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REAL-TIME MONITORING AND MANAGEMENT IN PUBLIC TRANSPORT SYSTEM – BELGRADE CASE STUDY[1]

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Abstract

The public transport system (PTS) is a complex organizational and technological system by its structure, operation and management. One of the basic and most important pre-conditions for effective and efficient PTS is an integrated management. Efficient management of complex PTS implies computerization of all processes in the system and data collection. In order to improve management of PTS in Belgrade local municipality has implemented new vehicle management and fare collection system. The new system is not only a reliable database and a tool for off-line planning and design of PTS, but it also enables real-time vehicle monitoring and management. The paper deals with this particular module of the system. Description of the system's architecture is presented with the main functional elements. Emphasis is placed on the description of the communication system and data structure necessary for the effective and efficient real-time monitoring and management.

Keywords - Public transport system; monitoring; real-time management

INTRODUCTION

The system of public transport in Belgrade is very complex because there are several public and private system operators and several mode subsystems (buses, trolleybuses, trams, minibuses), with considerably deployed resources (vehicles, staff, energy, finances).

[1] Professional paper

Managing such a complex system cannot be efficiently done without the computerization of all processes in the system and data collection in order to create a reliable database.

The question of an integrated tariff system and tariff policy, fare and ticketing system as well as centralized and integrated management and control of the transport process represents one of the main and most complex prerequisites for an efficient and effective system of public transport. It has been proven in practice that the efficiency of these and similar systems is increased through the information system based on an extensive database [1].

These issues are important for local authorities as one of the possible tools for implementing the policy of sustainable development via controlled use of passenger cars, social policy towards certain population groups, and for reaching the envisaged level of subsidies, meeting user needs by offering one of the most important services in the city.

In 2012, Directorate for Public Transport (DPT) of the City of Belgrade has implemented a new system for managing public transport, which represents a very powerful tool for reaching the foregoing goals and benefits of all stakeholders. Two main parts of the system are the subsystem for Tariff and Fare Collection and the subsystem for Vehicle Management. The part of the system concerning Tariff and Fare Collection was analysed and presented at an International Conference [2], also public private partnership for the introduction of e-ticketing in Belgrade was presented at an International Conference [3].This paper will focus on the Vehicle Management System and special attention will be given to the real time vehicle monitoring and management.

VEHICLE MANAGEMENT SYSTEM

Technically, the main elements of the management system (Figure 1) are: Control Center (CC – Main Dispatch Center), data center (main and support), other users (operators, clients), communication infrastructure and vehicle equipment [4].A computer network connected to the Internet, which enables the operational management and control of the main transport process, is installed at the Control Center. Main and support data centers archive collected data and transfer necessary data to the CC.Other system users are operators and passengers who can access the system information in accordance with their needs and demands (and in compliance with the defined user rights).

Communication infrastructure provides all necessary functionalities of data transfer between the vehicle and the CC, the vehicle and the depot, the CC and the bus stop, the CC and the operator. The type of network which is used for the transfer of data into the subsystem for vehicle management is the GSM cellular network, that is, GPRS and SMS communication.

