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Contents

EDITOR'S WORD

Has anything influenced our every-day lives more than traffic?

"The way in which people and things are moving from one place to another is, at first glance, a trivial matter. However, the process of moving includes many other elements and activities, which gave it a decisive role in the functioning society".

Obviously that these words of english writer George Wells, pronounced more than one hundred years ago, are still actual. Just think how much time we spend in moving ourselves or our things, or waiting for moving in order to accomplish our desired mobility. Or, more importantly, how many lives we lose in traffic every day because of our insufficient knowledge, incompetence, wrong work, superficiality, or perhaps because of not doing anything.

The car industry has is changing rapidly by adopting modern information-electronic technology achievements. It's no longer a question of whether we have electric cars and driverless cars, but when they will be in full function and on what kind of roads they will move. Soon we will have intelligent cars on intelligent roads, within intelligent transportation systems. That time will requare transportation professionals with a new way of thinking, an ability and commitment to a leadership vision for a challenging future. We beleive that authors of papers printed in this third issue of our TTTP journal, as well as in previous editions, belong to this type of transportation professionals.

The present issue features as many as ten papers, written by twenty-seven scholars. The papers' topics belong to scientific areas covered by our journal, and they met the set criteria for publishing. They received positive reviews and he readers are entitled to decide on their quality.

The authors who wish to collaborate are now encouraged to submit papers according to the guidelines published at the end of the journal and on our website.

Editor-in Chief
Mirsad Kulovic,

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ORIGINAL SCIENTIFIC PAPER

Design and Development of Comprehensive Railway Information and Communication Systems

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Abstract: Successful operation of the railways as a large technological system is directly related to the reliable and timely transmission of data and information. Therefore, the role of the information and communication system (ICS) has irreplaceable importance for operation and functioning of the railways. Considering that the railway modernization represents an uninterrupted process, it is necessary to ensure constant technical and technological development and application of the latest achievements in the field of information and communication systems. The railway ICS, among other things, provides infrastructure for the automatic control systems, traffic management and control, monitoring and navigation systems, data processing devices, and it also provides support to other subsystems designed for safe and consistent use of the line, as well as efficient management of the modern rail transportation system.

Key words: railways, transmission data and information, information and communication system, railway ICS.

INTRODUCTION

Based on traffic and technological requirements and characteristics of the official positions at the railways, this paper gives the proposal for the *ICS* architecture with all the necessary technical systems, depending on the technological and hierarchical level on the network at the Serbian Railways (SR). The levels of nodes in the *ICS* Railway, their physical and logical organization as well as the equipment and necessary services characteristic for individual nodes were identified and defined in the paper. Also, a universal model for organization of the information and communication system of the railways is proposed.

EXISTING STATE OF IKS ON THE RAILWAY

Media transmission in the telecommunications network of the SR

Communication networks at the SR use the following types of media and transmission systems:

- transmission by cable lines,
- transmission over optical cables,
- radio transmission,
- high frequency transmission and
- *SDH* transmission.

Telecommunication networks

In general, communication services within the national railway administrations of Europe, as well as at the SR network, are realized through networks that can be classified into two basic groups:

- telecommunication networks for general purposes and
- telecommunication networks for special purposes.

The point of general purposes network is to provide telecommunication services (voice and data transmission) for functioning and coordination of the railway services and administrative units at all levels. It includes telephone exchanges *PBX* (for telephony and telegraphy) as well as Intranet network for all services (*WEB, MAIL, FTP, DNS* and *AD*) and applications belonging to the information system of SR. In addition, *PIS, PA, CLOCK* system also belongs to the general purpose network. The networks for special purposes enable exchange of voice and data information for traffic operations, for railway safety and signaling systems and for remote control of contact line powering. It includes track phone system (for traffic and power management), radio dispatching system, *PMR* (Private Mobile Radio).

Unfortunately, at the Serbian Railways, even today, both networks are mostly made up of analog systems.

GLOBAL CONCEPT OF ICS RAILWAYS

The modern information and communication system of the railways represents the infrastructure for transmission of all types of data and information on the railways: speech, numerical data, video materials, multimedia contents and control signals.

ICS should enable connection to the existing railway communication network (ŽAT - telephony and ŽATg - telegraphy network, Intranet, all external railway dedicated systems (power system, remote control system, centralized traffic control, *OA* system, signal system) and external communication Public Switched Telephone Network (*PSTN*) systems, Public Land Mobile Network (*PLMN*) and the Internet.

Railway *ICS* should be highly reliable and scalable,

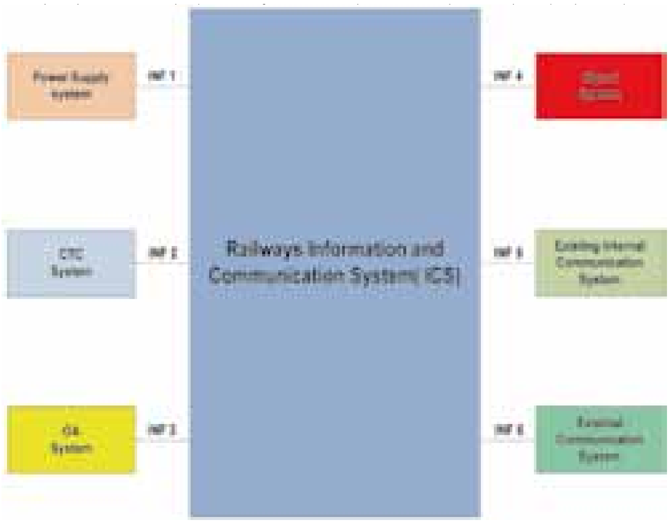

Figure 1. Global concept of the ICS system

The interfaces between *ICS* and internal and external railway systems are briefly described as follows (INFnis the identifier of the external interfaces of the information-communication system of the railway):

INF1 - interface with power supply system

The power supply system provides reliable *DC\AC* power supply for *ICS*. The Interface is set at *DC\AC* input of communication power supply equipment. *ICS* provides the communication channel for the power system controlled by dispatcher.

INF2 interface with *CTC* system

The CTC System provides external interface for database which enables *ICS* to access to the actual data related to railway transport, train departures and arrivals. The connection is performed with 10M/100M Ethernet port. The detailed format of database interface should be specified in phase of the system realization.*ICS* provides communication channel for *CTC* system to traffic control.

INF3 interface with *OA* system

IKS provides data communication channel for *OA* system, based on *IP* protocol. The connection is enabled using 10M/100M Ethernet port.

INF4 interface with signaling and security system

ICS ensures data communication channel for signaling and safety system which transfers data important for train transport management. The *PRI* protocol and *E1* link are used to connect *ICS* and signaling devices. IKS and signaling devices in the driver's cab are connected via the RS 422 serial cable. *GSM-R* interface is used for communication with the control center.

The signaling system shown into the interrupted line (Figure 1) refers to the European Train Control System Level 2, which will be built in the future.

INF5 interface with existing internal communication system

The modern *ICS* needs to be compatible with the existing internal communication system sat the Serbian Railways, as *CLOCK* system, *PBX* network and track phone system.

ICS uses twisted-pair cable to connect existing *CLOCK* system (outputs pulse 24V); the existing *PBX* network is connected via *E1* signal using *PRI* or *E&M* protocol. The track phone system is connected via *E1* link, using *PRI* or *SS7* protocol. This interface will also be specified after *ICS* subsystem is defined.

INF6 interface with external communication system

The new constructed *ICS* needs to connect to the external *PSTN, PLMN* and Internet network. The connection in *PSTN /PLMN* network should be performed via *E1*link, using *PRI* or *SS7* protocol, and the connection with the Internet should be enabled via fiber cable based on IP protocol. This interface will be also specified as soon as all *ICS* subsystems are defined.

ARCHITECTURE OF ICS RAILWAYS

Types of railway nodes depending on the technology of rail transport

From the perspective of logical functions, *ICS* consists of the transmission and *IP MPLS* networks, which represent the infrastructure for the transmission of the following services: *GSM-R, IP* telephony, video surveillance and video conferencing, *PIS, PA, CLOCK*, Intranet and track phone system.

Figure 2 shows different levels of services depending on the location and the hierarchal level in the railway network (from the center to the executive units for individual services). A detailed configuration of the equipment using hierarchical model will be given in the next chapter.

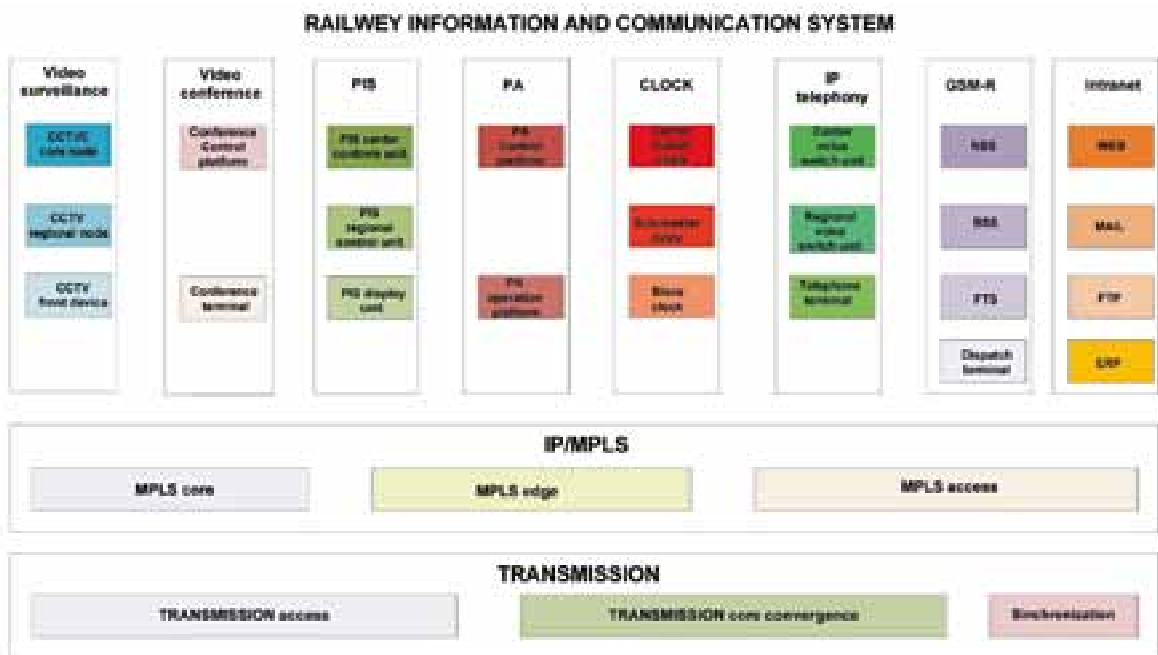

Figure 2. Railway *ICS* architecture

Function of the module in ICS subsystems

1）Transmission system

The transmission systems are composed of access layer, convergence layer and synchronization system

- Transmission access: provides various interfaces for connection of *GSM-R* and *IP/MPLS* network to implement the data transmission of communications services.
- Transmission core convergence: represents the uplink convergence of the access layer, the bearer of all services, high-speed, broad bandwidth in the backbone transmission network.
- Synchronization (Clock synchronization): provides synchronization to the whole network.

2）IP/MPLS network

MPLS network is created out of core, edge and access layer.

- *MPLS* Core–the core of the network, responsible for routing and *MPLS* fast forwarding.
- MPLS Edge – the edge of the network stores *VRF*, processes *VPN-IPv4* routing, responsible for *MPLS VPN* access.
- *MPLS* Access – access layer provides access to various services, publishes user network routing information.

3）GSM-R network

GSM-R network consists of *NSS, BSS, FTS* and dispatcher terminal.

- *NSS*: Implements the call relay, billing, mobility management, realizes railway additional services.
- *BSS:* Implements the *GSM-R* radio link management and the conversion between wireless and wired link.
- *FTS*: Fixed dispatcher terminal system, used for dispatcher's connection, using wireless and wired communication.
- Dispatcher's terminals: contain dispatcher station, cab radio, *OPH, GPH* and other terminals; they are used for dispatcher's communication with the official staff on railway.
- *GSM-R* represents the infrastructure for *ETCS.*

4）Video surveillance

The purpose of this system is to provide higher level of safety for passengers and station staff, to contribute to the protection of material goods of the railway, to alert on incidents and to provide material evidence about them in the form of video recording.

- *CCTV* core node: Provides distribution of video information, system management, user management, stores system alarm information and important video information. It represents the central part of the system in the form of a dispatcher center for video monitoring. At this level, it should have been used equipment for controlling the overall video surveillance.
- *CCTV* regional node: Provides access to video information, distribution, forwarding and system management in the regional node, directly stores video information which are collected in the regional node, also stores regional node alarm information and important video information.
- *CCTV* access node: Represents the collection point for video information access, distribution, and forwarding, interconnection with other sys-

tems, and also stores all belonging video and alarm information.
- *CCTV* front device: Collects and encodes the video image information.
- 5）Video conference (*VC*)
- Video Conference Systems provide an opportunity to arrange meetings of two or more remote participants and they can be applied in all areas as a simple and cost–effective form of communication.
- Conference call platform edits and distributes audio and video signal to each terminal, provides background management for the whole video conference system.
- Conference terminal collects and encodes audio, video and data information.

6）IP telephony

IP telephony solution implies the installation and configuration of a *VoIP PBX* central computer unit with additional devices that would take the role of a telephone exchange for the complete client communication system. This advanced *PBX* exchange should enable activation of a large number of services that standard telephone exchanges do not offer and it also represents the ideal combination of standard telephony and Internet services.
- Center switch unit works as the central server, provides voice services for all users who exchange voice services.
- Regional voice switch unit works as the second layer node; it provides voice services for regional users when the connection with the central server is interrupted.
- IP telephone provides the voice call function for end users.

7）PIS (*Passenger Information Systems*)

The *PIS* provides basic information for passengers on the whole line. It is a complex, centralized system for generating, distribution and displaying information on the train traffic.
- *PIS* central control unit collects external information (timetable) and processes them, then sends them to regional control units, appropriate displays, and *PA* devices.
- PIS regional control unit receives information from a higher-level node and send them to the corresponding *PIS* displays and *PA* devices.
- *PIS* display shows the timetable and information on the precise time.

8）PA (*Public Announcement*)

Audio informing subsystem provides service of audio notification, transmits audio information (train information) for passengers and / or employees.
- *PA* control platform: Connected to train arrivals database, updates database and provides *PA* commands
- *PA* operation unit: Executes *PA* commands received from *PA* control platform.

9）Clock systems

Clock systems with synchronization of the precise time is a complex system for generating, distributing and displaying signals with a time message, which provides a unique service for precise time and synchronization - clock for all *ICS* systems, for stations and all official sites along the rail lines.
- Center master clock synchronizes via *GPS* and information on precise time sends to sub-master clock and salve clock.
- Sub-master clock synchronizes with center master clock and sends time information to station slave clock.
- Slave clock gets the precise time information from the master clock, and shows them to passengers or employees.

10) Intranet

At the Serbian Railways information system essential is the position of the central location with all services and applications, based on the modern data center, with all kinds of redundancies that enable their continuous operation. The data center enables the operation of ERP (Enterprise Resource Planning), timetable, cargo and passenger traffic, IS tracking and train traffic management, as well as services *WEB, MAIL* and *FTP*. A complete redundancy of the central location is realized in the form of a disaster recovery solution.

Authorized users are enabled to work with the entire Intranet at SR.

Providing E2E QoS in ICS

Generally speaking, there are different services that should be classified. The key services are guaranteed on high priority and security level. Designing the system, the complete network is planned to provide end-to-end multi-services based on *E2E QoS* assurance method.

For this project, the services are listed according to the priorities, as follows: *GSM-R*>Video Surveillance>*IP* telephony>*PA*>*PIS*>*Clock*>video conference. Different types of services use different priorities and planning strategies and at the same time indicate high priority for access to available network recourses.

ORGANIZATION AND HIERARCHY OF NODES IN ICS RAILWAYS

The official sites on railways lines, which are defined as a node in the information and communication system, are the typical geographical locations where are generated the set-point signal, traffic, control, and other functions, that can be processed with services and applications.

At the SR network there have been identified various functional information and communication requirements generated in the main railway stations, regional stations, stops, end stations, marshalling stations, dispatcher centers and trackside.

Below are defined the functions and configuration of individual nodes.

The core nodes of ICS (level I and Ig)

A central node is located at the main railway station Belgrade Center where the cable infrastructure ends (optical and copper cables) from all main lines on the ŽS network. This is the location for the Belgrade Railway Node Management Center (without *CTC*), which represents the access point for the databases in the information system of SR.

