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[1.]Goran KUZMIC, [2.]Dusanka BUNDALO, [3.]Zlatko BUNDALO, [4.]Mirko SAJIC, [1.]Aleksandar STJEPANOVIC, [1.]Mirko STOJCIC

# INFORMATION AND COMMUNICATION SYSTEM FOR OPTIMIZATION OF LENGTH, DURATION AND COSTS OF TRAVELING IN ROAD TRAFFIC

[1.]Faculty of Transport and Traffic Engineering Doboj, University of East Sarajevo, BOSNIA & HERZEGOVINA
[2.]Faculty of Philosophy Banja Luka, University of Banja Luka, BOSNIA & HERZEGOVINA
[3.]Faculty of Electrical Engineering Banja Luka, University of Banja Luka, BOSNIA & HERZEGOVINA
[4.]Atos banka ad, Banja Luka, BOSNIA & HERZEGOVINA

**Abstract:** The possibilities and ways of design and implementation of distributed information and communication systems for management of traffic and road infrastructure in road traffic that are used in intelligent transportation systems, are considered and described in the paper. First, such intelligent transportation systems are shortly described. Then, the basic architecture of one distributed information and communication system for intelligent management in road traffic is proposed. The system consists of a central part of the system and several modules or subsystems, responsible for certain individual functions of control. Most of the paper is dedicated to the description of one practically designed and implemented module, or system, for optimizing travel and travel costs. The design and architecture of the implemented system are described. The system is intended for optimization of the length, time and cost of traveling of users in road traffic. It offers to the user several of the most favourable routes, i.e. traveling routes, between selected travel destinations, with their lengths, expected travel times and expected travel costs, on journeys that cross state borders and use roads with toll payment. It takes into account the duration of congestion at border crossings and toll payment stations, as well as the prices of tolls on the offered traveling routes. More detailed experimental research was performed on the designed and implemented system. Situations when crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia were observed practically and experimentally. Also, toll payment stations on highways in Republic of Srpska, Serbia and Croatia were observed. Some experimentally obtained results are given in the paper.
**Keywords:** road traffic, management of traffic, design & architecture, optimization

## INTRODUCTION

The constant development of computer, information and communication technologies and systems, as well as intelligent systems based on them, enables the improvement, advancement and increase of possibilities, efficiency and economy of operation of various types of systems in many practical areas and applications. Among the very important areas in which intelligent systems based on the application of information and communication technologies are used are transport and traffic. For control and management of transport and traffic in practice are increasingly being used intelligent transportation systems (ITS – Intelligent Transportation Systems). There are many advantages and benefits that the application of intelligent transportation systems enables and gives to those who organize and implement traffic, as well as to all traffic participants [1–7].

High costs of building transportation infrastructure, lack of space in urban areas, growing criteria for preserving the quality of the environment and acceptable levels of service of the transportation system, have imposed the need for better and secure use of existing capacity of the road network. Great opportunities for solving complex requirements that users and society as a whole place before the traffic system, are in the field of traffic management.

Although the development of hardware and software in the field of transport can provide a more efficient approach to traffic management, it becomes clear that traffic management, viewed as a separate entity, cannot solve all traffic problems. Significant attention is beginning to be paid to the integration of other systems into the framework of traffic management with the application of modern technologies. This concept of integration has contributed to the emergence and development of intelligent transportation systems (ITS) [1–7].

Development in the field of ITS is a strategically necessary component of the development of a country's transport system. Many ITS applications have already entered the framework of national strategies for the development of the future, popularly called e–transport, based on a high degree of integration of modes of transport based on different information and communication systems and platforms. The information and communication technology is always there to help people to perform their jobs and tasks with much less effort, in a more economical, more secure and more simplified way [1–7].

The ways and possibilities of implementation and design of distributed information and communication systems used in intelligent transportation systems for management of traffic and road infrastructure are considered and described in the paper. Described are architecture and organization of such systems, and information and communication technologies used in such systems.

It is proposed the basic architecture of one distributed information and communication system for intelligent management in road traffic. The system consists of a central part of the system and several modules or subsystems. Each module or subsystem is performing a certain individual function of control in the system.