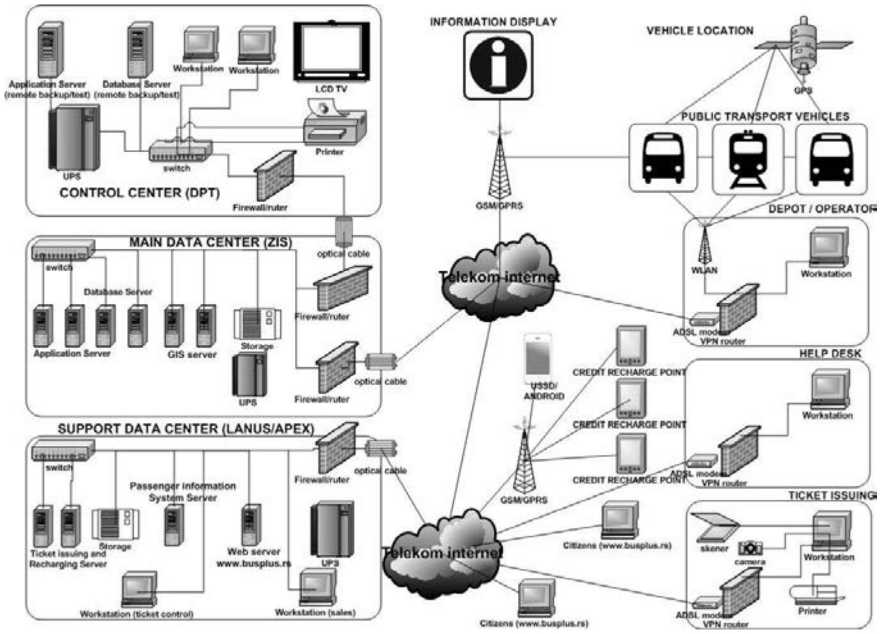

Fig. 1. The system’s architecture in Belgrade

The equipment installed in the public transport vehicles consists of a communication device (a complex device made of the GPS/GPRS module with its equipment, microprocessor, memory and power supply) and the driver’s panel (the main functions are communication with the dispatch center via the matching GSM/GPRS module and driver identification via RFID). An overview of all system elements is given in Table 1.

Table 1. Public transport management in numbers

System elements:	**Number:**
Servers	13
Vehicles	1950
Depots	39
Ticket issuing points	>60
Workstations	>100
Credit recharge points	>1750
Ticket control devices	>500
Information displays	>15

The system archives and analyses the vehicle data thus enabling a high-quality monitoring and control. The main goal and output of auto-location, and vehicle and staff surveillance in real time is to determine the degree to which planned and contractual obligations are met.

With a GPS device and a communication device, every vehicle sends two types of packages of User Datagram Protocol (UDP) data to the CC. A standard data package which is sent every 30 seconds and every 2 hours, as well as a forced data package sent in predefined events. In case of communication failure, data are stored in computer memory in the vehicle and right after the connection has been established again, they are sent to the CC.

In order to describe the place and time of predefined events more properly, the route scheme with a terminal and bus stops is presented in Figure 2. Most events are related to the zones of bus stops and terminals which are circular and defined by the adopted diameter of 40 meters. Predefined events are: driver login/logout, journey start/end, terminal stop in/out, stop in/out.

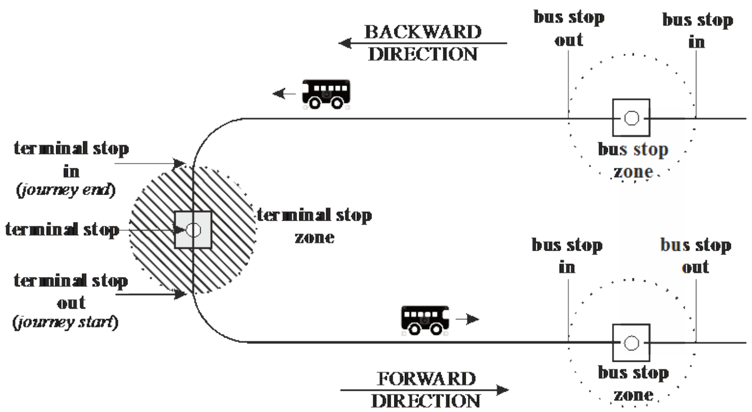

Fig. 2. Predefined events on the route

Information relevant for vehicle monitoring which the devices in vehicles record and send via the UDP package are:

- Vehicle ID (unique vehicle number), GPS position (longitude, latitude), sequence number (defined by schedule) and speed,
- Line code (unique line number) and direction (forward/backward),
- Trip number (every planned trip has a unique number),
- Terminal stop ID (unique terminal stop number) and in/out time,
- Bus stop ID (unique stop number) and in/out time,
- Bus stop count (number of passed bus stops on line direction),
- Driver ID (unique driver number) and login/logout time.