Services provided by the main node

The main node provides the core convergence and access layer, and it also includes the central clock location for *ICS* synchronization.

This node is the location for the center of *GSM-R* network with *BSC*, which are the access point for all base stations in the section (BG–Nis, BG–Subotica, BG–Šid) and a backup access point for all base stations for railways in BG node.

The main node in the Belgrade Center provides monitoring at the first level for video surveillance, first level control services for the *PIS* / *PA* system and the main clock system for stations.

This is also the transit node of the *IP* telephone system.

All the mentioned services are provided by *IP* telephones, telepresence meeting rooms, cameras and external units for *PIS* / *PA*/ Clock systems.

Performance and capacity of services

The calculated number of users in *GSM-R* network in this phase of the construction is 1.500.

The number of local users in the transit node of the *IP* telephone system is 3.330, considering the reserve capacity of 4.558 users, with the possibility for extension up to 10.000 users.

Basic interfaces in the node level I

- The interfaces toward database for the archiving of the timetable, the train number and details about train delays;
- The interface between *FTS* in *GSM-R* and the existing *RDS* system is *PRI*;
- Interface between neighboring *GSM-R* networks based on *SS7*.

Regional Node (Level I)

Services provided by the regional node

- This node provides the basic convergence and access layer and represents the location of the backup clock for synchronization in *ICS*.
- It also provides access to *GSM-R* base stations and monitoring point at the second level for video surveillance.
- It represents the second-level control center for the *PIS / PA* system and master clock system.
- This node also contains *IP* telephone system transit node.

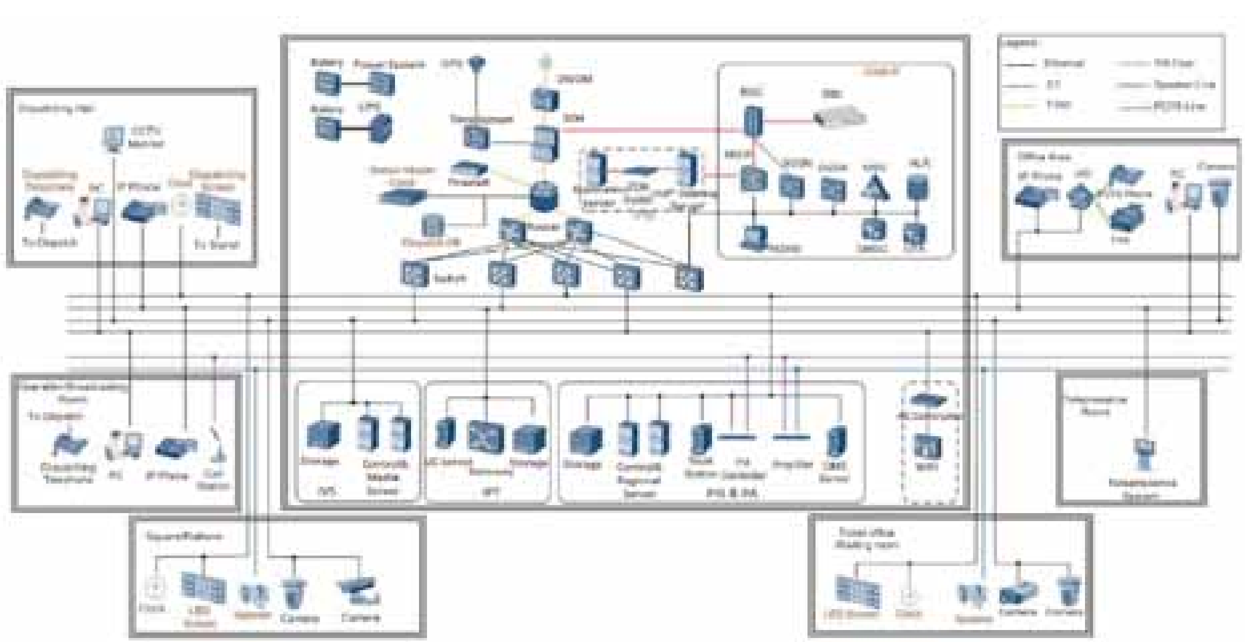

Figure 3. Configuration of the equipment stored in the main node

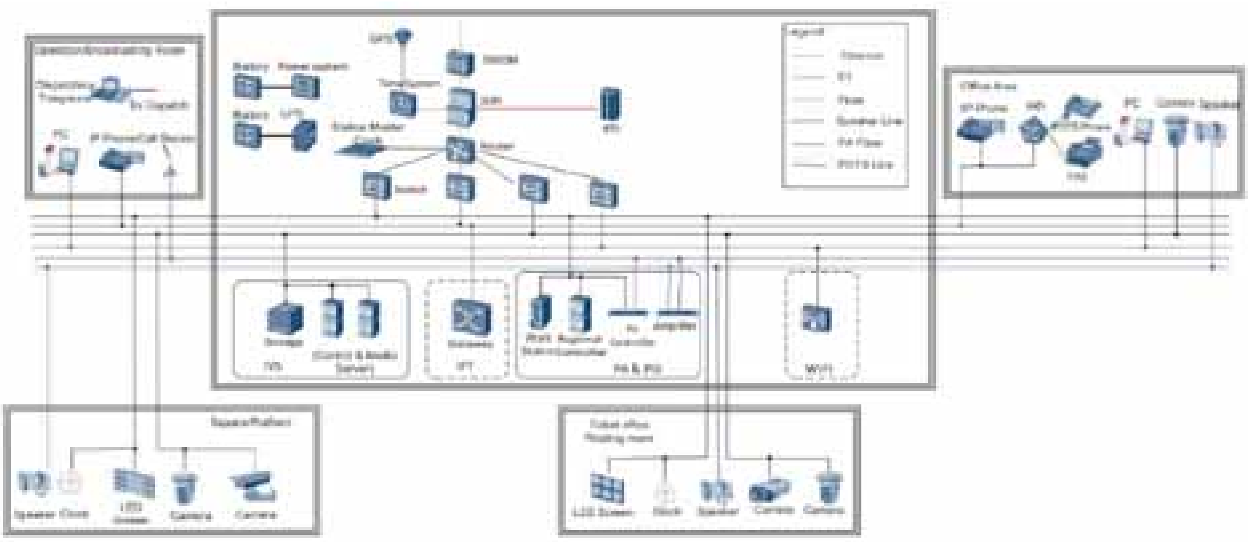

Figure 4. Equipment located in a regional node

- In this node are located: telephones, telepresence systems, cameras, dispatcher phones and executive units of the *STS* (*PIS* displays, speakers, clocks).

Node in the end stations (level II)

Services offered by the node in the end station

It provides an access layer for the data network and open access to *GSM-R* base stations.

It offers the third level of monitoring for video surveillance and access to *VoIP* and *STS* execution units.

The mentioned services at the stated location are enabled by cameras, *PIS* displays, clocks, speakers and *IP* phones.

Nodes in Stand Station (Level III)

Services offered by the stand station node

The node provides an access layer for the data network and open access to *GSM-R* base stations.

It represents the fourth point of monitoring for video surveillance and access to *STS* executive units.

Performance and capacity of services

The node contains the interface between *IP* phone and *PSTN / PLMN*: *PRI* (*PSTN*: 60, *PLMN*: 30) and the interface from the neighboring *GSM-R* networks: *SS7*.

The mentioned services at the stated location are enabled by cameras, *PIS* displays, clocks, speakers, *IP* phones and dispatcher phones.

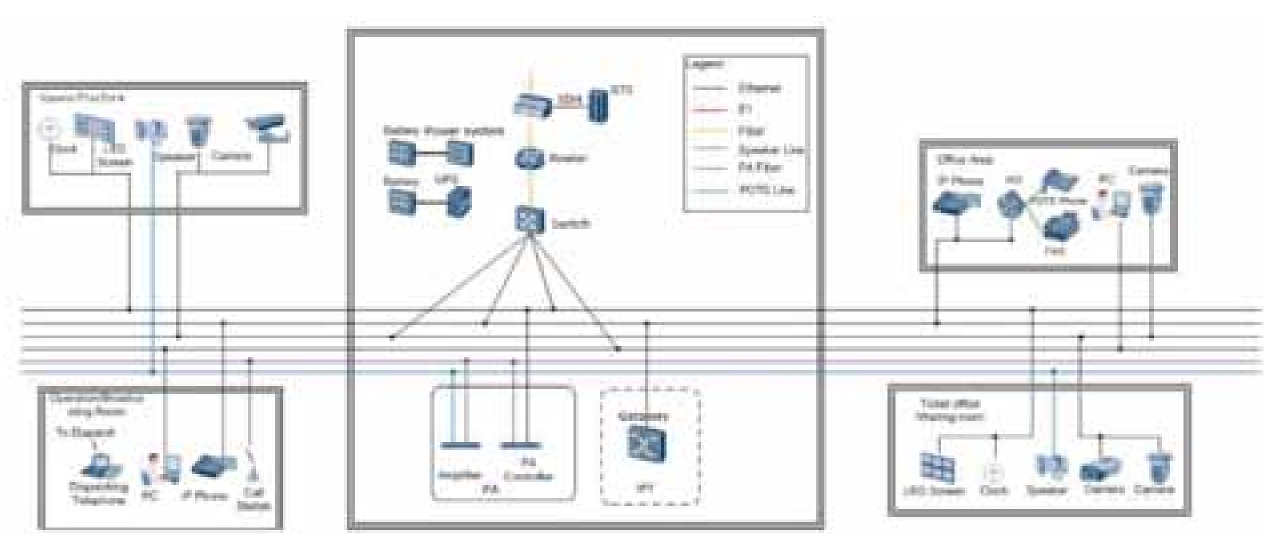

Figure 5. Equipment placed in the node at the end station

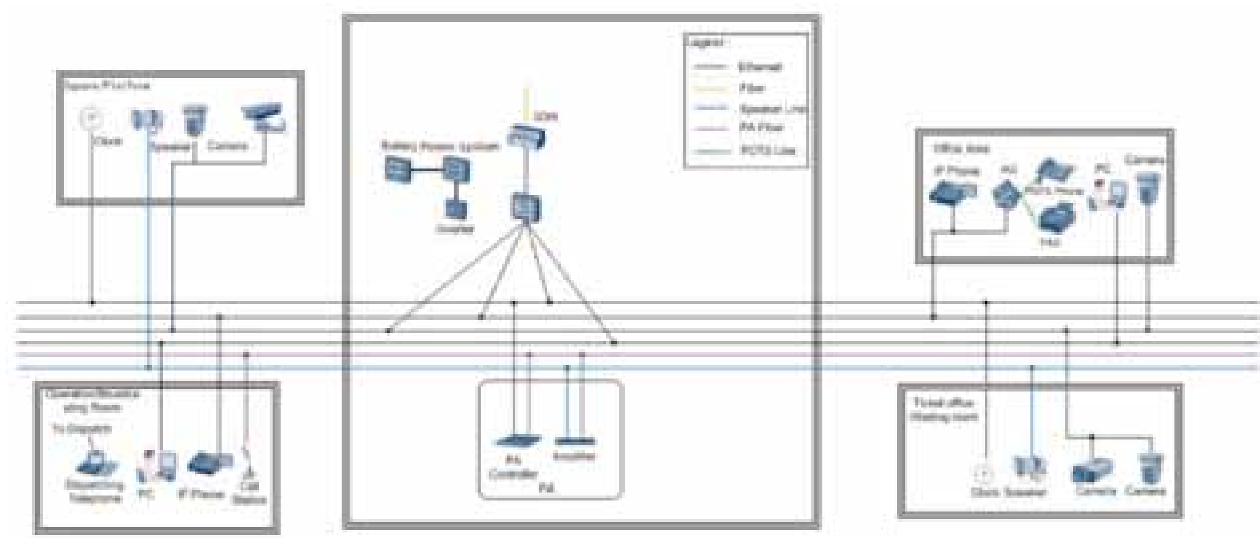

Figure 6. Equipment placed in the stand station

Node in the Shunting station (level II)

This is a freight station and the center for shunting and shipping of trains for directions: Belgrade – Sid, Belgrade – Subotica, Belgrade –cargo transport lines and Belgrade–Lapovo (two sections over Mladenovac and Mala Krsna).

Services offered by the node at the shunting station

This node provides an access layer for the data network and open access to *GSM-R* base stations.

It also provides the third level of monitoring for video surveillance and access to the *PA* / clock system.

Providing services at the stated location is allowed by using cameras, clocks, speakers, *IP* phones and dispatcher phones arranged at the corresponding locations.

Trackside (III level)

Services that offer a node at the trackside

The equipment located at the trackside provides an access level in the data network (optical / electrical conversion).

GSM-R wireless network for *GSM-R* terminals (Cab radio and *GPH* / *OPH*) covers all railway lines.

Video surveillance is granted at the fourth level of supervision and the service of dispatcher telephony along the track sides (access to the *FTS*).

5.6.2 Performances and capacity of services:

On the electrified lines of the Railway Station there are 1100 railway phone lines placed through the official sites and connected with the stations and dispatcher centers.

The services on the distance between the stations are provided by cameras, *GPH* / *OPH* and dispatcher phones.

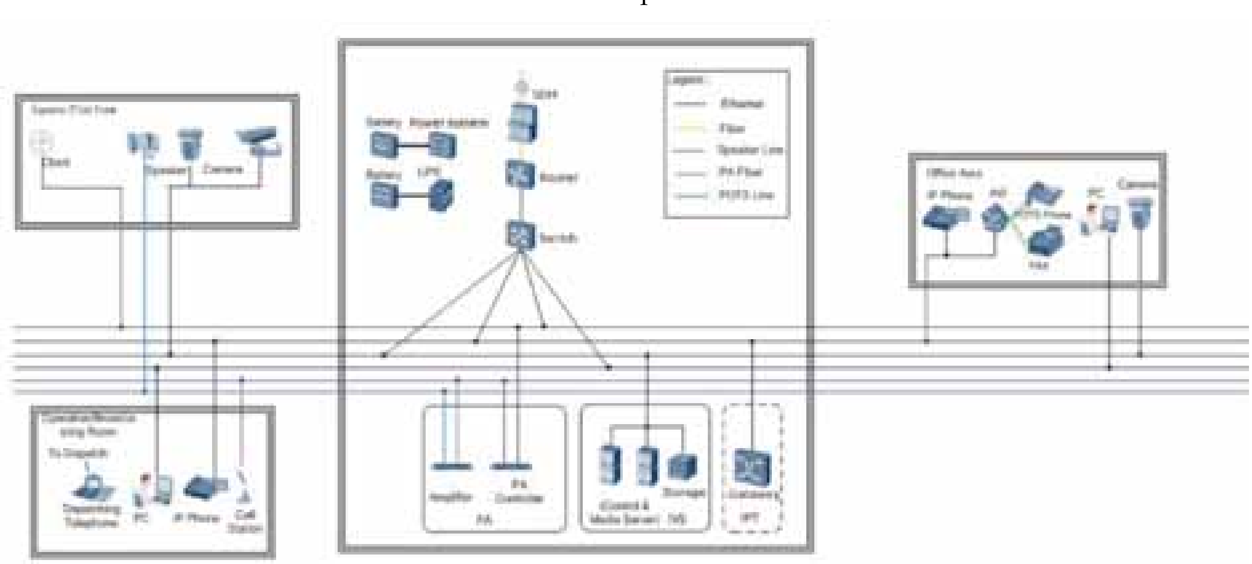

Figure 7. The equipment located in the shunting station

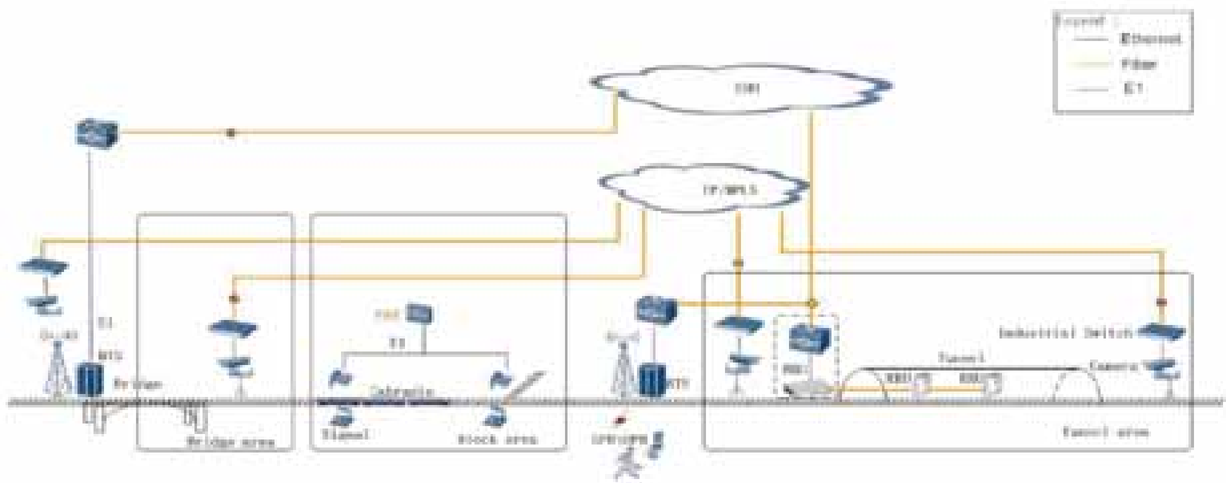

Figure 8. Equipment located at the trackside

ORGANIZATIONAL SCHEME OF THE RAILWAY ICS

The solution of the whole system

In accordance with the previous exposure and decomposition of the functional railways *ICS* subsystems, we will implement different functional subsystem modules at different physical locations (stations and trackside), and then we will generate a comprehensive physical architecture of the information communication system.