Most of the paper describes one practically designed and implemented module, subsystem or system, system for optimizing travel and travel costs. It is a distributed information communication system for monitoring and actively informing traffic participants, for actively monitoring and informing about the situation at border crossings, and for optimizing the length, duration and costs of travel. That system is intended for use for optimization of the length, time and cost of traveling of users in road traffic. It offers to the user several of the most favourable travel routes, between selected travel destinations, with calculated of their lengths, expected travel times and expected travel costs, on travels that cross state borders and use roads with toll payment. The system takes into account the duration of congestion at border crossings and toll payment stations. It also takes into account the prices of tolls on the offered traveling routes.

Situations when crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia were observed practically and experimentally. Also, toll payment stations on highways in Republic of Srpska, Serbia and Croatia were observed. Some experimentally obtained results are given in the paper.

## INTELLIGENT TRANSPORTATION SYSTEMS

Because of the rapid development, improvement of possibilities and increasing of economy of information and communication technologies, their application in traffic and transport management is constantly increasing. Systems based on these technologies are designed and implemented, which are used for many activities in traffic management: traffic infrastructure management, traffic signalization management, vehicles management, increasing traffic safety, informing traffic participants, reducing travel time and travel costs, etc. [1–7] [1–7]. Such systems for control and management of transport and traffic are intelligent systems, with a kind of intelligence, obtained using information and communication technologies, and are called intelligent transportation systems (ITS). Also, such systems are mostly distributed systems because they are based on the application of distributed information and communication systems [1–7].

The term intelligent transportation systems appeared in the 80s years of the last century, when professionals from the field of transport and traffic noticed the enormous importance and impact of developments in the field of information and communication technologies on those fields as well. Initially, the term intelligent transportation systems (ITS) referred to intelligent systems of vehicles on highways, so called IVHS (Intelligent Vehicle–Highway Systems). Later, it expanded to all systems from all areas of traffic and transport control and management [1–7].

Such systems are sets of interacting elements and established relationships between them, which have the ability to act adaptively in changing situations and conditions. System elements have some similar properties that are essential for the elements to interact or have defined relationships. Several different definitions of ITS are available in the professional literature. In general, it can be said that the term "intelligent transportation systems" refers to a system of measures and technologies applied in the transport system that combine and integrate information and telecommunication technology, with the aim of increasing the level of traffic safety, obtaining more efficient flow of traffic, without delays, with a lower level of environmental pollution [1–7].

Intelligent transportation systems apply information and communication technologies to the mobility sector. Such systems are systems in which information and communication technologies are applied in the field of road transport and traffic, including infrastructure, vehicles and users. The systems are used in traffic management and mobility management, as well as for interfaces with other modes of transport. ITS is used to improve the efficiency and safety of transport in a number of situations, i.e. road transport, traffic management, mobility, etc. ITS technology is used across the world to increase capacity of busy roads and to reduce travel times and costs. ITS services and applications create many benefits as are increased transport efficiency, sustainability, accessibility, safety and security, as well as decreased energy consumption and decreased pollution of environment [1–7].

### — Architecture of intelligent transportation systems

In order to achieve maximum quality and benefit from an intelligent transportation system, it is necessary to base its architecture and implementation on a certain strategic framework. The goal of the system architecture, when introducing ITS in transport, is to provide that framework. The framework includes the principles of system design and development with observing the entire life cycle of the system [1–7]. The most common division of ITS architecture is into [1–7]:

- Logical architecture,
- Physical architecture,
- Communication architecture.

The logical architecture, which is also called functional or functionality architecture, defines the internal logic of the relationships between individual parts or units of the system. The physical architecture defines and provides descriptions of the parts of the functional architecture, which may or may not be connected, such to form physical parts or units. Communication architecture defines the ways and forms of communication between parts or units of the system, the flows of data and information. The architecture of ITS is mainly decentralized, i.e. distributed, with more interconected functional modules or subsystems. It is based on adequate application of hardware and software computer, information and communication technologies and systems [1–7].

The architecture of ITS, as well as other information and communication systems, can be viewed as [1–7]:

- System or hardware architecture,
- Software or program architecture.

