures in Section 4.1.

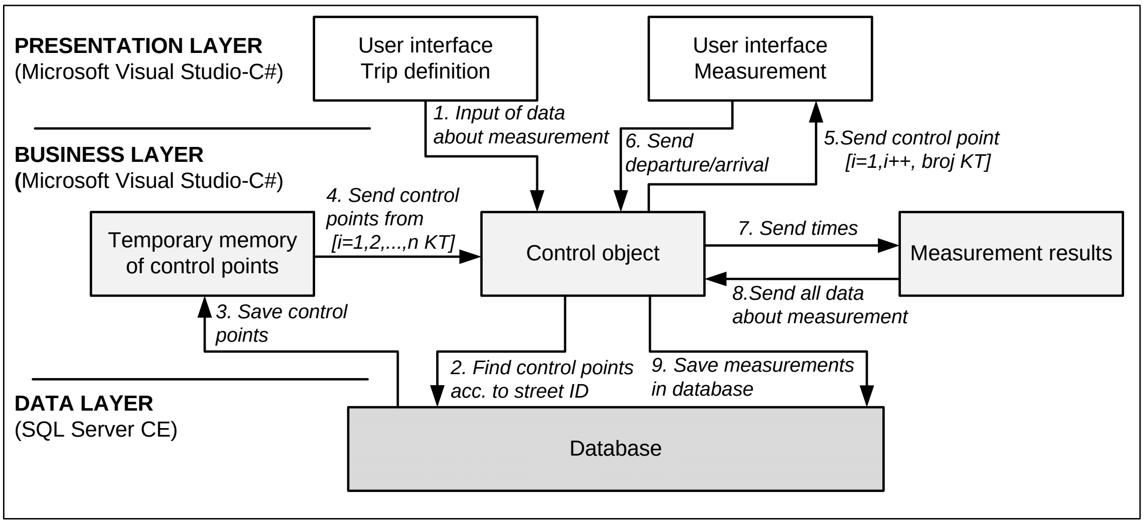

Figure 3: UML collaboration diagram

Figure 3 shows UML collaboration diagram of the layers and individual programming blocks. The ordinal numbers in the figure mark the sequence of process performance. Step (1) refers to the definition of measurement parameters, based on which the data about the control points are retrieved in step (2), which are adapted and displayed on the screen step (3, 4, 5). With step (6) the data about the time intervals of arrival to and departure from the control point are entered. Steps (4, 5, 6) as well as steps (7, 8), which serve for data processing and preparation for recording into the base, are repeated as long as the measurement is taking place. In step (9) the final measurement results are stored in the database.

The determination of indicators that will be finally saved in the measurement base as results is based on the usage of timers that are integrated in the "TRAM FPZ" application. The measurer uses the activation buttons on the MEASUREMENT form to send to the system the time moments on control points. Using the recorded time variables and the known corridor parameters the indicators are calculated.

The software code of the "TRAM FPZ" application was written in the programming language C#. C# is a modern object-oriented programming language developed for .NET environment, **[9]**. The programming code of this application contains 653 lines divided into three programming modules, which are assigned appropriate forms for communication with the user.

4. RESULTS

4.1. Testing the TRAM FPZ application

The TRAM FPZ application was tested on the CiViTAS ELAN demonstration corridor depicted on Figure 4 (*Savska cesta* Street from *Frakopanska* PT station to *SD Stjepan Radić* PT station). *Savska cesta* Street is one of the most important streets in Zagreb because it carries a high amount of traffic load during the day and it connects the historical city centre with suburban areas of the city. This corridor is 3337 metres long and in it there are 10 PT stations in each direction of travel and 13 intersections, thus it contains 23 control points.

When the user starts-up the application on the PDA device, the login form appears where the user inserts the basic data. In the next form, depicted in Figure 5, user can define the basic parameters of the measurement, such as: corridor, direction of travel and number of the tramway line. In order to minimize the possibility of making an error the application automatically checks the data which was inserted. For example, if the user does not specify the number of the tramway line or if he/she inserts the wrong number of the line, which does not travel in the specified corridor, the application will warn the user that the error, in the data input, has occurred.