Figure 9 shows the organizational scheme with possible hierarchical levels at the railways *ICS*, depending on the traffic and technological level on the lines at the Serbian Railways. The displayed levels are: main stations (centers), geographic redundant center, regional stations, end stations, stops, trackside and shunting stations.

In Figure 10, nodes are sorted on the railway line Šid -Belgrade-Niš, including the Belgrade and Niš railway junction. There are also highlighted the central nodes of the I and Ig levels Belgrade Center and Belgrade Marshalling Yard, regional nodes and levels of Ruma, Belgrade Center, Lapovo and Niš, as well as all other nodes of II and III levels in end stations, stands, shunting stations and trackside.

Based on the proposed model, it is possible to sort all the official points on the railways network at the Serbian Railways and anticipate the necessary equipment that will enable the required services for regular and safe operation of the railway transport and placing the complete rail service to a higher level.

CONCLUSION

The paper defines the place of the information and communication system in the entire railway technology and transport system, as well as the need of connection with

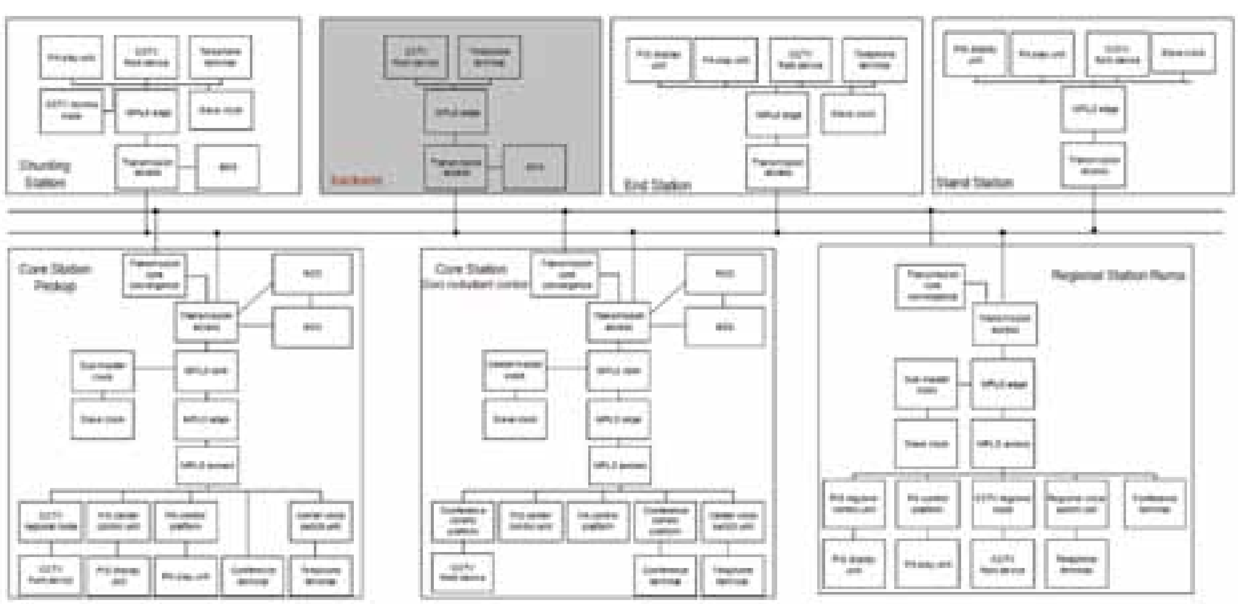

Figure 9. *ICS* organizational model

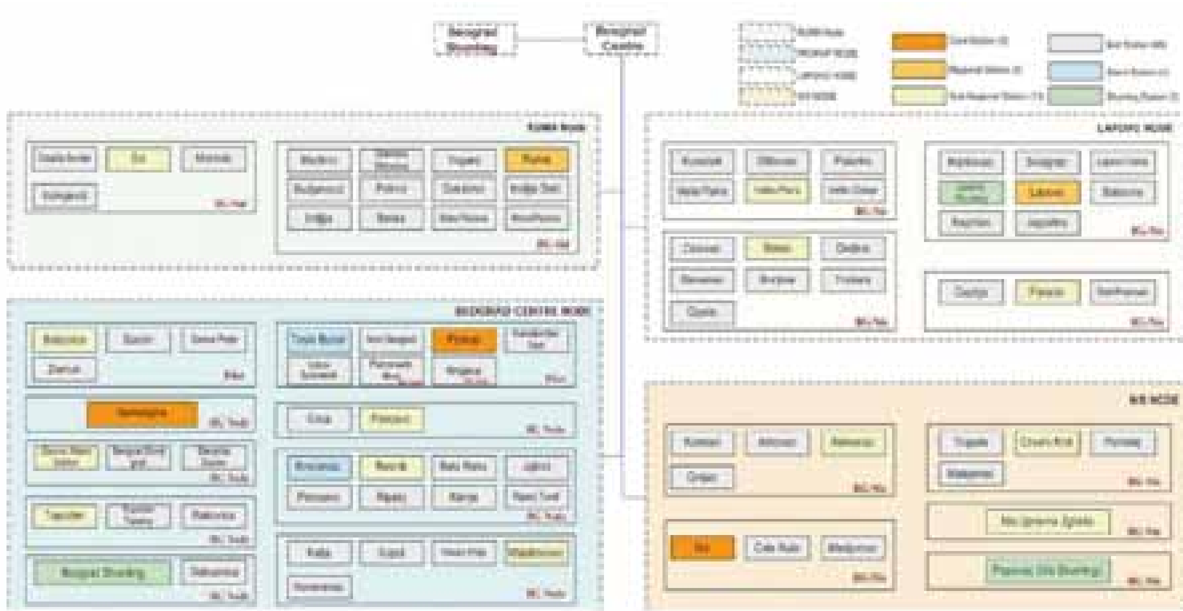

Figure 10. Nodes in ICS on the railway line Šid–Belgrade (Belgrade Node) – Niš (Niš Node)

other railway technological systems and external communication and other systems of interest for the functioning of the railway.

On the basis of traffic and technological requirements and characteristics of the official positions on the lines, the paper gives the proposal of *ICS* architecture with all the necessary subsystems, and depending on the technological and hierarchical level of the railway network in the Republic of Serbia. The levels of nodes in the railway *ICS* and their physical and logical organization were also identified, as well as the equipment and services characteristic for the individual nodes. An organizational model is proposed for the information and communication system of the railways, which would be applicable at the railways network of the Serbian Railways and other modern railway administrations, especially in our region.

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LIST OF ABBREVIATIONS AND ACRONYMS

A&A	NAME IN ENGLISH LANGUAGE
BBU	*Baseband unit*
BSC	*Base Station Controller*
BSS	*Base Station Subsystem*
BTS	*Base Transceiver Station*
CCTV	*Closed Circuit Television*
CTC	*Centralized traffic control*
E2E	*End to End*
ERP	*Enterprise Resource Planning*
ETCS	*European Train Control System*
FTS	*Fixed Terminal Sub-system*
GPH	*General Purpose Hand-portable*
GPS	*Global Positioning System*
GSM-R	*Global System for Mobile communications – Railways*
ICS	*Information and Communication System*
IS	*Information System*
MPLS	*Multi Protocol Label Switching*
NSS	*Network switching subsystem*
OA	*Office Automation*
OPH	*Operational Hand-portable Radio*

A&A	NAME IN ENGLISH LANGUAGE
PA	*Public Announcement*
PBX	*Private branch exchange*
PIS	*Passenger Information Systems*
PLMN	*Public land mobile network*
PRI	*Primary Rate* Interface
PSTN	*Public Switched Telephone Network*
QoS	*Quality of Service*
RDS	*Radio dispatch system*
RRU	*Remote Radio Unit*
SDH	*Synchronous Digital Hierarchy*
SPEV	*Stable electrical welding plants*
SS7	*Signaling System No. 7*
STS	*Station Telecommunication System*
VC	*Video Conference*
VoIP	*Voice over Internet Protocol*
VPN	*Virtual private network*
ŽAT	*Railway automated telephone exchange*
ŽATg	*Railway automatic telegraph exchange*
ŽS	*Serbian Railways*

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ORIGINAL SCIENTIFIC PAPER

Fuzzy Model for Assessing the Scope of Work of Railway Passanger Transport Undertaking

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Abstract: The main objective of the European policy of rail transport is the development of a single railway area. The opening of the railway sector to market competition impose that railway undertakings behave like any other modern enterprises in other markets and in other industries. It means, they must constantly develop and maintain competitive advantages, and be better than others. In today's very intense competition conditions, this is the most difficult to achieve. The railway undertakings are challenged to find optimal solutions to operate efficiently and effectively, in order not only to survive on the transport market, but also to develop and maintain a competitive advantage. The paper developed innovative model for the evaluation of efficiency of railway operators for passenger transport assessing the scope of work of railway undertakings that can greatly help to increase the competitive ability of railway undertakings in the single railway market. The developed models allow the integration of indicator groups (resources, operational, financial, quality and safety indicators) into a single assessment of the scope of work of railway undertakings and also allow the provision of information about the corrective actions that can improve the scope of work of the railway undertaking. The proposed model has been tested on actual examples, e.g. railway undertaking Railways of Republic of Srpska. The analysis of the results shows exceptional suitability for use of developed approach for assessing the scope of work of railway undertakings.

Key words: railway undertaking, efficiency, method, fuzzy logic, model.

INTRODUCTION

Today, modern business primarily involves a highly demanding market battle, regardless of whether it is production or providing transport services. Great competition requires that the organization of the company becomes a central determinant of business, while the activities that are being implemented are fully harmonized and financially cost-effective for both the carrier and the users of services. In order to survive on the market, companies are trying to find the optimal relationship between the resources invested and the achieved goals. The efficient railway transport is a very important component of the economic development on a global and national level. It is therefore of particular importance to rationally restructure the railways and develop their competitive capabilities. In a large number of countries in Europe, but also in other countries of the world, standards have been adopted regarding the restructuring of the railway system. Appropriate legal acts were adopted for the transformation of railways. The previous stages of restructuring did not allow complete liberalization of the railway transport market, the expected positive operation of the railway sector, fulfilment of the requirements of the transport market, raising the quality of railway services to the required level, interests of the community at national, regional and local levels and others. The restructuring of the railway system brought only partially positive business results in the main railways or pan-European corridors, mainly in transit traffic [15]. Although the quality of the services of the railway system has slightly increased, it is still far from the quality required by the transport market. In providing adequate quality of railway services, railway undertakings have a very important role in addition to railway infrastructure in terms of: reliability, frequency, timetable, traffic speed, safety, organization of work in railway stations, competitive prices in the transport market, etc. In the present conditions in a large number of countries, transport is mainly performed by national operators that have emerged from the transformation - a division of railway companies. Mostly these companies are managed by the state.

The complete liberalization of the railway transport market implies, above all, a free and non-discriminatory access to the railway infrastructure, with the fact that the transport function is performed by a larger number of operators on the appropriate national railway network. The effectiveness and efficiency of transport activities significantly affect the profitability of business of all entities involved in the process, but they cannot be provided without much effort in the process of quality management and transport activities.

The subject of this research paper stems from the needs of the countries of Europe, whether EU members or applying for membership, to establish the market principles of business in the railway sector. Primarily, this relates to the liberalization of the railway market and introduction of a larger number of railway undertakings, and in the context of its reforms, harmonized with integration into EU and a modern international transport market. In the narrower sense, the subject of the research focuses on the concept of a railway undertaking through the development of a model for assessing the scope of work of railway undertakings, in particular in the process of restructuring European railways, and then by testing on a concrete example. Using the Fuzzy Logic, a model for assessing the scope of work of railway undertakings has been developed.

MODEL FOR ASSESSING THE SCOPE OF WORK OF RAILWAY PASSENGER TRANSPORT UNDERTAKING

Fuzzy sets are sets whose elements have degrees of membership. ln classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1].

The core technique of fuzzy logic is based on three basic concepts: (1) fuzzy set: unlike crisp sets, a fuzzy set has a smooth boundary, i.e. the elements of the fuzzy set can be partly within the set. Membership functions are employed to provide gradual transition from regions completely outside a set to regions completely in the set; (2) linguistic variables: variables that are qualitatively, as well as quantitatively, described by a fuzzy set. Similar to a conventional set, a fuzzy set can describe the value of a variable; (3) fuzzy "if-then" rules: a scheme, describing a functional mapping or a logic formula that generalizes an implication of two-valued logic. The main feature of the application of fuzzy "if-then" rules is its capability to perform inference under partial matching. It computes the degree the input data matches the condition of a rule. This matching degree is combined with the consequence of the rule to form a conclusion inferred by the fuzzy rule [13].

In assessing the scope of work of railway passenger transport undertakings, fuzzy input and output parameters have been defined. Fuzzy input parameters are the available number of rolling stock, the number of passengers carried, the costs for railway infrastructure charges, the Suitability - the ability of the offered services and the number of serious accidents. The Fuzzy output variable evaluates the operation of the railway undertaking. Rolling stock are the basic assets of railway undertakings that have the function of working means in the process of enabling transport services. It includes traction means i.e. locomotives and other self-propelled vehicles and tracked vehicles, i.e. all types of vehicles for transport of passengers.

It is of particular importance for a railway undertaking to achieve optimal capacity which implies such use of rolling stock, to achieve a relatively favorable relationship between the wearing of the useful properties, on one hand, and their productivity, on the other. The indicators of production, transport of passengers as the main activity of the railway undertakings is expressed through the number of passengers carried. The railway passengers transport undertaking collects certain revenues through the criteria that give the opportunity to see the amount of work done.

The cost for railway infrastructure charges directly affects the state of the railway undertaking in the transport market. When a domestic undertaking is able to provide the appropriate level of quality of the transport service, high charges will disincentive competition in the rail market. If the charges are high, there will be no interest from the private sector in the introduction of new operators. Also, no foreign operators will come to countries and railways where these charges are high. The number of serious accidents as an input for the model is very important for assessing the scope of work of the railway undertaking, as it affects the size of passenger transport and revenue, and affects as well the assessment of the scope of work of the undertaking, while railway accidents are damaging and destroying high value means of operation, cause large damage to property and traffic disruptions [3].The model proposed in this paper has been developed in a way that has not been used in the literature so far. The proposed model has been tested and verified through a survey conducted on the sample of the railway undertaking in BiH, i.e. the railways of Republic of Srpska. Figure 1 shows the layout of the model structure for assessing the scope of work (workload) of the railway passenger transport undertaking.