There are three types of system or hardware architecture of ITS: centralized, decentralized and hybrid. ITS mainly use decentralized, i.e. distributed system architecture. It is based on the adequate application of computer hardware, information and communication hardware technologies and devices

There are several different software or programming architectures of ITS. As this are distributed systems, the most important software architectures of ITS are: layer–based architectures, object–based architectures, data–based architectures and event–based architectures. They are based on the adequate application of software information and communication technologies, on adequate software solutions and applications.

ITS architecture is primarily related to information exchange and control between systems at different levels of abstraction. Four levels of ITS architecture can be defined: Level 0, Level 1, Level 2 and Level 3. Level 0 includes the level of technical components and subsystems, and the way of their design. Level 1 relates to the level of used technologies. Level 2 refers to a level within an organization or system. Level 3 deals with the possibilities of interoperability of the work of multiple organizations or systems

Various frameworks of ITS architectures have been developed around the world. The United States of America has done the most, where the national ITS architecture focuses on the physical aspects. Next is Europe, where the focus of national ITS architecture is on user needs and functional aspects. Then comes Japan, Australia and Canada, who have used the good sides of all available architectures, and made adjustments to their own needs.

— Communication architecture of intelligent transportation system

In planning and developing the architecture framework of ITS, a very important segment is the view on communication in the system and the communication architecture. The communication architecture ensures the unity of the transport and communication system. There are more different technologies available for implementing of communication and communication architecture in ITS. Practically all communication technologies, wired and wireless, can be used. Wired technologies are mainly used for connecting and communicating of stationary parts of transport infrastructure and stationary parts of ITS. For most other purposes, wireless technologies are used, the application of which is constantly increasing. Wireless technologies are used for communication between vehicles, communication between vehicles and road infrastructure, communication between traffic participants and the system, and communication of the entire system with the central monitoring system or central station. Also, cooperation between traffic participants and road transport infrastructure requires the existence of appropriate communication possibilities, mostly wireless. Different types of communication with and from the vehicle are used, which are also wireless [1–7].

Wireless communication technologies for purposes of ITS are classified into [1–7]:

≡ General purpose wireless communication technologies (DVB, DAB, Cellular networks, WiMAX, WLAN, WPAN and IR),
≡ Dedicated wireless communication systems for vehicles (V2V and V2I based on DSRC and CALM technology).

European approach to communication architecture of ITS consists of four separate subsystems or stations, Personal Station (PS), Central Station (CS), Vehicle Station (VS) and Roadside Station (RS), and their interconnection [1–7].

## INFORMATION AND COMMUNICATION SYSTEM FOR MANAGEMENT IN ROAD TRAFFIC

Here is described one proposed distributed information and communication system for intelligent management in road traffic and its design. Basic architecture of the distributed information and communication system for intelligent management in road traffic is proposed and described. The system consists of the central part of the system and several modules or subsystems. Modules or subsystems are performing certain individual functions of control in road traffic and in the system.

Basic architecture of proposed distributed information and communication system for intelligent road traffic management is shown in Figure 1. The main part of the system is the central part of the system, central monitoring system (DIKS ITS). The central monitoring system communicates with the modules and coordinates their activities and operations. Each module or subsystem performs one concrete function and activity of control in the road traffic and transportation.

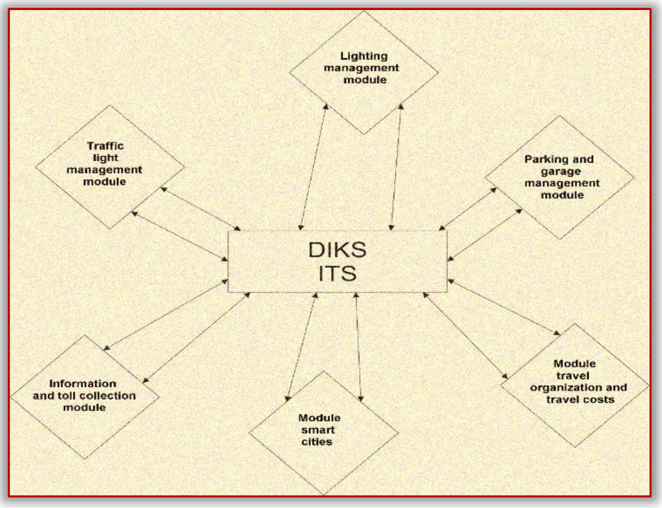


Figure 1. Basic architecture of the proposed system

The basic modules or subsystems of the proposed system are [8–11]:

≡ traffic lights management module,
≡ lighting management module,
≡ parking and garages management module,
≡ information and toll collection management module,

- module of smart cities,
- module for optimization of travel organization and travel costs.