When the user clicks *Next* (Figure 5 – *Spremi*) the measurement starts and the next form appears (Figure 6). In this form the control points of the selected corridor are presented. The user can see on the screen the control point position in the corridor, name and type of the control point, arrival and departure time on the control point and the elapsed time since the last tramway stopping. The measurement itself is initiated by clicking the activation keys: ⟨*Dolazak*⟩, ⟨*Odlazak*⟩ and ⟨*Prolazak kroz zeleno*⟩ (i.e. ⟨*Arrival*⟩, ⟨*Departure*⟩ and ⟨*Pass through green*⟩, respectively).

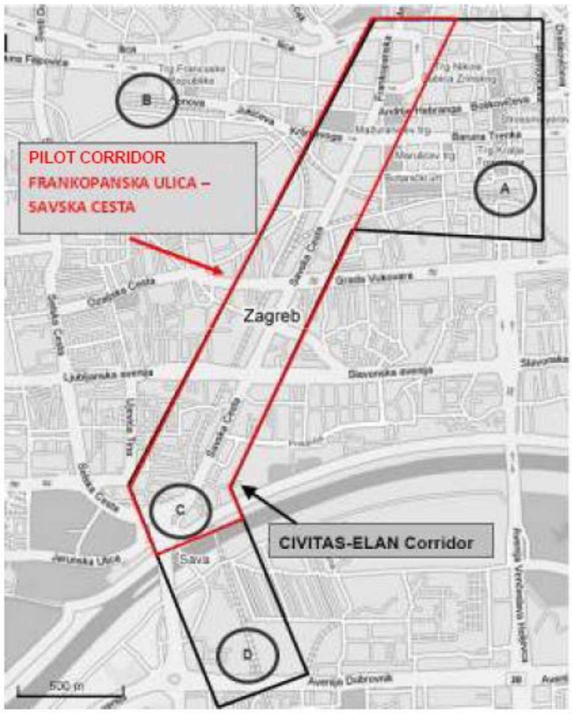

Figure 4: Test corridor **[6]**

Figure 5: Presentation of form - Defining the measurement parameters

The measurement proved to be a significantly simpler in compared with manual measurements. In this case the measurements were conducted without any errors. Nevertheless, note that the final results depend on the human factor, i.e. the user who is final responsible for activating virtual keys on the screen.

Figure 6: Presentation of form - Measurement
(1) Control point position;
(2) Title and type of the control point;
(3) Activation keys;
(4) Integrated timers

4.2. MEASUREMENT RESULTS

After the measurement, the results and calculated values of performance indicators can be analyzed on a computer. Data transfer between PDA device and computer is made by using the application Database.NET.

Figure 7 depicts the results of the measurements of performance indicators for a single tramway journey. In this example the table shows the basic information about the user (name, surname etc.). On the special sheet the data about the tramway line, date and measurement duration is presented, as well as derived commercial speed. On the final result sheet the main results are shown. For each control point of the corridor the following set of data is indicated:

- Type of control point (PT station or intersection)
- Arrival and departure time on the specific control point
- Running time between adjacent control points
- Dwell time / Intersection delay on specific control point.

In this case (depicted in Figure 7) results are presented for tramway line number 17, direction of travel - A (southbound). Some critical values may be identified. These values show that on several spots in the corridor the improvements are needed. For example, the commercial speed in this specific journey was only 9 km/h (red rectangle no. 1) while average commercial speed in City of Zagreb is 17 km/h. This proves that in this period of the day transport demand in the corridor is on its peak value. Furthermore, on some segments of the corridor the speed reaches the minimum values of 6 km/h (this speed is derived from the data marked with red rectangle no. 2). Dwell time on certain PT stations is also unusually long (red rectangle no. 3). Based on this data a various graphical presentations of data can be made.