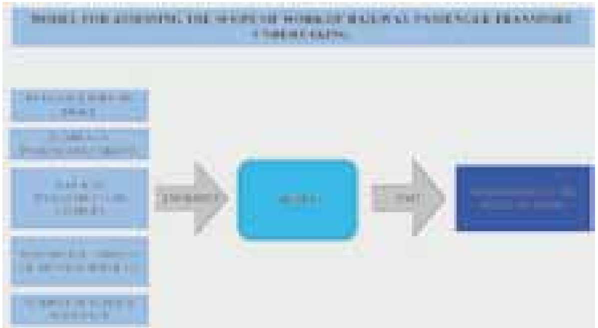

Figure 1. Structure of the model for assessing the scope of work of the railway passenger transport undertaking

DEFINING FUZZY VARIABLE

Fuzzy output variable A and fuzzy input variables B, C, D, E, and F are defined in the model for assessing the scope of work of the railway passenger transport undertaking. Fuzzy output variable A estimates the operator's scope of work. It is assumed that the grade can be: "BAD", "SATISFACTORY" or "GOOD", and that the quantification is from 1 to 10. The functions of belonging to the fuzzy sets A_{BAD}, $A_{SATISFACTORY}$ and A_{GOOD} are presented in Figure 2. Fuzzy input variable B is available number of rolling stock. It is assumed that the number of rolling stock can be "SMALL" (MBVS), "SATISFACTORY" (ZBVS) or "LARGE" (VBVS), and that the quantification of the scoring is from 120 to 180 rolling stock. Functions belong to fuzzy sets B_{MBVS}, B_{ZBVS} and B_{VBVS} are presented in Figure 3.

Figure 2. Functions belong to fuzzy sets: A_L, A_Z i A_D

Figure 3. Functions belong to fuzzy sets

Fuzzy input variable C describes the work achieved by the undertaking through the number of passengers carried. It is assumed that the number of passengers carried can be: "SMALL" (MBPP), "SATISFACTORY" (ZBPP) or "LARGE" (VBPP), and the quantification of the estimated 300 to 700 thousand transported passengers. Functions belong to fuzzy sets C_MBPP, C_ZBPP and C_VBPP are shown in Figure 4. Fuzzy input variable D describes the cost of railway infrastructure charges. It is assumed that these costs that reflect the operating costs of the operator can be: "SATISFACTORY" (ZTN), or "UNSATISFACTORY" (NTN). Functions belong to fuzzy sets D_{ZTN}, and D_{NTN} are shown in Figure 5.

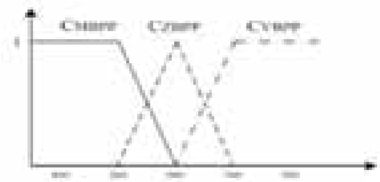

Figure 4. Functions belong to fuzzy sets: C_{MBPP} , C_{ZBPP} i C_{VBPP}

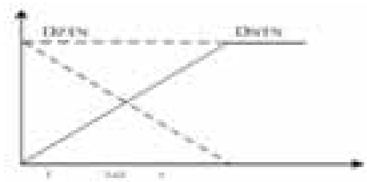

Figure 5. Functions belong to fuzzy sets: D_{ZTN}, *i* D_{NTN}.

The Fuzzy Input Variable E represents the Suitability - the ability of the offered services. This parameter represents a significant quality service evaluation. It is supposed to be "BAD" (LP) or "GOOD" (DP). Functions belong to the fuzzy sets ELP and EDP are presented in Figure 6. Fuzzy input variable F represents the number of serious accidents per driving kilometer. This parameter represents a significant quality service evaluation because safety is one of the most important quality elements. Based on the standards set by the European Safety Commission, it is assumed that the level of security can be "BAD" (LB) or "GOOD" (DB). Functions belong to fuzzy sets FLB and FDB are shown in Figure 7.

Figure 6. Functions belong to fuzzy sets: E_{LP} *i* E_{DP}.

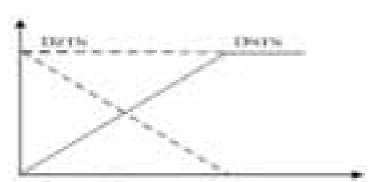

Figure 7. Functions belong to fuzzy sets: F_{LB} i F_{DB}

FUZZY LOGIC

Fuzzy logic is the base of fuzzy system. It enables making decisions based on incomplete information, and models based on fuzzy logic consist the so-called "IF-THEN" rules. "IF-THEN" rules are interconnected with "ELSE" or "AND". When we assume that $x = [x_1, x_2, \ldots, x_n]$ is a vector of features describing any object or state and $y = [y_1, y_2, \ldots, y_m]$ is the vector of output values of a system, the rules are represented in the for

$$R^r: IF\ x_1\ is\ A_1^r\ AND\ x_2\ is\ A_2^r\ AND \ldots AND\ x_n\ is\ A_n^r\ THEN\ y_1\ is\ B_1^r, y_2\ is\ B_2^r, \ldots, y_m\ is\ B_m^r,$$

where: $x \in X = X_1 \times X_2 \times \cdots \times X_n$, $y \in Y = Y_1 \times Y_2 \times \cdots \times Y_m$ i are the fuzzy sets [10]. Fuzzy logic is defined using algorithms for approximate reasoning. The special significance of fuzzy logic is in the possibility of its application for modeling complex systems in which is very difficult to determine the correlation of certain variables that exist in the model. Possible and logical rules are with weight 1, less possible 0.5. The approximate reasoning algorithm for evaluating the scope of work of railway undertakings for passenger transport, developed in this paper, consists of the following fuzzy rules [2]:

I. Available rolling stock "SMALL" ≤ 120

Number of passengers carried SMALL				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	bad	1
satisfactory	good	good	satisfactory	0.5
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	bad	1
satisfactory	bad	bad	bad	1
satisfactory	bad	good	bad	1
unsatisfactory	good	bad	bad	1
unsatisfactory	good	good	satisfactory	1

Number of passengers carried SATISFACTORY				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	satisfactory	0.5
satisfactory	good	good	satisfactory	0.5
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	bad	1
satisfactory	bad	bad	bad	0.5
satisfactory	bad	good	bad	0.5
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	satisfactory	0.5

Number of passengers carried LARGE				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	satisfactory	1
satisfactory	good	good	good	1
unsatisfactory	bad	bad	satisfactory	0.5
unsatisfactory	bad	good	satisfactory	0.5
satisfactory	bad	bad	bad	0.5
satisfactory	bad	good	bad	1
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	good	0.5

II. Available rolling stock "SATISFACTORY" 120 do 180

Number of passengers carried SMALL				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	satisfactory	0.5
satisfactory	good	good	satisfactory	1
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	bad	0.5
satisfactory	bad	bad	bad	1
satisfactory	bad	good	satisfactory	0.5
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	satisfactory	0.5

Number of passengers carried SATISFACTORY				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	good	0.5
satisfactory	good	good	good	0.5
unsatisfactory	bad	bad	bad	0.5
unsatisfactory	bad	good	satisfactory	0.5
satisfactory	bad	bad	satisfactory	0.5
satisfactory	bad	good	satisfactory	0.5
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	good	0.5

Number of passengers carried LARGE				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	good	0.5
satisfactory	good	good	good	1
unsatisfactory	bad	bad	bad	0.5
unsatisfactory	bad	good	satisfactory	0.5
satisfactory	bad	bad	satisfactory	0.5
satisfactory	bad	good	satisfactory	0.5
unsatisfactory	good	bad	good	1
unsatisfactory	good	good	good	1

III. Available rolling stock "LARGE" ≥ 180

Number of passengers carried SMALL				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	satisfactory	0.5
satisfactory	good	good	satisfactory	0.5
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	bad	1
satisfactory	bad	bad	bad	1
satisfactory	bad	good	satisfactory	0.5
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	satisfactory	1

Number of passengers carried SATISFACTORY				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	good	1
satisfactory	good	good	good	1
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	satisfactory	0.5
satisfactory	bad	bad	satisfactory	1
satisfactory	bad	good	satisfactory	0.5
unsatisfactory	good	bad	satisfactory	0.5
unsatisfactory	good	good	good	0.5

Number of passengers carried LARGE				
Railway infrastructure charges	Suitability	Number of serious accidents	Assessment of the scope of work	Weight
satisfactory	good	bad	good	0.5
satisfactory	good	good	good	1
unsatisfactory	bad	bad	bad	1
unsatisfactory	bad	good	satisfactory	1
satisfactory	bad	bad	satisfactory	0.5
satisfactory	bad	good	satisfactory	1
unsatisfactory	good	bad	good	0.5
unsatisfactory	good	good	good	1

MODEL TESTING RESULTS FOR THE ASSESSMENT OF THE SCOPE OF WORK OF RAILWAY PASSANGER TRANSPORT UNDERTAKING

Input variables in fuzzy systems are the so-called linguistic variables that take different values, such as "available rolling stock", "number of passengers carried", "railway infrastructure charges", "suitability-ability of offered

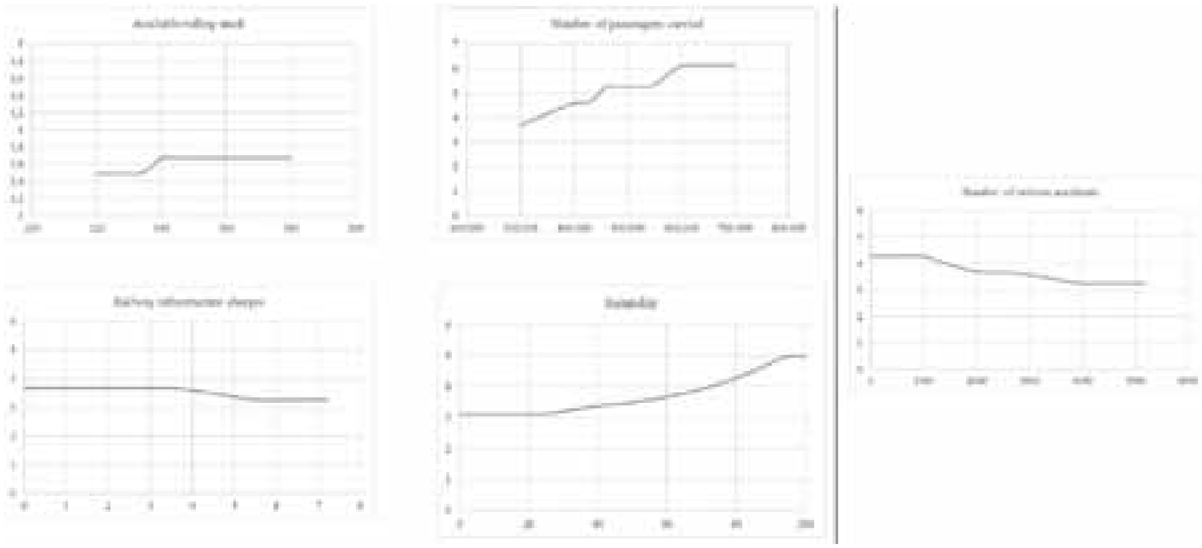

Figure 8. Assessment of the scope of work of railway passenger transport undertaking in the function of input parameters

services" and "number of serious accidents". The output is given in a continuous form. All possible values of the output variable are determined by the appropriate degree of belonging. After considering the degree of belonging of individual values of the output variable, defuzzification is performed. Defuzzification involves selection of one value of the output variable. The Centroid method (Center of gravity-COG or center of area-COA) is the basic defuzzification method that calculates the center of gravity of the function of belonging. The output value x*, which is the result of applying the Centroid method, is calculated according to the form (1).

$$x^* = \sum_{i=x_{\min}}^{x_{\max}} x_i \cdot \mu(x_i) \Big/ \sum_{i=x_{\min}}^{x_{\max}} \mu(x_i) \qquad (1)$$

where $\mu(x_i)$ has the belonging function. This paper uses the Mamdani fuzzy inference system (Centroid defuzzification), the minimization method for the operator "AND" and the maximization method for the operator "OR". In accordance with the defined variable output function, the scope of work of the railway undertaking has been assessed. It should be noted that in such fuzzy models there is no possibility of strictly defining the interval limits. The obtained results on the assessment of the scope of work of the railway passenger transport undertaking on a randomly selected sample in the function of all 5 input parameters is presented in Figure 8 [2].

The graphical display of the output fuzzy variable A (assessment of the scope of work) in function of the input fuzzy variable B (available rolling stock), C (number of passengers carried), D (railway infrastructure charges), E (suitability) and F (number of serious accidents) is presented in Figure 9.

In order to examine the impact of the input variable on the evaluation of the scope of work of the railway undertaking, model testing was conducted, i.e. the answer

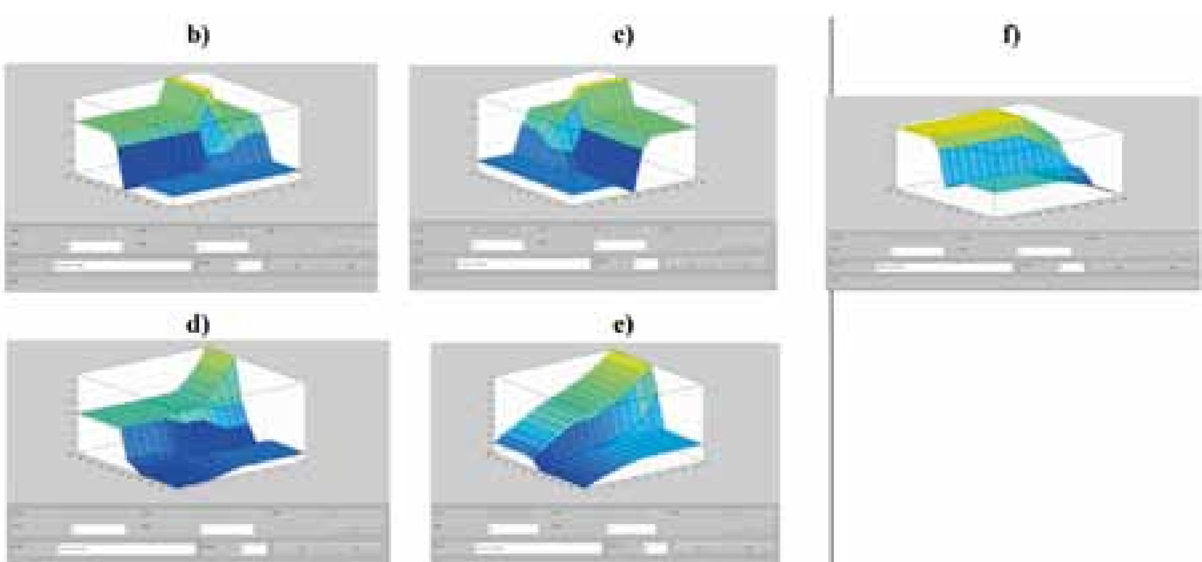

Figure 9. Output fuzzy variable A as a function of the input fuzzy variables B, C, D, E and F

to the question "WHAT-IF". For example, if the assessment of the scope of work in the function of the available number of rolling stock is observed with the constant values of other input variables, it is noticeable that the workload rating is rising to the level of 140 rolling stock. It should be noted that the function has no linear growth trend with an increase in the number of rolling stock and its value stagnates at an estimate of 3.67 for the number of rolling stock from 140 to 180. This can be explained by the fact that the operator has a surplus rolling stock for the volume of work that is currently performing (Figure 8). When it comes to the assessment of the scope of work of the undertaking in the function of the incoming variable number of passengers carried, provided that the other input quantities are constant, it is noticeable that the function has a growth trend by increasing the number of passengers carried. Changing the number of passengers carried in the range of 300,000 to 700,000, causes a change in the output variable to 67% (Figure 8). Observing the input variable costs of railway infrastructure charges, provided that the other input sizes are constant in the function of assessing the scope of work of the undertaking, it is noticeable that the value of the workload estimates ranges from 3 to 4. Changing the cost of railway infrastructure charges in the interval of 0 to 7, 2 causes a change in the output size to a maximum of 13%. This can be explained by the fact that the level of the railway infrastructure charges in BiH is among the lowest in the EU and the countries of the region (Figure 8). By analyzing the scope of work of the railway passenger transport undertaking when considering the incoming variable Suitability - the ability of offered services, provided that the other inputs are constant, it is noticeable that the function has a linear growth trend by increasing the undertaking benefits - Figure 8. If the input variable number of serious accidents is observed, provided that the other inputs are constant, it is noticeable that by decreasing this input variable in the range 0 to 5180 FWSIs, the workload rating is increased for 30% Figure 8.

Based on the results of the fuzzy model for the given values of the input variable, it can be concluded that the assessment of the scope of work (workload) of the railway undertaking railways of Republic of Srpska for passenger transport is poor. The definition of the fuzzy model for assessing the scope of work of the railway undertaking is shown in Figure 10.