Every module is independent and performs its specific function in the road traffic management system. All modules are coordinated by the central monitoring part of the system and they also communicate with each other.

## SYSTEM FOR OPTIMIZING OF TRAVEL ORGANIZATION AND TRAVEL COSTS

It was practically designed and implemented module or system for optimizing of travel organization and travel costs. The operation of the system was also experimentally tested and verified. It is module of distributed information communication system for monitoring and active informing of road traffic participants, for active monitoring and informing about situation on border crossings and for optimization of length, duration time and costs of travel. The system suggests to the user a few the most favourable traveling routes, between selected travel destinations, for travels that could cross state borders and use roads with toll payment. It gives users calculated lengths, expected travel times and expected travel costs for all suggested traveling routes. The duration of congestion at border crossings and toll payment stations, as well as the prices of tolls on the suggested routes are taken in the account. Practically and experimentally were observed traveling routes with crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia. Toll payment stations on highways in Republic of Srpska, Serbia and Croatia were also observed.

### — Organization and operation of the system

Based on the analysis of user needs and wishes of interested parties, participants and users of the system, the following functions of the system were defined:

- Monitoring of current delays at the border crossings of the borders of Bosnia and Herzegovina, Croatia and Serbia by downloading and receiving data from the border crossings about the time needed to cross the border,
- Downloading and taking the current location of the travel participant (user) based on his/her GPS location,
- Estimation of the time needed for user to arrive at individual border crossings,
- Monitoring of current traffic congestions at individual toll booths along the observed road section,
- Calculation of total toll costs along the observed road section
- Informing users about the time needed to arrival at individual border crossing, about current delays at individual border crossings, about current delays at toll booths and about total toll costs that should be paid,
- Determining the optimal parameters for the travel based on the criteria given by the user (length of the travel, time duration of the travel, travel costs, etc.).

By using the application on his/her mobile phone, the user selects the destination of travel. The application determines user current location using the application GPS module, i.e., the user mobile phone. Based on the given location of the destination and the current location of the user, the application processes the given activity and sends a request to the central monitoring system (command or control centre) to update data on current conditions at border crossings and toll stations. The command centre processes the received request. On the basis of information on current conditions at border crossings and toll stations and data placed in the database on traffic congestions during the day at individual border crossings, the command centre updates the data and performs needed calculations.

The proposed system is divided into two parts:

- command or control part,
- acquisition part.

The command or control part is located in the monitoring and control centre. It processes all the data and presents it and obtained results to users via changeable traffic signs or via the application on a mobile phone.

The acquisition part is located in the field, on roads and border crossings, and collects the data. It consists of sensors and surveillance cameras at border crossings and toll booths on the highways along the road route being travelled.

Figure 2 shows the structure and principle of operation of the command, control or central, part in the monitoring and control centre.

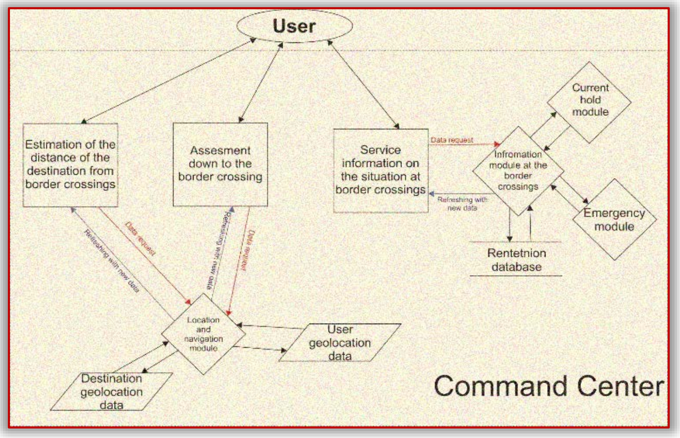


Figure 2. Structure and principle of operation of the command, control or central, part in the monitoring and control centre