The amount and quality of information contained in the packages depend on the frequency of sending a particular package as well as on the event itself (in the case of forced data).

QUALITY OF SERVICE

The users of Mass Passenger Public Transport chose "vehicle comfort" and "transport reliability" as two most important features of the quality of service. These features were chosen by almost 80% of users [5]. Similarly, according to users, the two sub-features of transport reliability - regularity and punctualityhold the first two places among all sub-features of service quality.

During the transport process functioning, schedule disruption is a common occurrence. The disruption decreases the quality of service, i.e., leads to the dissatisfaction of users. It also causes a difference between planned and realized transport performance. The causes of disruption can be related to the operator’s performance on a particular line (internal) or to the impact of the environment in which the public transport system is functioning (external). Figure 3 shows the main causes of service variability and also indicates which element is affected [6].

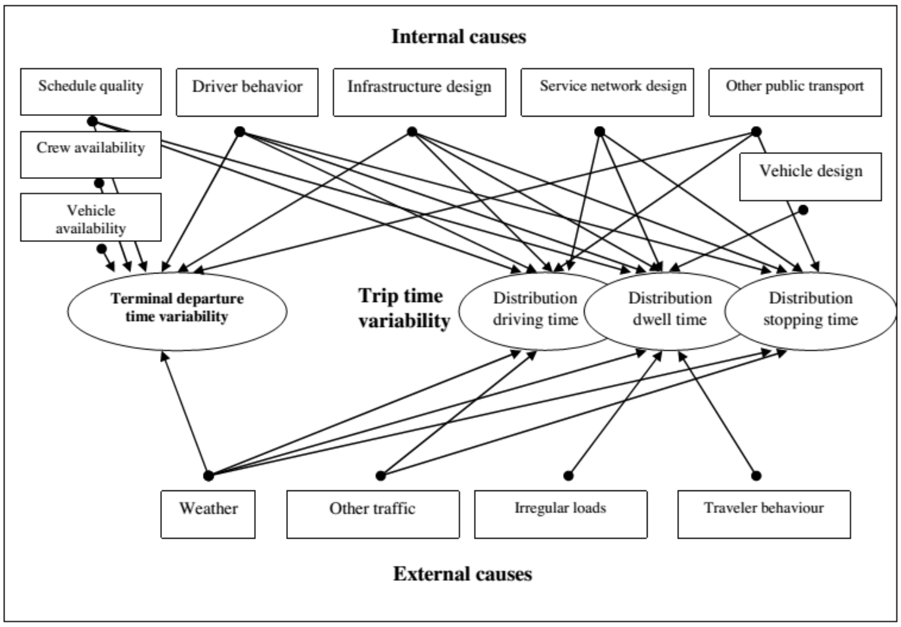

Fig.3. Main causes of service variability [6]

Common operational measures used to eliminate the disruptions are:

- Reducing/Increasing the waiting time at terminals,
- Reducing/Increasing the turnaround time on the line,
- Reducing/Increasing or increasing the planned headway,
- Replacing the vehicle which "deviates" from the schedule with a replacement vehicle from the depot,
- Route changes – service only on one part of the route and/or only on selected stops.

Dispatcher of the CC are responsible for the implementation the above measures. The basic prerequisite for the successful elimination of disruptions is the availability of quality data in real time.

REAL TIME VEHICLE MONITORING SYSTEM

The vehicle management system in Belgrade monitors transport in space (routes, stops, terminals, etc.) and in time (schedule, vehicle speed, turnaround time, driver's working hours, shifts drivers work on, etc.).Automatic data collection provides two different sets of collected data: real time and off line. (Figure 4).Off line data are used for a detailed and long-term analysis of the transport process and will not be taken into consideration in this paper. Real time data are data vehicles send during the transport process functioning in a two-way communication with the system.