CONCLUSION

Efficient railway transport is a very important component of economic development on a global and national level. It is therefore of particular importance to restructure the railways and develop their competitive capabilities. In order not only to survive on the transport market, but also to develop and maintain competitive advantages, they must operate effectively and efficiently. Effectiveness and efficiency of transport activities significantly affect the profitability of the business of all entities involved in the process, but they cannot be provided without much effort in the process of quality management and transport activities. Measuring the efficiency and effectiveness of railway undertakings inevitably becomes a condition for their survival in a unique transport sector. Efficiency and effectiveness have a positive impact on a number of other important indicators of functioning of railway undertakings, such as better use of resources, more rational energy consumption, increased security, increased quality of service, etc.

This paper has developed a fuzzy model based on which the management of railway undertakings can monitor the process of quality management and transport activities, and also define appropriate corrective actions. The developed model is tested on a realistic example, i.e. on railway undertaking ŽRS. The variable

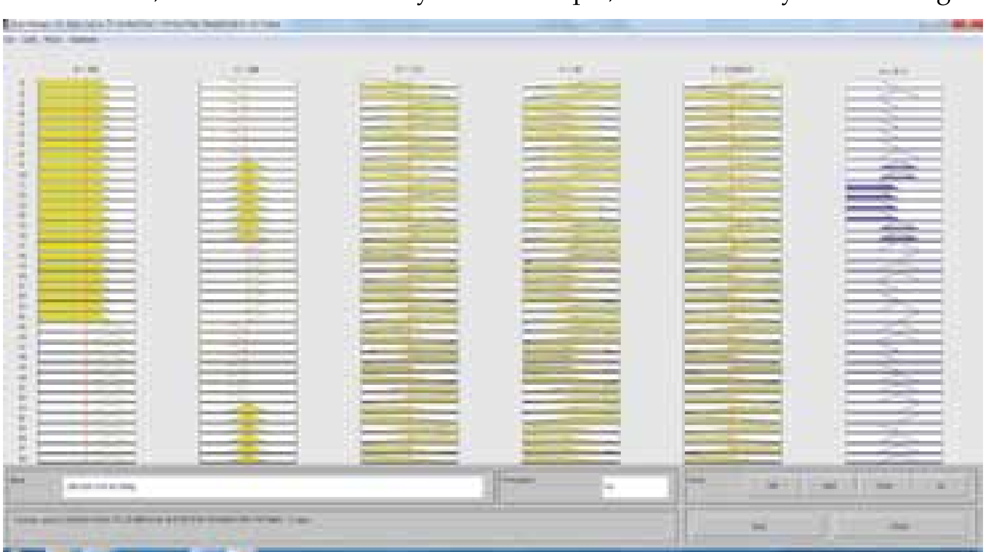

Figure 10. Defuzzification of the fuzzy model for assessing the scope of work of the railway passenger transport undertaking railways of Republic of Srpska

quantities and their values were identified based on the analysis of the railway undertaking ŽRS. The results obtained by testing this model for evaluating the scope of work of the railway passenger transport undertaking relate to the impact of the criteria on the output of the model. The criterion that most affects the output of the model for evaluating the scope of work of the railway passenger transport undertaking is the number of passengers carried. For the defined cases of testing the fuzzy model, the obtained results for evaluating the scope of work of the railway passenger transport undertaking are valid. In this way, the applied fuzzy model shows that the fuzzy logic technique can be applied efficiently and give good results in assessing the scope of work of railway undertakings. The universality of the developed model is reflected in its application to all railway undertakings.

This paper opens the possibility of further research to lead to development of new models that would combine the proposed approach with other approaches such as simulation, optimization models, etc. In this way, certain limitations would be exceeded and the process of evaluating the scope of work of railway operators would be improved.

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ORIGINAL SCIENTIFIC PAPER

The Effect of Countdown Pedestrian Signals on Pedestrian Behavior in Various Weather Conditions - Case Study in Banja Luka

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Abstract: Pedestrians represent the most vulnerable category of participants in traffic. More and more complex traffic conditions in cities across Europe, and therefore BiH, threaten traffic to become a challenge for pedestrians, and pedestrians often experience traffic as a challenge. Studies of behavior of pedestrians at signalized pedestrian crossings conclude that there is a high level of insecurity and a high percentage of unsafe crossings by pedestrians. Timers that add pedestrian signals indicate the length of the red light, the remaining time to the beginning of the green light for the safe crossing of pedestrians across the street. This paper analyzes the effect of the countdown pedestrian signals- CPSs in different weather conditions, ie the comparison of pedestrian behavior (switching to red light) without CPSs and with CPSs in different weather conditions (sun, snow, rain, no precipitation with a temperature of 0 degrees) was performed. The paper analyzes a traffic light pedestrian crossing over the road that consists of four traffic lanes in Banja Luka, BiH.

Key words: pedestrians, countdown pedestrian signals- CPSs, pedestrian behavior, crossing the street to red light.

INTRODUCTION

Walking is the basic and common mode of transport in all societies around the world. Each trip begins and ends on foot. Travelling on foot has proven environmental and health benefits, but unfortunately there is an increased risk of traffic accidents.

According to the World Health Organization (WHO, "Pedestrian Safety" 2012), around 270,000 pedestrians died in 2010, accounting for about 20% of the total number of dead people, and their 2013 report ("Global status report onroad safety "2013) shows that a lot of attention should be paid to the safety of pedestrians and cyclists, and it is necessary to work on establishing measures to promote non-motorized movements and for which they must be able to be safe.

Traffic accidents involving a motor vehicle and a pedestrian are19 times more likely to result in death, than accidents involving only vehicles, while the risk of mortality depends on age and gender (1) (DETR, 1999).

The International Transport Forum (ITF) in its report (2) shows that pedestrians experience traffic as something hostile and that many experience fear of complex traffic.

In order to increase the safety of pedestrians, local authorities create a combination of specific activities, called 3E (engineering, enforcement and education). Pedestrian injury can be the result of one or more factors, the behavior and habits of pedestrians, infrastructure design, and the environment.

RESEARCH BACKGROUND

The irregular and unavoidable crossing of pedestrians across the road at pedestrian crossings with traffic lights, during the blazing red light, is a frequent occurrence and one of the most common ways of occurrence of traffic accidents with the involvement of pedestrians - (3) (Wang et al.2011).

Many studies emphasize the important role of infrastructure on the safety of pedestrians (4) (Elvik, 2009); (5) (Miranda-Moreno et al., 2011).

In order to improve the behavior of pedestrians at pedestrian crossings and improve their safety, countdown pedestrian signals CPSs are increasingly used as a supplement to traditional traffic lights. The main role of countdown pedestrian signals CPSs is to show pedestrians the information on the remaining duration of the red light, to show the time remaining until the start of the green light, ie the beginning of the stage for their safe crossing across the street. The main goal is to reduce the number of pedestrian crossings to red light, to increase the safety of pedestrians, and to provide better traffic flow.

Previous scientific studies on the effect of the pedestrian timer show a decrease in the percentage of red light transitions. Eccles et al. (2003) (6) investigated 20 pedestrian crossings and obtained results that generally reduce the number of street crossings to red light, with the percentage reduction not the same and it depends on the microlocation of pedestrian crossings.

Researchers (PHA Traffic Consultants) from Berkeley concluded in their research (7) that the percentage of crossing the street at a red light was reduced from 23% to 15%, following the installation of countdown pedestrian signals, and that the 5% reduced the number of pedestrians who have tried to switch to red flashing light.

The reduction of 27.3% to 23.9% crossing at a red light, was proved in a research by Lipovac K. 2013. (8)

A survey in Montreal, Canada, analyzed the type of injuries and came to the conclusion that a 15% reduction in injuries was achieved at timer crossings - (9) Brosseau, M., Zangenehpour, S., Saunier, N., Miranda-Moreno, L., 2013.

Minnesota Department of Transportation (Mn/DOT) conducted a before-and-after study of CPSs at five intersections in the Minneapolis and Saint Paul metropolitan area (10) (Cook Research and Consulting, Inc., 1999; Farraher, 2000). After replacing conventional pedestrian signals with CPSs, researchers observed an increase in crossing success from 67 percent to 75 percent. The greatest increase was observed for teenagers, whose rates of compliance and success increased by 20 percent.

The City of San Francisco, CA conducted a preliminary evaluation of pedestrian behavior before and after conventional signals were replaced by CPSs (11) (DKS Associates, 2001).The CPSs pilot program involved 14 intersections. Investigators found a significant increase in crossing success (from 86 percent to 91 percent) when conventional pedestrian signals were replaced by CPSs, though pedestrian behavior differed substantially between sites. There was also a small, statistically insignificant increase in compliance with the pedestrian change interval after the CPSs was installed.

Markowitz and colleagues (12) conducted a before-and-after study in San Francisco, California, to assess the effectiveness of countdown pedestrian signals at 14 intersections. This study found that the countdown signals reduced the numbers of pedestrian crashes and injuries, that countdown signals reduced the proportion of pedestrians who completed the crossing during the red signal, and that pedestrians viewed countdown signals favorably.

Eccles and colleagues (13) performed a study in Montgomery County, Maryland, to evaluate the effectiveness of countdown pedestrian signals at five intersections. In that study, the authors reported a statistically significant increase (based on the t-test), in the after period, in the percentage of pedestrians crossing during the "Walk" interval at six of the eight locations studied. The results of the before-and-after study indicated that countdown pedestrian signals had no effect on vehicle approach speeds during the pedestrian clearance interval, that countdown pedestrian signals generally increased the number of pedestrians who entered on the "Walk" indication, and that countdown pedestrian signals significantly decreased pedestrian–vehicle conflicts. Additionally, the authors found that the pedestrians interviewed were aware of and understood the countdown pedestrian signals correctly.

The goal of this paper is to determine the percentage, the number of pedestrians crossing the roadway to the red light before setting the countdown pedestrian signals CPSs, after the CPSs is set, in different weather conditions.

METHOD

The research in this article was done in the central area of the City of Banja Luka, at a traffic light at a pedestrian crossing near the building of the City Administration. The traffic light works in such way that the green pedestrian light is 13 seconds, the protective time is 10 seconds, and the red light is 87 seconds (110 seconds in total). The street that pedestrians need to cross consists of 4 lanes (2 lanes for each direction), with a total width of 12m.

Research involves 5 phases:

- Phase I - before setting the CPSs,
- Phase II - CPSs set - sunny weather (temperature around 20^0),
- Phase III - CPSs set - snowfall,
- Phase IV - CPSs set - rain and
- Phase V - CPSs set - clean weather, temperature 0^0.

The research of each phase was conducted during 3 hours during the day. In the phase I of the study, the behavior of pedestrians was analyzed before setting the countdown pedestrian signals CPSs. The video camera was placed in a kiosk near the pedestrian crossing, and it can be said with certainty that it had no effect on the observed sample. The recorded video material was transferred to the computer, then it was statistically processed and analyzed the behavior characteristics of pedestrians for different phases of research.

RESULTS

Before setting the CPSs (Phase I), it was found that 23.30% of pedestrians started crossing the street duringthe red light.

The results after setting the CPSs, in different weather conditions exhibit the following (Figure 1):

- Phase II - during sunny weather with a temperature of about 20 degrees: the number of crossings of the street during the red light was reduced to 16.3%,
- Phase III - during the snowfall: the CPSs did not have a significant impact,
- Phase IV - during the rains: the number of crossings of the street during the red light was reduced to 15.8% and
- Phase V - clean weather, with a temperature of about 0 degrees, the number of crossings of the street during the red light was reduced to 6.8%.

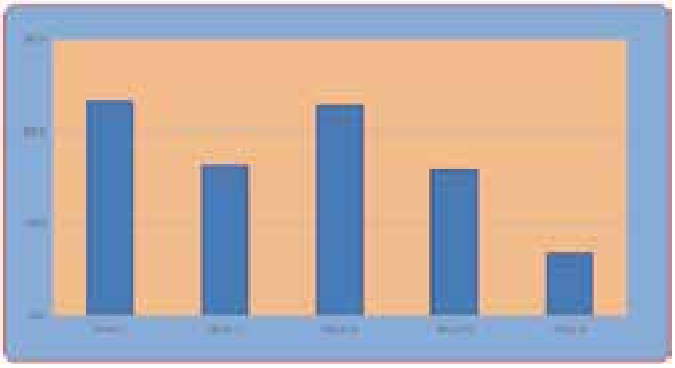

Figure 1. the number of crossings of the street during the red light (%)

If you analyze pedestrian crossings, without pedestrians who started crossing the road in the first 5 seconds of the red light and pedestrians that started their transition 5 seconds before the start of the green light (the last 5 seconds of the red light), the results are as follows (Figure 2):

- before setting the CPSs (Phase I): 10.9% of pedestrians started crossing the street during the red light;
- during sunny weather with a temperature of about 20 degrees (Phase II): the number of crossings of the street during the red light was reduced to 5.5%;
- during the snowfall (Phase III): the CPSs did not have a significant impact;
- during the rains (Phase IV): the number of crossings of the street during the red light was reduced to 6.0% and
- clean weather, with a temperature of about 0 degrees (Phase V): the number of crossings of the street during the red light was reduced to 3.2%.

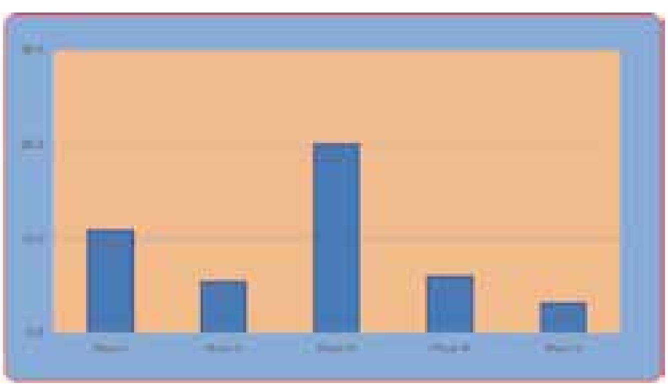

Figure 2. the number of crossings of the street during the red light (%) – without the first/last 5 seconds of the red light

Analyzing the moment of transition during a red light, it was found the same behavior of pedestrians, except in the phase when the snow falls (Figure 3).

After setting up a CPSs, pedestrians decided to cross the street in the first or last period of the red light in all phases. (Figure 4 - moment of transition during a red light without phase 5).

Analyzing the age structure of pedestrians crossing the street during the red light, the CPSs had no impact on the different age categories of pedestrians (Figure 5).

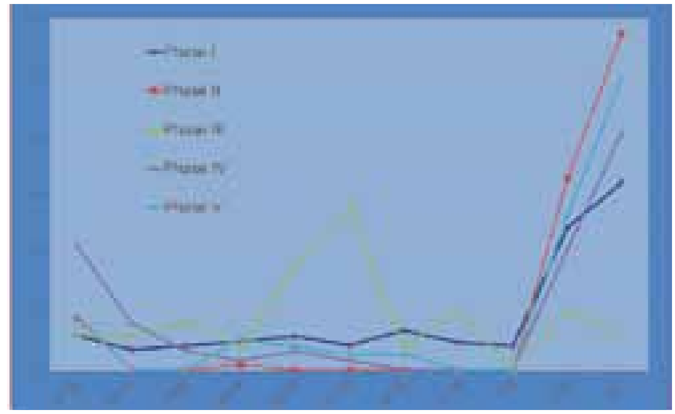

Figure 3. moment of transition during the red light

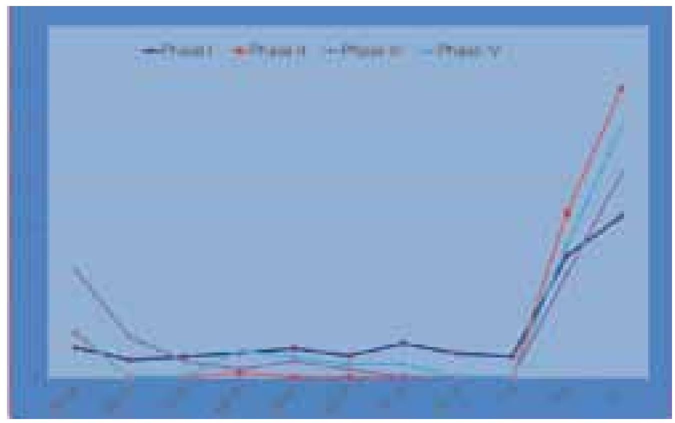

Figure 4. moment of transition during the red light without phase 5

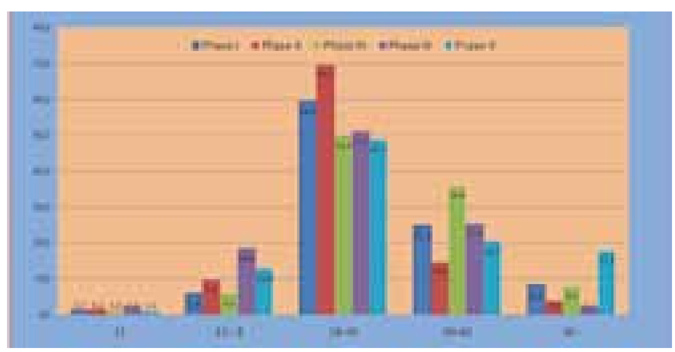

Figure 5. Age structure of pedestrians crossing the street during the red light

DISCUSSION

The study found that the setting of the countdown pedestrian signals – CPSs had a positive effect. The total number of pedestrians crossing the red light decreased in all phases of the research (in all weather conditions), except during snow, (Phase V) when there is no impact.