Based on the initial data given by the application user, the command centre performs the following steps:

- Based on the data received from the user, calculates the approximate time needed (T1) to the user to arrive at individual border crossings, as well as the average time required to arrive at the destination from the border crossing (T2),
- Calculates the current distance of the user from individual border crossings (S1) and the distance between border crossings to the destination (S2),
- Based on the data on the current conditions at the border crossings and the average delay at the border

crossings, calculates the time needed to cross the border crossing (T3),

≡ Based on the data about tolls at the toll boats on the travel route, calculates the total toll cost (C) to be paid
≡ Returns to the user the information about individual border crossings with the data about the total time needed to arrive at the destination and cross the border (T=T1+ T2+ T3), about the total distance of travel (S= S1+ S2) and about total toll cost (C) for the travel.

Based on the obtained information, the user decides on which rout to travel and via which border crossing. Also, based on certain criteria that can be defined by the user, the system can suggest the most favourable route to the user for realization of that travel. These criteria can be: the shortest travel time, the smallest distance travelled or the minimum of travel costs. Thus, the optimization of the road route and travel costs can be achieved.

Figure 3 shows structure and principle of operation of acquisition part of the system. In the acquisition part are used cameras for the surveillance of border crossings, sensors and surveillance cameras at the toll stations. Video sensors are used to detect accidents and traffic congestion at toll stations of highways in the Republic of Srpska. Changeable traffic signs are planned to be installed on certain sections of the highways. It will be used for information of road users, on which the results of current delays at border crossings and toll stations would be presented via the control centre. The algorithm of operation of the acquisition part is as follows:

≡ The traffic management module sends a request to the video sensors and they, in the form of cameras, send to the module the current photo or video, as needed.
≡ The analysis of the obtained photograph is performed in the traffic management module, obtained information is forwarded to the information module, from where the information is further sent to traffic participants via dynamic traffic signs.
≡ In case an accident is detected, the information is forwarded to the call centre module, from where the information is further forwarded to the interested services.

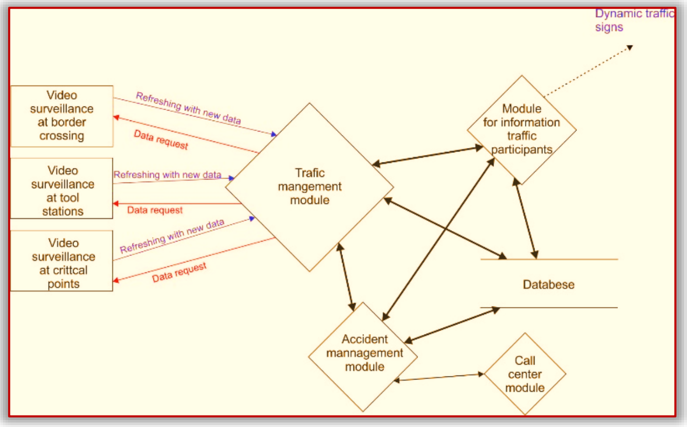


Figure 3. Structure and principle of operation of acquisition part of the system

The system that was proposed, designed and used in the experiment consists of a hardware part and a software part. The software part includes applications installed on the user's mobile phone and web applications installed on the server, which interact with the database. The hardware architecture of the system consists of the user's smartphone, computers of sensors and video surveillance installed at border crossings, and a central computer installed in the command centre for monitoring, traffic management and informing traffic participants.