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RBM	Datum	Ulica_ID	Ulica_Naziv	Linija	Vrijeme_mjerenja	Komercijalna_brzina
21	08.04.2010	1	Savska smjer A	17	00:21:39	1. 9

RBKT	NazivKT	TipKT	Dolazak	Odlazak	Zadrzavanje	Voznja	Zaustavljanje
1	FRANKOPANSKA	Stajalište	13:08:35	13:09:27	00:00:52	00:00:00	00:00:00
2	Dalmatinska/Varšavska	Semafor	13:09:42	13:09:42	00:00:00		
3	Deželićeva/Masarykova	Semafor	13:10:28	13:11:02	00:00:34		00:01:00
4	TRG MARŠALA TITA	Stajalište	13:13:07	13:13:53	00:00:46	00:03:39	00:02:04 2.
5	Kačićeva/Trg M. Tita	Semafor	13:13:58	13:14:35	00:00:37		00:00:04
6	Kršnjavoga/Vukotićeva	Semafor	13:15:09	13:15:09	00:00:00		
7	VODNIKOVA	Stajalište	13:15:39	13:16:02	00:00:23	00:01:45	00:01:03
8	Vodnikova	Semafor	13:16:12	13:16:39	00:00:27		00:00:09
9	Jukićeva/Crnatkova	Semafor	13:16:48	13:16:57	00:00:09		00:00:08
10	Trg D. Petrovića	Semafor	13:17:47	13:17:47	00:00:00		
11	STUDENTSKI CENTAR	Stajalište	13:18:03	13:18:26	00:00:23	00:02:00	00:01:04
12	Zgrada T-Com	Semafor	13:18:35	13:18:35	00:00:00		
13	Vukovarska avenija	Semafor	13:21:25	13:22:39	00:01:15	3.	00:02:58
14	ZAGREPČANKA	Stajalište	13:22:52	13:23:20	00:00:29	00:04:25	00:00:11
15	Gagarinov put	Semafor	13:23:51	13:24:05	00:00:13		00:00:30
16	UČITELJSKI FAKULTET	Stajalište	13:24:11	13:24:45	00:00:35	00:00:49	00:00:05
17	Slavonska avenija	Semafor	13:25:20	13:25:35	00:00:15		00:00:33
18	VJESNIK	Stajalište	13:25:49	13:26:10	00:00:21	00:01:02	00:00:12
19	Prisavlje	Semafor	13:26:33	13:27:10	00:00:37		00:00:23
20	PRISAVLJE	Stajalište	13:27:35	13:27:53	00:00:18	00:01:24	00:00:23
21	VESLAČKA	Stajalište	13:28:30	13:28:45	00:00:15	00:00:37	00:00:37
22	Savska/Horvaćanska	Semafor	13:29:16	13:29:16	00:00:00		
23	SAVSKI MOST	Stajalište	13:29:36	13:30:14	00:00:38	00:00:50	00:00:50

Figure 7: Example of measurement results

5. CONCLUSION

Performance indicators are important variables which have to be considered in the process of investigating traffic flow characteristic and network performance, not only for PT system but also for general traffic. There is also a link between PT performance and PT quality of service which has not been comprehensively investigated so far, but the relation between those two cannot be denied.

Traditional, manual measurement technique (using stop watches and writing time intervals into tables) has proven to be inefficient and time-consuming. Furthermore, there is a high possibility of making an error which makes end results unreliable. This is further reflected on the evaluation conclusion derived from that kind of data. On a specific case we showed that introduction of PDA device and TRAM FPZ application into the measurement process, significantly improves accuracy of the measurement. TRAM FPZ application reduces the window for making an error but it still needs a human operator, thus errors are reduced but not cancel out.

The used PDA device has proven fairly satisfactory regarding measurement performance. The display had a good characteristics: sufficient size, resolution and contrast. The “TRAM FPZ” application is designed in a three-layer programming architecture which makes it possible to meet the requirements: scalability of application and flexibility, i.e. possible changes in the database without having the need for modifications in other parts of the application. Graphic User Interface designed in the presentation layer provides simple performance of the measurement.

TRAM FPZ computer system can be efficiently applied for field data collection. After the measurements and data transfer into a computer, end results are presented in tables. This then enables the users to analyze the data in more detailed manner and to reach conclusions about PT system performances on a specific corridor or segment, for a specific PT line or time of the day. Those conclusions can have a high value when trying to determine which parts of the network need improvements. Additionally, the amount of data which is collected creates an important data source. Base on those data different traffic simulations (micro, macro and mezzo) and solution can be developed (i.e. PT priority schemes, adaptive signalling plans etc.).

In our future research we will focus on integration of PDA computer system and GPS. If successful, the synergy between those two technologies, and the connecting application, will ensure completely automated and low cost data collection process.

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