An additional analysis was done for the phase when it was snowingand showed that about 90% of pedestrians lacked adequate clothing for weather conditions (there is no hood or umbrella), and that the speed of traffic flow is reduced, so pedestrians choose to cross the street during red light.

Also, if we do not analyze the initial 5 seconds of the red light and the last 5 seconds of the red light, the use of the CPSs had a far greater impact on the pedestrians. Again, it is necessary to emphasize that in the phase of snowfall, the CPSs does not have a significant impact.

Analyzing the age structure of pedestrians before and after setting the timer in different weather conditions, pedestrians between 18 and 40 years of age conducted a number of improper behaviors, which is in line with previous scientific studies on the impact of timers on the behavior of different age structures when crossing the street (7) (LIpovac, (2013); (14) King et al. (2009); (15) Ying and Keping, (2011)).

By analyzing the distribution of the street crossing during the red light, it was determined that the pedestrians decide on an irregular crossing during the first and last 5 seconds of the red light. The above can be explained in the way that, by setting the CPSs , the pedestrians have information about the duration of the red light, or the duration of time for which they will be able to cross during the green light.

If the pedestrians notice that the red light has just begun or that there is very little time left to start the green light (the end of the red light), pedestrians are more likely to decide to cross the street in an irregular, unsafe way.

After 5 seconds of the red light for up to 5 seconds until the end of the red light, the CPSs had a significant positive effect and it can be concluded that these seconds represent the limit values for deciding to cross the street during the red light from the pedestrian area. From the distribution analysis, the phase was dropped when the snow fell, for which it was again confirmed that the CPSs had no significant impact.

CONCLUSION

The countdown pedestrian signals – CPSs have a positive effect on the behavior of pedestrians and their decision to cross the street, in the weather conditions when it is sunny (Phase II), when it rains (Phase III) and when there is no precipitation (clear time –) and the temperature is 0 degrees (Phase IV), and there is no significant impact during snowfall (Phase V).

The effect of the CPSs on the age structure of pedestrians does not exist and often those who are crossing the street during the red light at all phases of the study are pedestrians from 18 to 40 years.

The study found that CPSs influence the decision to cross the street, and the 5th second of the start and the 5th second before the end of the red light can be considered as the limit value for the decision of the pedestrian.

The research and results confirm previous experience of the effect countdown pedestrian signals on pedestrian behavior.

The research should expand and analyze the average number of pedestrians who crossthe street during the red light, the impact of pedestrians crossing the street during the red light on pedestrians waiting for the green light, the duration of the waiting time of pedestrians crossing the street during the red light, analyzing pedestrian crossings on different types and characteristics of roads, the percentage of crossing the street in relation to traffic flows of different parameters, in order to establish more accurate conclusions on the influence of the effect that the countdown pedestrian signals CPSs have in the areas of different cities in BiH.

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ORIGINAL SCIENTIFIC PAPER

The Impact of the Efficiency of the System for Vibrations Damping on the Efficiency of Vehicle Braking

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Abstract: This paper presents the plan and results of the research of the efficiency of the braking system depending on the condition of the shock absorbers and the velocity of the vehicle movement at the moment of braking. As expected, it has been proven that the braking efficiency decreases with decreasing efficiency of the system for damping vibrations. The interdependence of these two systems is also represented by a mathematical model that can serve for practical purposes in the analysis of traffic accidents.

Keywords: shock absorber, braking system, efficiency.

INTRODUCTION

Statistics show that we have a large number of vehicles in service with significant age characteristics that affect the operating performance of the vehicle. It is to be expected that some systems lose projected performances and have an impact on other systems and their efficiency or reliability. One of these systems is the elastic suspension system, which was the subject of this research, whose purpose is to determine its impact on other systems, and especially on the braking system. It is to be expected that there will be degradation of the efficiency of the braking system with aging of the vehicle or reaching vehicle designed service life. The aim of the research is to determine the regularity that is connecting the efficiency of the braking system depending on the efficiency of the vibration damping system, using scientific approach and modern scientific tools and methods.

VEHICLE`S SUSPENSION SYSTEM

The connection between the vehicle body and the surface is established using running gear. Their purpose is primarily to provide constant contact between the pneumatics and the road, maximum comfort and safety for the driver and passengers. Practically, the purpose of suspension system is to transfer all reactive forces and moments which occur between wheels and the ground, during different conditions of moving, to the frame or chassis, with as much as possible damping of shock loads, as well as to provide the necessary stability of the vehicle, particularly in braking and cornering of the vehicle. The suspension system, in general, is a very complex system, which consists of four sub-systems:

- linkage mechanism, (bar system),
- elastic elements (springs),
- damping elements (shock absorbers),
- stabilization elements (stabilazer bars).

The purpose of the mechanism for wheel guiding is to provide optimum wheel guidance in relation to the vehicle chassis. In addition, this mechanism must ensure the transfer of horizontal reactive forces (lateral and longitudinal) and moments from the wheel onto the chassis. The main purpose of the elastic elements is to convey reactive forces to the chassis, and to ensure their maximum mitigation with minimal shock loads during transfer of vertical forces. The purpose of the elements for damping is to dampen vibrations of elastic elements, or suspension systems and the vehicle as a whole, while reducing shock loads. Additionally, special elements are built into the suspension system, the so-called stabilizers. The purpose of the stabilizers is to ensure stability of the vehicle while moving in curves.

Flexible suspension of the vehicle

Flexible suspension system of a motor vehicle is such mechanism that achieves a elastic connection between the basic construction of a motor vehicle, as sprung weight and the axle with wheels as unsprung weight.

Due to external influences and service conditions that arise from the type of road surface and motor vehicle driving modes, there is a manifestation of external malfunction of uniform movement of the basic construction of the vehicle. This malfunction can affect the linear and angular movement of the basic construction of the vehicle along the x, y and z axes (Figure 1).

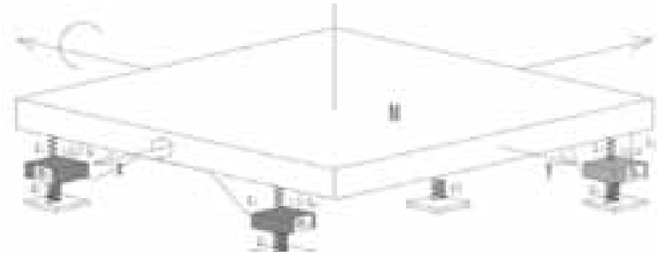

Figure 1. Model of motor vehicle vibrations

These vibrations, according to figure 1, have their standard names: vertical (*z*), longitudinal (*x*), transversal (*y*), angular around *x-axis* – rolling (*β*), angular around *y*-axis – pitch (*ά*), angular around *z-axis* – yaw (*θ*).

Motor vehicle presents itself as a very complex vibration system. In Figure 1, it is represented through an equivalent vibration system with five masses. Mass *M* is the mass of the basic vehicle structure, and $m_1,$ $m_2,$ m_3 *and* m_4 are the masses of the front and rear wheels, as unsprung masses. Different values for stiffness parameter of flexible elements are marked with c_1, c_2, c_3, c_4, and ct_1, ct_2, ct_3, ct_4, and different values for damping are expressed through damping coefficients k_1, k_2, k_3 *i* k_4.

The elastic suspension system of the vehicle consists of a spring system and the vibration damping system-shock absorbers. With good harmonization of spring system and vibration damping system, the parameters that affect comfort and safety as a whole should be optimized.

Vibration damping elements – shock absorbers

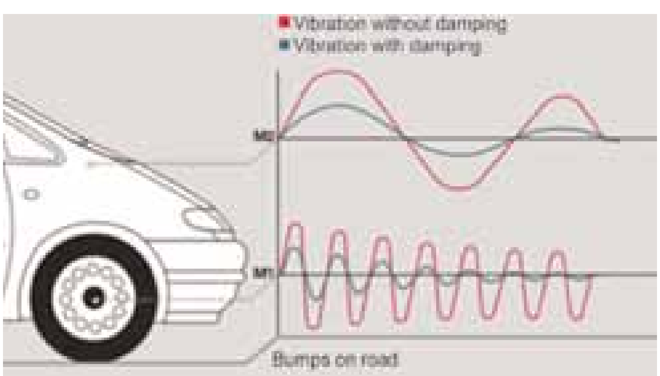

Figure 2. Display of vibrations M_1 (axle + wheels) and M_2 (vehicle chassis + cargo)

The purpose of shock absorbers is to dampen vibrations of elastic elements i.e. the suspension system and the vehicle as a whole, while reducing shock loads. This directly affects vehicle`s comfort, stability and safety of movement, so these elements are classified as active safety elements of the vehicle. When a vehicle passes over a bump, elastic damping elements get compressed. The resulting shocks are absorbed by suspension system that prevents contacts between the mass with suspension and mass without suspension. The springs prevent amortized components M_2 (vehicle chassis + cargo) to come into contact with unamortized components of M_1 (axle + wheels). Since frequencies of vibration of the axle and wheel, or body, mutually differ, shock absorber, with its function both vibrations dampen as shown in Figure no 2.

This is the reason why the shock absorber is placed between the chassis and the supporting elements of the wheel. Elements for damping of shock absorbers need to meet strict criteria to quickly dampen vibrations of the vehicle and prevent the occurrence of resonance.

The characteristic of the shock absorber is defined by damping force *F* depending on velocity of piston *v* movement in the cylinder of shock absorber. Characteristics of shock absorbers' force are determined according to vehicle weight, axle design, springs, and other elements of the vibration system. For the shock absorber, maximum damping forces are significant during compression, tension and capacitance. During service, shock absorbers lose their properties and the damping force is reduced, and thus their efficiency, as shown in figures 3 and 4, which reduces the overall reliability of the vehicle as a whole.

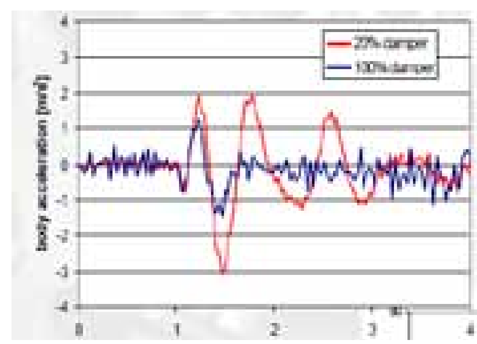

Figure 3. Vibrations of the body in relation to the damping of the shock absorber

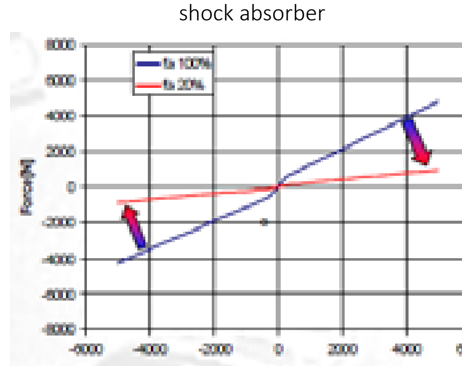

Figure 4. Impact of shock absorber wear on its characteristics

RESEARCH PLAN

To achieve the set goal, experimental studies that were carried out determined the operating performance of the shock absorber on the vehicle's specimen and braking system performance depending on the condition of the built-in shock absorber for three levels of damping.

Research on shock absorbers operating performance

Based on prominent assumptions that the damping elements - shock absorbers also play a significant role in terms of overall function of the vehicle, investigations of the shock absorbers operating performances were carried out on vehicles in service, randomly. Testing and inspection were carried out on 356 vehicles of category M1. The following sizes were identified by carrying out inspection and control: vibration damping efficiency individually for each shock absorber, the difference between the damping efficiency achieved by the shock absorbers at the front and rear axles and failures identified by visual examination. Tester device was used to identify the efficiency of vibrations damping generated by shock absorbers at the frequency of 15 Hz. The criteria for evaluation were: shock absorbers are defective if their coefficient of damping efficiency is ≤ 0.2, as well as if the difference of damping efficiency produced by the right and left shock absorber on the front and rear axle is ≥ 25%. The results of the tests showed that 39% of the vehicles had a defective shock absorber and the unapproved asymmetry of their characteristics.

Research of the performance of the braking system

Experimental research on the polygon has measured the performance of the braking system at different speeds and with three different packages of shock absorbers, depending on the damping characteristics. A Golf 4 vehicle was used for the experimental research. Testing was done on dry asphalt, at an ambient temperature of 32 ° C. Target velocities at which the breaking was done were as follows: v_{z1} = 50 km/h, v_{z2} = 80 km/h and v_{z3} = 100 km/h. Measurement generated data on stopping distance, deceleration, time and velocity. The device Vericom VC 3000 was used for measuring.

Testing of braking performance, depending on the condition of shock absorbers, was done in three phases with an average calculated coefficient k_i, $k_i = \frac{k_{pl} + k_{pd} + k_{zl} + k_{zd}}{4}$ where k_{pl}, k_{pd}, k_{zl} and k_{zd} are measured damping efficiency values achieved by the left and right shock absorbers on the front axle, or left and right shock absorber on the rear axle.

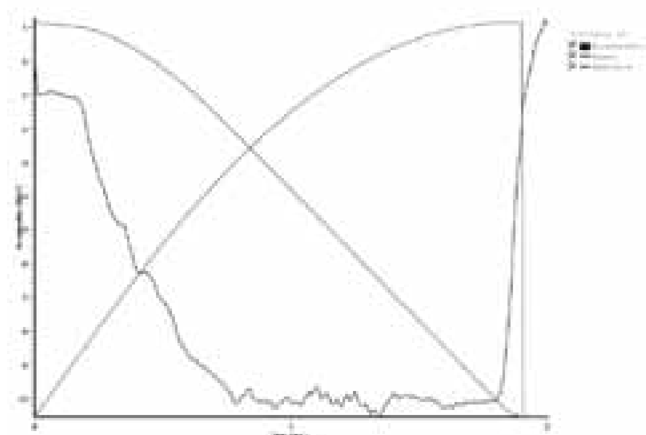

Figure 5. Braking diagram for v=54.52 km/h, and k_i = 0.1

The experiment matrix is shown in Table no 1 for each coefficient of damping, measurements were made at speeds of 50, 80 and 100 km/h.

Table 1. The experiment matrix

Coeff. k	Velocity km/h		
k_1=0.1	50	80	100
k_2=0.272	50	80	100
k_3=0.525	50	80	100

Table 2. Results of total measurements

Coeff. .ki	Ord. no	Braking velocity (v_i) [km/h]	Stopping distance (s_{zi}) [m]	Specified velocity (v_z) [km/h]	Stopping distance (v_z) [m]	Braking velocity (v_i) [km/h]	Stopping distance (s_i) [m]	Specified velocity (v_z) [km/h]	Stopping distance (v_z) [m]	Braking velocity (v_i) [km/h]	Stopping distance (s_i) [m]	Specified velocity (v_z) [km/h]	Stopping distance (s_{zi}) [m]
k1 = 0.1	1	54.52	16.6	50	13.81	80.33	33.09	80	32.73	102.3	50.23	100	48
	2	52.49	14.88	50	13.72	81.81	34.07	80	32.59	107.2	56.00	100	48.80
	3	53.37	15.96	50	14.00	82.29	33.79	80	31.94	111.5	58.88	100	47.34
	4	53.56	15.98	50	13.90	78.06	30.48	80	32.02	103	49.91	100	47.05
	Szsi				13.85				32.32				**47.60**
k2 = 0.272	1	48.27	11.47	50	12.28	79.54	27.90	80	28.30	98.4	42.46	100	43.86
	2	51.57	12.44	50	11.78	74.32	24.75	80	28.76	101.5	49.45	100	48.00
	3	57.24	15.30	50	12.03	78.57	29.00	80	30.07	93.41	37.92	100	43.46
	4	46.5	10.10	50	11.95	76.30	29.83	80	32.73	101.08	49.61	100	48.56
	Szsi				12.01				29.97				**45.97**
k3 = 0.525	1	45.64	8.46	50	10.01	82.93	30.20	80	28.17	93.41	36.65	100	42.01
	2	47.07	9.00	50	10.16	80.27	27.54	80	27.36	107.32	48.38	100	42.10
	3	61.17	15.51	50	10.36	70.00	20.90	80	27.94	98.16	41.62	100	43.00
	4	53.92	12.46	50	10.37	81.91	29.17	80	27.78	101.08	43.42	100	43.20
	Szsi				10.23				27.81				42.58

RESEARCH RESULTS

The measurement results are shown in Table 1 with information on velocities and stopping distance, for all three series of measurements. Figure 5 shows measurement diagram for velocity of v=54.2 km/h and k_1=0.1.