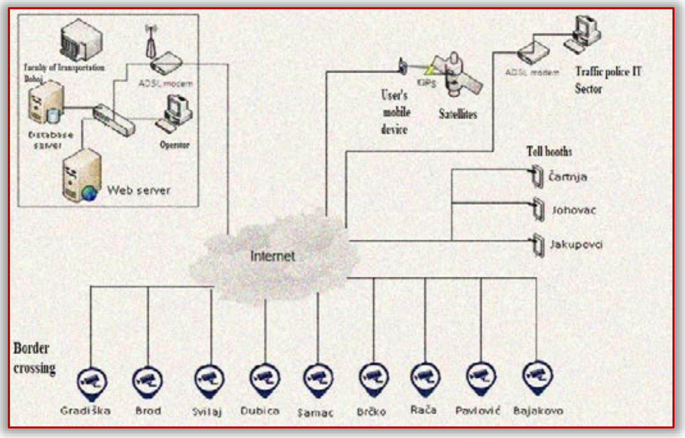


Figure 4. Architecture of distributed information communication system for traffic monitoring and actively informing traffic participants

The architecture of that system for monitoring traffic and actively informing users about congestion at border crossings and at toll booths, as well as for optimizing the travel route and travel costs, is shown in Figure 4. The system consists of following modules:

≡ Central monitoring system installed at the Faculty of Traffic and Transport Engineering in Doboj, Bosnia and Herzegovina,
≡ Multimedia devices (smart mobile phones of users),
≡ Computers (Raspberry PI with the necessary software) placed at border crossings with traffic surveillance cameras,
≡ Server with installed application for collecting and processing data from border crossings and toll booths,
≡ Server with installed database (MySQL).

❖ Software organization of the system

The software architecture of the system designed and used in the experimental research is shown in Figure 5. It can be seen that the software consists of two separate parts: the software for the smart mobile phone and the software for the central monitoring system.

The software for the smart mobile phones includes applications installed on the user's mobile devices and with the appropriate GUI (Graphic User Interface). By accessing these applications, users interact with the transportation system through a central monitoring system. The software for the central monitoring system consists of applications based on HTML5, CSS3, JavaScript, PHP, Google Maps technologies, which are placed on the server in the central monitoring system. Those applications have the function of connecting of all modules into a unique system. They enable active information of traffic participants and the determination and selection of the optimal travel route, taking into account the length, time duration and costs of the travel.

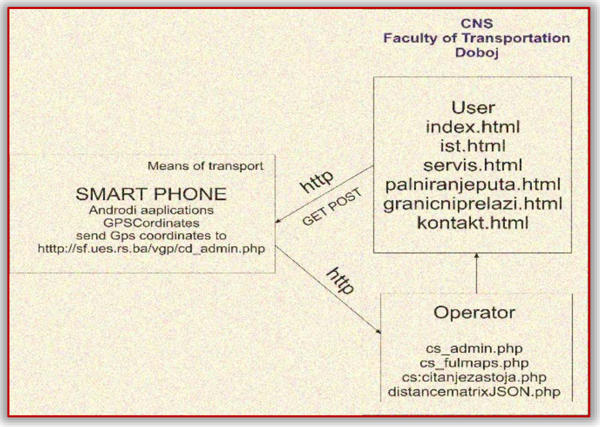


Figure 5. Software system architecture

The free phpMyAdmin tool, available at web page sf.ues.rs.ba/vgp/phpmyadmin, was used for the design and management of databases implemented in MySQL. A database (baza1) was designed, which was placed on the server sf.ues.rs.ba/vgp/baza. The database is storing data of the geolocation of individual border crossings that are included in the research and data of the geolocation of individual toll stations located on highways in the Republic of Srpska. In addition to geolocation, the database includes the time delays at border crossing locations for every hour of the day. Three tables were designed. The first table contains data of the locations of border crossings, with associated attributes–columns. The second table contains data of the delay times at border crossings and toll booths. The third table contains data about toll costs at toll booths. For database modelling, the MOL model (Model–Object–Links) was used, which is based on the concept of entities (objects and links).

An integral part of the software are applications programmed for Android OS and web applications written in HTML5 language. Some web applications are executed on the client side (written in JavaScript and Java code), and some are executed on the server side (written in PHP script and Payton). Different user interfaces (UI) have been designed to access the applications, i.e. the system. The user interface for Android applications consists of a part for display on the phone screen and the part for processing of events.