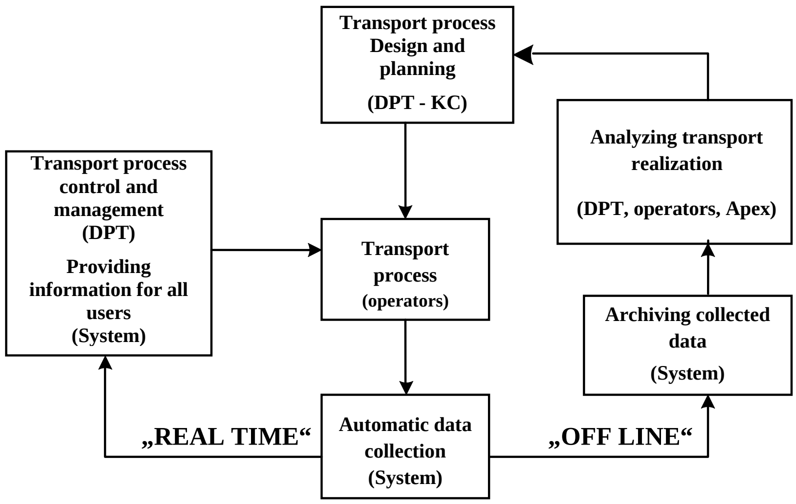

Fig. 4. Diagram of management process in public transport

The implemented system represents a link between the transport process functioning (public transport vehicles on the network of lines) and the management and control sector. The system automatically collects the information sent by vehicles (data packages) in real time. All collected data are archived in the main data center and forwarded to DPT CC. At the CC, Real time vehicle performance module (RTVPM) analyses the data received and following the predefined criteria alerts the dispatchers about disruptions that occurred in real time. All disruptions which are controlled and reported for each line and direction individually.

The module follows five most important parameters of the transport process functioning. Name of parameters, criteria for activating the alarm and short description are presented in following table.

Table 2. Parameters of transport process and criteria for activating

Name		Criteria for activating	Description
Planned headway disruption (Regularity)		$if\, i_r < i_p - \frac{i_p}{2} and if\, i_r > i_p + \frac{i_p}{2}$	i_p- planned headway i_r- realized headway
Planned journey start time violation (Punctuality)		$if\ \lvert t_{journey} - t_{plan} \rvert > 5\ min$	$t_{journey}$- journey start time (terminal stop out time) t_{plan}- planned trip start time
Vehicle accumulation		$if N_{stop} = 0$	N_{stop} - number of bus stops between two following vehicles
Route violation		$if R_{dev} > 150\ m$	R_{dev}- vehicle current position distance from defined line route
Unrealized trip	Urban lines	$if t_{system} - t_{plan} > 5\ min$ and $if\ not_{journey}$	t_{system}- current system time t_{plan}- planned trip start time
	Suburban lines	$if t_{system} - t_{plan} > 10\ min$ and $if\ not_{journey}$	

The criteria defined in this way enable an easy and quick comparison of data on the functioning in real time with the data defined according to a plan and archived in the system's database.

CONCLUSION

A brief analysis of the new public transport management system in Belgrade given in this paper clearly shows that the introduction of this system can lead to an increased public transport management effectiveness and efficiency. In order to achieve this goal special attention is given to the design of the Real time vehicle performance module and its elements.

Five parameters of the transport process functioning were defined for the system of public transport in Belgrade. Accurate criteria for activating the alarm which warns the dispatcher that a disruption occurred were defined for every parameter.

In the upcoming period, it is necessary to carry out the research which would precisely determine and quantify the benefits of the new system and investigate the possibilities of further enhancement. Further development and improvement should focus on the introduction of new parameters for the transport process control in real time. Besides, the system performance should permanently be monitored using the analysis of existing parameters and adjusting their criteria for alarm activation.

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