PROCESSING OF MEASUREMENT RESULTS

Through the measurement results for the stopping distance, as shown in Table no. 2, the conclusions regarding the first series of measurements with defective shock absorbers will be reported.

Table 3. Data for stopping distance when k_i=0.1; k=0.272; k=0.525

v_i	v_1 = 13.89 m/s			v_2 = 22.22 m/s			v_3 = 27.78 m/s		
k_i	0.1	0.272	0.525	0.1	0.272	0.525	0.1	0.272	0.525
S_{ki}	13.86	12.01	10.23	32.32	29.97	27.81	47.60	45.97	42.58

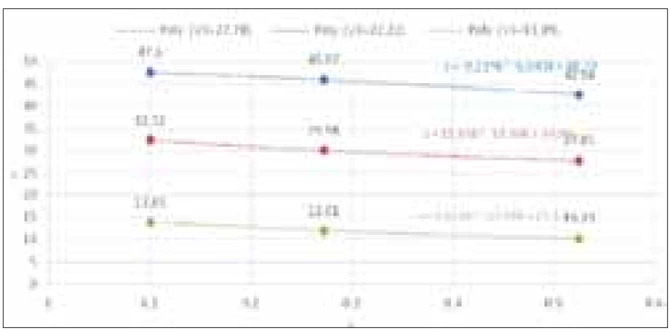

Figure 6. Diagram of stopping distance in function of shock absorber characteristics S=f(k)

From the data given in Table 2 and the comparative diagram given in Figure 6, it is evident that the stopping distance depends on the condition of the shock absorbers and the velocity at the moment of starting the braking of the vehicle. The conclusion is that the stopping distance is reduced if the shock absorbers with a higher damping efficiency are fitted into the vehicle. The braking efficiency of a vehicle is determined on the basis of the following expression:

$$E_{ks} = \frac{s_{k1} - s_{ki}}{s_{k1}} \cdot 100(\%) \quad (1)$$

where:

E_{ks} – is efficiency of the vehicle's braking system;

S_{k1} – is braking distance for a vehicle with defective shock absorbers $k_1 \leq 0.2$;

S_{ki} – is braking distance for a vehicle with the properly functioning shock absorbers $ki > 0.2$.

Based on the data from Tables 2 and 3 and mathematical expression (1) table 4 is systematized and diagram $E_{ks} = f(k,v)$ shown in Figure no 7 was made.

From the above, it is evident that with the increase of the vibration damping efficiency of shock absorbers, the efficiency of vehicle breaking is also increased. When braking at higher velocities, the efficiency of the braking of motor vehicle is reduced, that is, the effect of the shock absorber state is reduced.

Table 4. Braking system efficiency- obtained results

v (m/s)	k_i	$S_{k1} - S_{ki}$	E_{ks} (%)
13.89	0.1	0	0
	0.271	1.85	13.3
	0.525	3.63	26.19
22.22	0.1	0	0
	0.271	2.35	7.22
	0.525	4.51	14
27.78	0.1	0	0
	0.271	1.83	3.8
	0.525	5.22	11

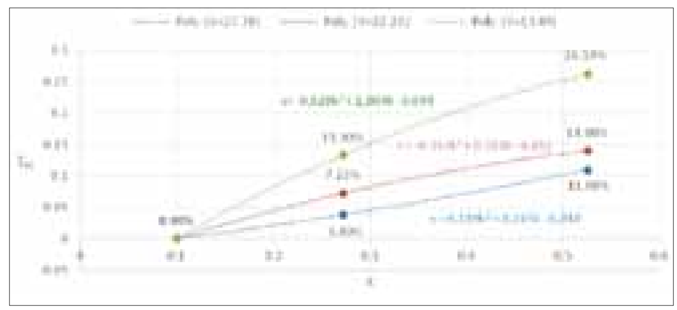

Figure 7. Efficiency of the braking system in function of velocity and characteristics of the shock absorber

By using the data in Table 4 and the diagram shown in Figure 7, A dependency diagram was generated $E_{ks} = f(k)$ in Figure 8 where the curve is defined by a mathematical expression that reads:

$$E_{ks} = -27.47 \cdot k^2 + 57.31 \cdot k - 5.456. \quad (2)$$

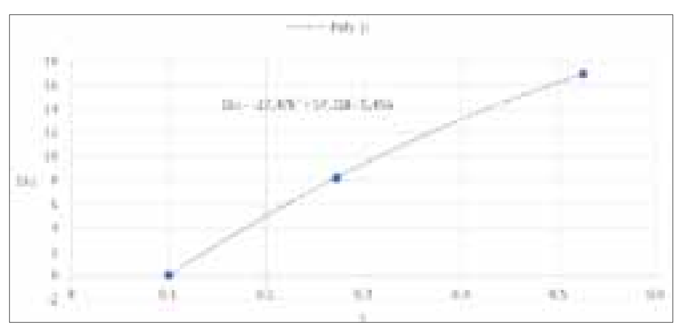

Figure 8. Efficiency of the braking system in function of the shock absorber characteristics E_{ks} = f(k)

A special analysis was performed in statistical software Minitab with General full factorial design experiment plan. Two factors were used in the analysis: factor of velocities and factor of the shock absorbers' characteristics. The analysis was performed in the encoded coordinates of the experiment factor plan. The analysis generated a linear, spatial and contour form of the function of the braking system's efficiency depending on the velocity and characteristics of the shock absorber.

Regression Analysis: Eks versus A; B
The regression equation is

Eks = - 0.44 - 4.12 x velocity + 8.53 x characteristic

Predictor	**Coeff**	**SE Coeff**	**T**	**P**
Constant	-0.443	4.235	-0.10	0.920
Velocity	-4.115	1.439	-2.86	0.029
Characteristic	8.532	1.439	5.93	0.001

S = 3.52397 R-Sq = 87.8% R-Sq(adj) = 83.8%

Analysis of Variance

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	2	538.34	269.17	21.67	0.002
Residual Error	6	74.51	12.42		
Total	8	612.85			

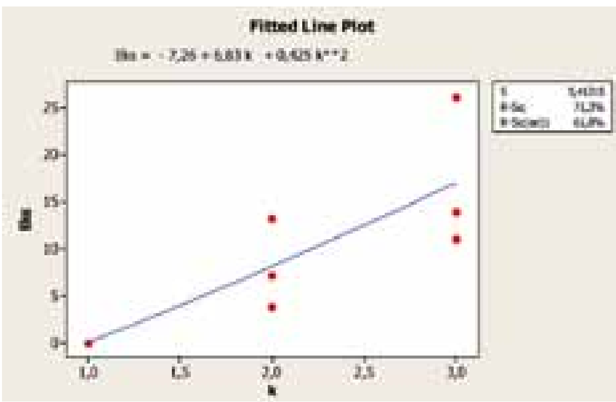

Figure 9. Linear form of braking system efficiency function, $E_{ks} = f(v,k)$

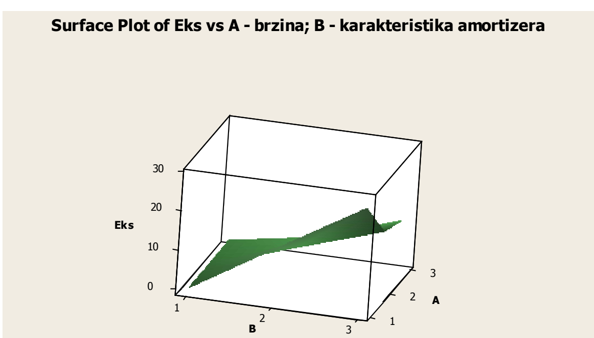

Figure 10. Spatial appearance of braking system efficiency function, $E_{ks} = f(v,k)$

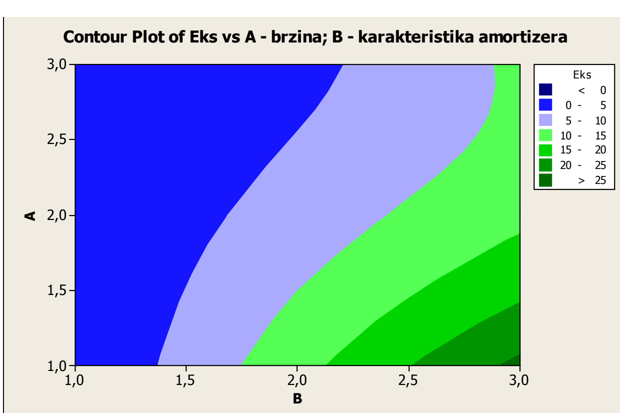

Figure 11. Contour appearance of braking system efficiency function, $E_{ks} = f(v,k)$

CONCLUSION

The research shows that the stopping distance, that is, the braking efficiency of the vehicle, is significantly dependent on operating performance of the shock absorbers. Likewise, it is evident that the efficiency of the braking system changes at different velocities. The higher the vehicle velocity, the impact of the state of the shock absorber on the stopping distance is lower.

Mathematical expression of a function that represents the dependence of the system's efficiency by a mathematical expression

$$E_{ks} = -27.47 \cdot k^2 + 57.31 \cdot k - 5.456.$$

Since the inspection of the shock absorber operating performance is not included in the periodic inspection of the vehicle during technical inspection, it would be prudent to pay attention to this circumstance and develop methods and procedures for inspection of shock absorbers through the legislation system.

Obtained results and determined interdependency $E_{ks} = f(v,k)$ can also be used for practical purposes with analysing the occurrence of traffic accidents from the aspect of the impact of the shock absorbers safety on the stopping distance, since so far this factor has not been influential in carrying out time-spatial analyses during expert evaluations in the field of traffic.

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ORIGINAL SCIENTIFIC PAPER

The Influence of Modern Technical Systems in Vehicles on Road Safety

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Abstract: A vehicle is a very complex technical system with several aspects. The basic purpose of each motor vehicle, is its primary goal to ensure the safety of the vehicle and, therefore, the safety of all traffic users. In order to achieve the basic goal, in the latest motor vehicle engineer development, during the development itself to the ultimate serial production, considerable attention is paid to the development and improvement of technical systems that help and improve vehicle management, and improve the control of the dynamic movement of vehicles. The ABS system (Anti-lock Braking System) is a precursor to the development of these systems, based on which a whole spectrum of active management systems has been developed. There is an overview of positive impacts of some system on the vehicle safety. Influence of the system of the active safety of traffic is presented through the correlative interaction between the number of traffic accidents with light bodily injuries, number of the light injured persons and number of vehicles possessing ABS and/or ESP system and number of traffic accidents and their consequences in the Republic of Srpska. The results showed that there is a strong correlation between the number of traffic accidents with light bodily injuries, number of light bodily injuries and number of vehicles possessing ABS and/or ESP system. Furthermore, the results showed that the increase of number of the registered vehicles increases the percentage of vehicles possessing the mentioned systems. Safety of vehicles is a very important factor of the traffic safety. Decrease of the average age of the fleet contributes to the great extent to the decrease of a number of the traffic accidents and their consequences.

Keywords: road safety, systems of active and passive road safety, modern devices for controlling of dynamic movement of vehicles, ABS, ESP.

INTRODUCTION

The vehicle is one of the basic factor of the road safety. The importance of the vehicle as an important factor of the road safety is becoming more and more prominent due to the increase of number of vehicles. At the same time, this fact implies the obligation that this factor given even more attention. There are basic measures for improvement of safety in terms of movement of motor vehicles on the roads. Drivers and other persons responsible for proper operation of the vehicles on the road must neither manage the vehicles nor order any other person to do it, which is not in a technically proper condition or which does not meet the requirements prescribed for participation in the traffic.

There has been a sudden increase of number and complexity of the electronic systems in vehicles for the last four decades. Share of electronics in the today's vehicles is even 25% of the total generation price. Analysts estimate that more than 80% of innovations in the vehicle industry are based on the electronic systems (DEKRA, 2017). However, for the purposes of systematic survey of the traffic safety, it is most important to find understanding of complex interactions between man, vehicle and road (lanes, namely surrounding). Interactions of man-road-lane (surrounding) are very important both for safety and traffic management as well as for the design of traffic roads and vehicles. Threat to the traffic safety and occurrence of traffic accidents result from the false behavior of the users, namely, the sub-system of traffic, as a complex social-technical system. The ideas of the information technologies were joined with the method of traffic safety control on the vehicle (sensors, mechanical elements, sets,) and central processing units which regulate the correction of mistakes caused due to different reasons during the vehicle movement. ((Tešić i dr. 2012).

The surveys (Elvik and Vaa, 2004; WHO, 2004; WHO, 2009) point out the importance of the constructive characteristics of vehicles, as one of segments for improvement of the traffic safety condition. Namely, that is the reason to have the procedures for assessment of the vehicle safety characteristics introduced worldwide, in a form of a so-called NCAP tests (New Car Assessment Program), known as the "crash" tests. The surveys showed that vehicles which have better grade at the Euro NCAP tests lead to 30% less deaths and severe injuries ((Lie and Tingvall, 2000). Technically proper condition of vehicles has an important role in the system of the traffic safety. Considerable influence on this segment of the traffic safety can be carried out through the reinforced inspection control of work of the stations in charge of technical examination of vehicles. The surveys (Hakkert et al., 2007) show that the death risk in vehicles which are more than 30 years old is more than ten times compared to new vehicles. The reasons for these results are actually in the protection equipment systems of vehicles. Pešić (2012) analyzed the average age of the fleet of the USA. The regression analysis showed that indicators of "average age of the fleet" and "number of the persons who died in the traffic accidents are in so-called "negatively strong relation" (r= -.851, r= 0.01). This dependence is not expected with the increase of the average age of the fleet, the number of traffic accidents is reduced, but if the term "compensation of the risk" is taken into account, then, on the other side, the results are more than realistic.

Active safety of vehicles

Active safety of vehicles is, first of all, related to all prevention measures, which the constructor of the vehicle should include even in the vehicle design phase, and which are related to the system of driver – vehicle – road – surrounding, in order to avoid the conflict situations. The measures which belong to this group are: finding possibilities for timely noticing and reacting in relation to other traffic users (pedestrians, traffic structures, other vehicles) and limit of information which the driver can timely and concurrently *receive*, everything from the aspects to remove the risks of traffic accidents. Electronic elements in the vehicle, contributing to avoidance of the conflict situations are, inter alia:

- efficiency and reliability of the braking and controlling system of the vehicle;
- decrease and removal of inappropriate conditions in the vehicle (driving comfort, noise, oscillations, winding and air-conditioning, inappropriate layout of the control panel and ergometric factors);
- automatic communication between vehicles (*Vehicle to Vehicle – V2V*) and communication between the vehicle and traffic infrastructure (*Vehicle to Infrastructure- V2I*).

Active safety of vehicles is defined through possibilities to manage, reliably and with as much control as possible, the motor vehicle and accordingly avoid conflict situations on the road. Systems for automatic regulation of the vehicles' movement contain the devices which, with the minimized actions of drivers, enable proper maintenance and stability of the vehicles' movement, regardless of the road conditions. The intense technological development is obvious when it is about these systems, but the influence of drivers is still not possible to be eliminated. Accordingly, the basic function of such systems is actually the support for the driver, which provides him with a possibility to anticipate but also relatively later to react whereby maintaining the stable movement of vehicles.

Passive traffic safety aims at reducing consequences of the traffic accidents. When the traffic accident happens, it is reasonable to ask questions how to reduce the consequences, how to reduce the number of those injured, how to reduce the weight of suffering and reduce material damage. Today, in the world, there are a lot of generators of vehicles. With each of those generators, the element abundance of active and passive safety is different, being conditioned by the regulations and standards of the generator's country, level of development of generation, tradition of generation, etc.