For the purpose of research, and for the needs of the experiment, a web application was designed based on publicly available opensource tools. The web application was developed using the HTML5 language, CSS3 styles, JavaScript, Java Applets that are executed on the client side, and PHP language for execution on the server side. Among other technologies, Android OS, Java, Google Maps service for displaying maps, "Distance Matrix API" service for calculating the time needed to cross a certain section of the road were used.

The developed applications perform following functions:

- The "GPSCordinates" application is installed in the client's mobile phone. Through the GPS module, it finds the GPS coordinates and sends them to the application located on the server. In addition to the GPS coordinates, the user also enters the travel destination, which is also forwarded to the application on the server. The data is sent via the HTTP protocol (GPRS technology), a text file containing the geocoordinates of the client and the destination. The web application, placed on the domain www.sf.ues.rs.ba/vgp, reads the sent data through a PHP script and sends it to the "baza1" database in the „privremenipodaci" table.
- The application located on the server downloads data from the „privremenipodaci" table. Based on the data of the current location and the location of the border crossings, from the GPiNM location table, it sends that data with a JSON query to the "Distance Matrix API" web service. From the file returned by the web service "Distance Matrix API" following data are read: distance and time duration for each border crossing. Based on the distance data, two or three border crossings are selected using the shortest distance method.
- After selecting the two or three most suitable border crossings and based on the client's destination data, the application sends this data via a JSON query to the web service "Distance Matrix API". The following data is such obtained and read: distance and time duration from the border crossings to the destination.
- The obtained data is processed, and then by the SQL code from the „vrijemezadrzavanja" table are read the data of the current delays at the border crossings and the obtained values are added to the already existing values.
- By the SQL code from the „putarine" table are read the data of the toll costs on toll boots along travel route and calculated total toll cost for the travel.
- Thus obtained the data is sent to the client in the text form, where two or three border crossings are offered, with estimated travel times, travel distances and total tool costs.

## OPTIMIZATION OF TRAVEL ROUTE AND TRAVEL COSTS

For the experimental verification and testing of the proposed system, two road routes were taken and used. The first road route is Doboj – Zagreb, with border crossings Svilaj, Brod, Gradiska and Dubica. The second road route is Doboj – Beograd, with border crossings Svilaj, Samac, Brcko, Raca and Pavlovica Most.

The HP ProLiant DL320e Gen8 server was used to test the system in real conditions, which was installed at the Faculty of Traffic and Transport Engineering in Doboj. The Linux system Centos 7.5 and the following software are installed on that server:

- phpMyAdmin, intended for working with the PHP script language,
- Apache server, intended for working and testing web applications on a local server,
- MySql, which is used for database design.

Together with the software for working with databases and testing of applications, on the server are installed applications on the website (www.sf.ues.rs.ba/vgp), for user and system interaction. Access to the application is possible using smartphones, tablets, stationary and laptop computers. A method based on the application of the web service "Distance MatriX API" was used to estimate the time of arrival at the destination via individual border crossings.

❖ Case 1: Travel route Doboj – Zagreb

On this travel route, the following four border crossings between Bosnia and Herzegovina and Croatia were taken into observation: Svilaj, Brod, Gradiska and Dubica. Figure 7 shows a block diagram with practically obtained distances between border crossings and destinations with estimated travel times for this case.


Figure 6. Case 1, travel route Doboj – Zagreb

❖ Case 2: Travel route Doboj – Beograd

On this travel route, two directions with six border crossings between Bosnia and Herzegovina and Serbia were taken into consideration. The first direction is with the Svilaj, Samac, Brcko and Bajakovo crossings. The other direction is with Raca and Pavlovica Most crossings. In the first direction, it is travelled through two state borders, Bosnia and Herzegovina – Croatia and Croatia – Serbia. In the second direction, it is travelled through one state border, Bosnia and Herzegovina – Serbia.


Figure 7. Case 2, travel route Doboj – Beograd

Figure 7 shows a block diagram with practically obtained distances between border crossings and destinations with estimated travel times for this case.

— Methods for travel time estimation

Two methods were used to estimate the travel time:

- Method that uses the web service "Distance MatriX API",
- Method that uses the Kalman filter.

Web service "Distance MatriX API" of Google is a service that gives feedback information about the distance between two points and the travel time on a selected road route, based on a user given query. As input parameters of the query are defined the initial and final destinations. The input parameters can be given in the form of destinations names or in the form of geocoordinates of selected locations. Of the other parameters are chosen the way of transport and the units in which the output values will be given. For users of the free API, the number of requests per day is limited to 2500. As a response to the given query, two forms of documents can be obtained, in XML and JSON (JavaScript Object Notation) form.

The use of the Kalman filter for time prediction is based on the calculation of estimated states, based on measurements with noise, for a random process, which is described by a linear discrete model in the space of states. The Kalman filter is an optimal estimator and predictor of an unknown quantity and has found wide application in time prediction, navigation, tracking, and object trajectory prediction.

Both used methods give approximately equal results.

— Obtained results

For a simpler and faster use of the possibilities of this system, as part of the overall realized software, an application was developed and implemented for the graphic presentation of the suggested most favourable routes, with the showing of maps for all those options. The application is activated by selecting the "Planiranje puta" option. Figure 8 and Figure 9 show examples of such obtained results for one day in March 2022, for two travel routes from Doboj to Zagreb, via different border crossings. The figures show all the details for the selected travel routes: starting and ending points of the travel, suggested routes, calculated distances, times needed to travel to the given destination and total tolls for those travels.

Figure 8 shows example of obtained results for travel route Doboj – Zagreb, via the Gradiska border crossing. Figure 9 shows example of obtained results for other travel route Doboj – Zagreb, via the Brod border crossing. From the results shown, it can be seen that the travel route Doboj–Gradiska–Zagreb is shorter and that the total duration of the travel on that route is also shorter. Also, that travel route is faster to travel because most of the road is a highway. However, the time needed to cross the border crossing at the Gradiska was much longer than at the Brod border crossing. Also, the total toll that needs to be paid on that travel route is higher. Based on these given data and his preferences, the user can decide to choose one of the offered travel routes.

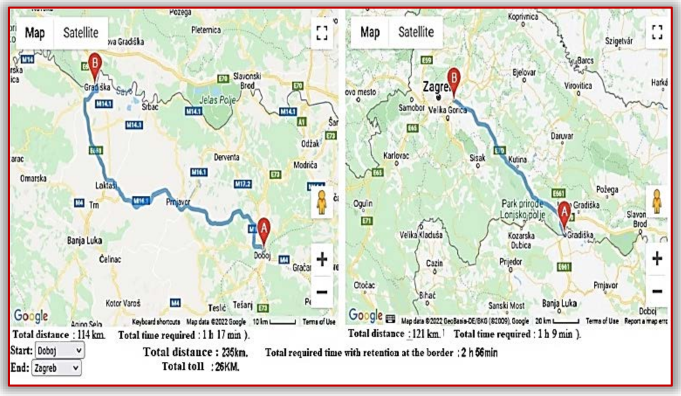


Figure 8. Obtained results for trave route Doboj – Gradiska – Zagreb


Figure 9. Obtained results for travel route Doboj – Brod – Zagreb

## CONCLUSION

By implementing the distributed information communication system with dynamic web applications included, it is provided the possibility of active monitoring of current situations at border crossings, as well as on individual sections of the road selected sections. By connecting information and communication flows within intelligent transportation system and distributed information systems, it has been shown that it is possible to achieve the necessary impact by improving the performance of transport systems, in order to achieve more efficient, faster and more accurate problem solving in transport and in various dynamically complex situations. By applying distributed information systems in interaction with communication technologies, it improves multi–aspect traffic management, from real–time vehicle monitoring, monitoring of conditions on certain sections of the road, real–time monitoring of border crossings, and constant coordination of traffic participants through media in traffic.

Using such distributed information and communication system it is possible to travel participants to effectively optimize their traveling in road traffic. Very easy, using their smart mobile phones, users can obtain data about length of travel, time duration and costs of travel in road traffic for his/her traveling route. Based on his/her preferences, minimal length of travel, minimal time duration of travel or minimal costs of travel, the user can choose one of the offered travel routes, that is optimal for his/her needs and wishes.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA)

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