Brakes

One of the basic systems on the vehicle which considerably affects the safety of the traffic users and which belong to the scope of active safety is the braking system. The role of this system is to provide, in a controlled and stable way, the vehicle with fulfillment of the following conditions such as: 1) deceleration in order to reduce the speed; 2) prevention of the movement when parking; 3) braking when moving along the slope. The braking system in a physical sense is achieved by friction, which transforms the vehicle movement energy to the heat energy. The method of exploitation and safe realization of great exploitation speeds depends on capability of the efficient, safe and stable deceleration of the motor vehicle. For the above mentioned reasons, the braking characteristics are considered to be very important element of dynamic features of the vehicle. The braking process itself is realized through the braking system and other systems of the motor vehicle actively participate in it, first of all the cycles with pneumatics as well as the support system. The braking system has a great impact on the whole traffic safety and that is why the braking system is one of the first and most detailed standardized systems with the motor vehicles, within the international framework. All systems of active, as well as of passive safety are mutually amended and added. Each of them is made with the aim to save as many people as possible. Looking from different aspects, without modern technology and new systems, the safety level in traffic would be significantly less and it is necessary to further pay attention to development and improvement of active systems for the vehicle safety in order to achieve as good communication between the vehicle-driver-surrounding as possible.

Contemporary electronic systems for control of the dynamic behavior of the vehicle

Increase of the traffic safety is ensured by applying the systems which increase the braking efficiency and contribute to better stability of the vehicle, such as ABS, BAS, ESP and ASR systems. With sudden development of the information technologies, the serial generation of electronic system for control of the vehicle stability when braking, was initiated. The first such system, based on which the whole range of products was developed, within the vehicle behavior control is the Anti-lock Braking System – ABS, often called the Anti-block system. The system itself was previously applied in the aviation especially on big planes. Further development of the information technologies and decrease of prices, the whole range of other systems which improve dynamic behavior of vehicles, based on the ABS system, was achieved, such as:

- control of ETS operation,
- slipping control with acceleration ASR,
- stability control ESC, ESP
- automatic blockage of differential ALD and
- electronic division of the braking force EBD;

In the next part of the document, there will be basic characteristics and method of functioning of the most applied contemporary systems, and it is about ABS and ESP systems.

Anti-lock Braking System ABS

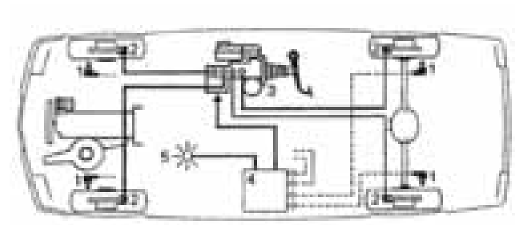
The basic idea, on which functioning and operation of the anti-lock braking system is based, for application with the motor vehicles was the intention to develop the system which will be adapted to the driver' behavior while braking. In some situations in the traffic, it often happens that even very experienced drivers urgently and in a panic brake because of other traffic users. Such reaction is particularly expressed with the non-experienced drivers, which normally, results in blockage of cycles and loss of the control over the vehicle.

The main goal, while developing this system, was to prevent the blockage of cycles and keep the possibility of realization of the side forces on the cycles, which would enable the control also in cases when the braking control has been activated by the excessive force, accordingly resulting in a higher level of safety. It comes out from this that the basic advantage of the vehicle with ABS system is that it can, even apart from the maximum braking avoid unfavorable contacts with maneuver and can also strongly brake even with the too fast turning. The results obtained testing and assessing confirm the assumption that ABS is particularly efficient and useful on the bases with the reduced adhesion. So, for example, when testing on the wet concrete, when the vehicle moves at the speed of 140 km/h, the vehicle without ABS has the braking path of 181 m, while the braking path of the same vehicle, equipped with the ABS, under the same conditions, is 112 m which is for about 40% shorter path of stopping. The speed of the vehicle movement which does not possess ABS, in the moment when the vehicle with ABS stopped, is 86 km/h (www.dekra.de).

From the mentioned results, considerable significance of this system with the motor vehicles is visible as well as its possibility to correct the human mistakes, but it can help in no way if the driver does not take care of the conditions of the road and traffic. Unlike the standard braking system where the braking forces are regulated according to the previously defined law, anti-lock braking systems operate in a way that they follow and detect deceleration of each cycle separately, immediately turn its brake off and turn them on again when the cycle starts turning. With the last generation of these systems, the brakes release before the complete cycle blockage, regulating the pressure at the turning on again in order to provide for maximum utilization of the cohesion coefficient.

Basic elements of ABS are:

- sensors for the turning speed of cycles;
- control device (computer) and
- electric magnetic valves;



1. Sensor of number of turns
2. Braking cylinder on cycles
3. Hydro generator with the main braking cylinder
4. EUJ- (CPU)
5. Signal lamp

Figure 1. Anti-block braking system (ABS)

System for control of stability - ESP

This system permanently analyzes behavior of vehicles according to the estimated intentions of driver, in order to immediately react and correct each behavior which deviates from the desired and which might cause the loss of control over the vehicle. The system selectively applies, precisely and independently, the controlled braking pressure on each cycle of the front and/or back axis, and if necessary, electronically reduces the engine motor. EPS system was developed on the basis of ABS, whereby there was extension with sensors which detects 150 times in a second, information about the turning angle of the controlling cycles, vehicle turning around the vertical axis as well as about the side acceleration and based on those data, it determines deviation from the desired optimum path and defines the required correction. The correction is carried out through the ABS subsystem, system for control of ETS operation and system for electronic division of EBD braking forces. Apart from maneuverability of ESP, it automatically stables the vehicle in different situations in driving, particularly in a badly estimated curve, at the sudden local changes of adhesion and during sudden maneuvers of avoidance.

METHODOLOGY

According to the available data (taken from the database of the Ministry of Interior of the Republic of Srpska, Ministry of traffic and communications and Audiotex – ltd.) on the registered motor vehicles in the Republic of Srpska for the period from 2012 to 2017, there was a permanent increase of a number of the registered vehicles (this term is meant by the vehicles which passed the regular technical examination of vehicles). So in 2012, total number of the registered vehicles in the Republic of Srpska was 298,270 vehicles and in 2017 it was 366,890 vehicles which is the increase of about 23%. In this number of totally registered vehicles, the group of motor vehicles M1, M2, M3 is dominant, thenH1, H2, H3 lorries, as well as the terminal vehicle O4 equipped with ABS and ESP systems (Table 1.).

Table 1. Structure of the fleet in the Republic of Srpska from the aspect of the registered vehicles and vehicles which possess ABS and/or ESP in the period from 2012 to 2016

	2012	2013	2014	2015	2016	2017
Total number of the registered vehicles in the Republic of Srpska	298.270	312.361	320.889	328.271	342.884	377.076
Number of vehicles with ABS and/or ESP systems	108.010	130.473	151.956	171.781	194.738	239.256
% vehicles with ABS and/or ESP systems compared to the total number of the registered vehicles	36.21 %	41.76%	47.35%	52.32%	56.79%	63.45%

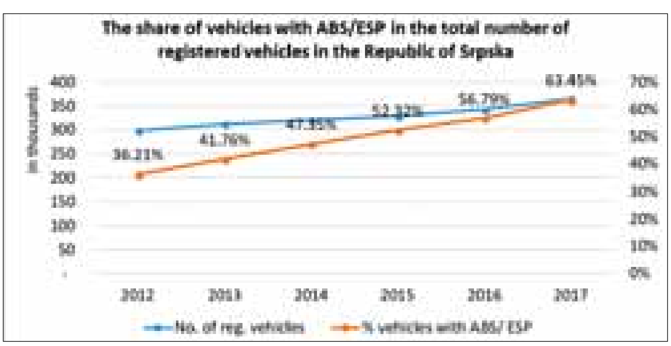


Figure 2. Trend of increase of vehicles with ABS and/or ESP systems (in %) and number of the registered vehicles in the Republic of Srpska

In the Figure 2, trend of increase of number of the registered vehicles in the Republic of Srpska for the period of five years can be noticed. However, it is interesting to notice that a share of vehicles which are equipped with ABS or/or ESP has been constantly growing for about 5 and more % annually which considerably affects the traffic safety in the Republic of Srpska (63.45% in 2017). This is particularly important to mention when it is known that the factor Vehicle affects with 13% in occurrence of the traffic accidents (Figure 3).

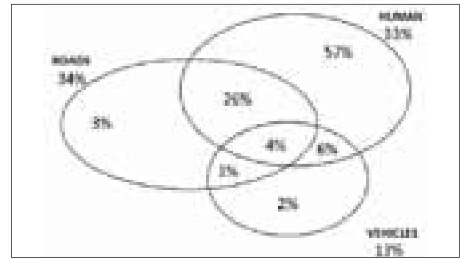


Figure 3. Traffic safety factors as causes of the traffic accidents (PIARC, 2003)

In the Table 2, there is a structure of the traffic accidents and their consequences in the Republic of Srpska in the period from 2011 to 2017. Analyzing these data, it is clear that at the national level there is no firmly established system of the traffic safety.

Table 2. Structure of the traffic accidents and their consequences in the Republic of Srpska in the period from 2011 to 2017

	2011	2012	2013	2014	2015	2016	2017
Number of traffic accidents	9378	8441	8589	8581	9295	9783	9637
a) with killed persons	150	130	146	123	135	121	103
b) with heavily injured persons	577	541	498	534	599	577	550
c) with lightly injured persons	1526	1312	1470	1505	1662	1741	1591
d) with material damage	7125	6458	6475	6419	6899	7344	7393
Persons affected	3382	2961	3093	3155	3631	3711	3301
a) Killed persons	163	140	153	131	150	130	115
b) Severely injured persons	702	651	607	632	745	703	646
c) Lightly injured persons	2517	2169	2333	2392	2736	2878	2540

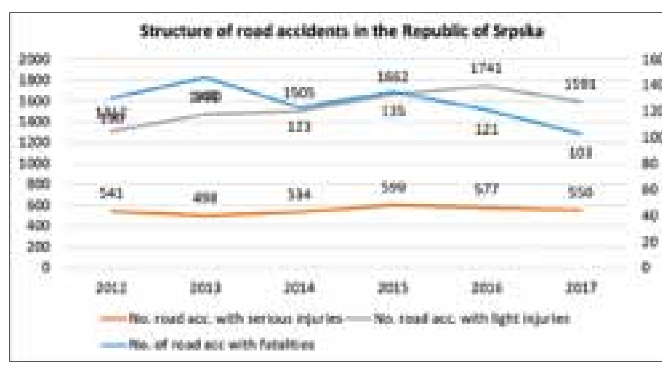


Figure 4. Structure of the traffic accidents in the Republic of Srpska in the period from 2012 to 2017

In the Figure 4 it can be noticed that number of the traffic accidents with the killed persons "varies" and there is no clear trend of decrease of these traffic accidents. Additionally, in the Figure 5, there is a structure of those affected in the traffic accidents. There is a similar situation as it is with number of the traffic accidents. Number of those killed in the past period has no constant trend. It can be concluded that at the national level there is no firm and independent system of defense against the traffic accidents established.

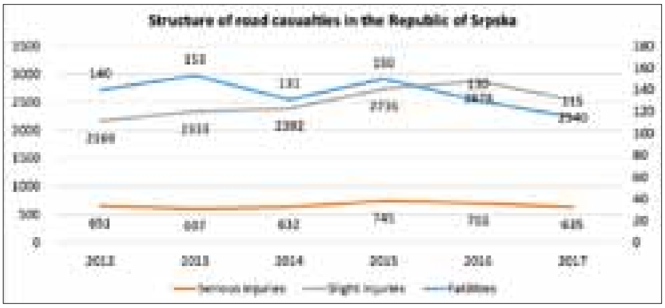


Figure 5. Structure of those affected in the traffic accidents in the Republic of Srpska in the period from 2012 t0 2017

The method which was used for analyses of the relations between previously stated indicators is Spearman's correlation. The data presented include the whole territory of the Republic of Srpska and five-year's period from 2012 to 2017.

RESULTS

Spearman's correlation showed that there is a strong correlation between the number of traffic accidents, their consequences and representation of the braking systems with ABS and ESP in the fleet of the Republic of Srpska for the period from 2012 to 2017 (Table 3)

Table 3. Intensity of the correlation between the number of vehicles with ABS and/or ESP systems in the fleet in the Republic of Srpska and the number of the traffic accidents and their consequences in the period from 2012 to 2017

Correlations	SN_{pog}	SN_{ttp}	SN_{ltp}	SN_{mat}	POG	TTP	LTP
Correlation Coefficient	- .714	.600	.829**	.829**	- .714	.314	.829**
Sig. (2-tailed)	0.111	0.208	0.042	0.042	0.111	0.544	0.042
N	6	6	6	6	6	6	6

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

SN_{kill}	number of traffic accidents with the killed persons
SN_{hip}	number of traffic accidents with the severely injured persons
SN_{lip}	number of traffic accidents with light injured persons
SN_{mat}	number of traffic accidents with material damage
POG	number of the killed persons in the traffic accidents
TTP	number of the severely injured persons in the traffic accidents
LTP	number of light injured persons in the traffic accidents

Pursuant to the Table 1, it can be concluded that there is a strong correlation (r= .829, p= .01) between the number of traffic accidents with lightly injured bodies and number of vehicles in the fleet of the Republic of Srpska which possess the braking systems with ABS and/ or ESP (hydraulic + ABS, air + ABS, combined ABS, hydraulic + ESP, air + ESP, combined + ESP). Also, there is a strong correlation between the number of traffic accidents with light injured persons and number of light injured persons with number of vehicles in the fleet which possess the previously mentioned braking systems (r= .829, p= .01). In the Figure 6 and Figure 7, there are graphs indicating the dependence between the number of traffic accidents with light injured persons and number of light injured persons with the number of vehicles in the Republic of Srpska which possess the braking systems with ABS and ESP.

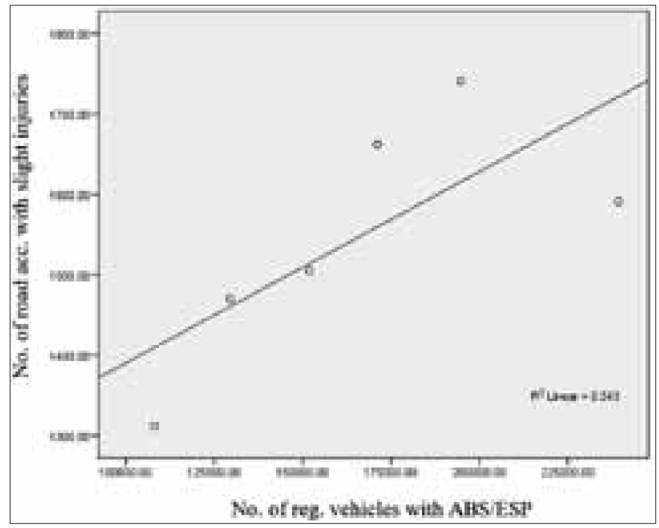


Figure 6. Dependence between the number of traffic accidents with lightly injured persons and number of vehicles in the fleet which possess the braking systems with ABS and/or ESP

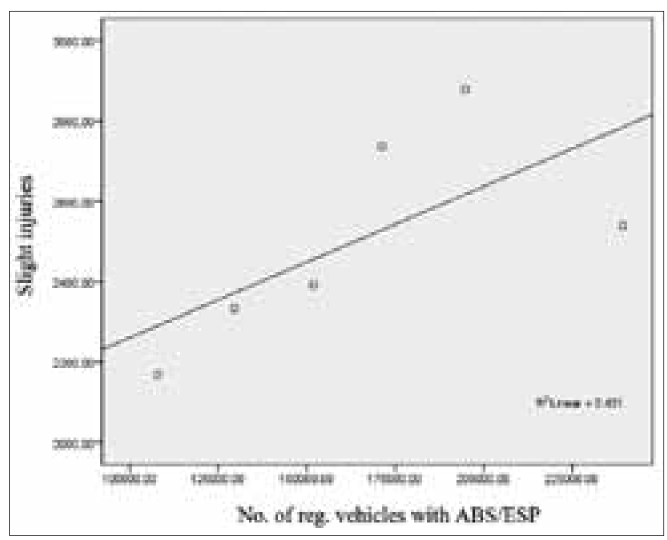


Figure 7. Dependence between the number of lightly injured persons and number of vehicles in the fleet which possess the braking systems with ABS and/or ESP

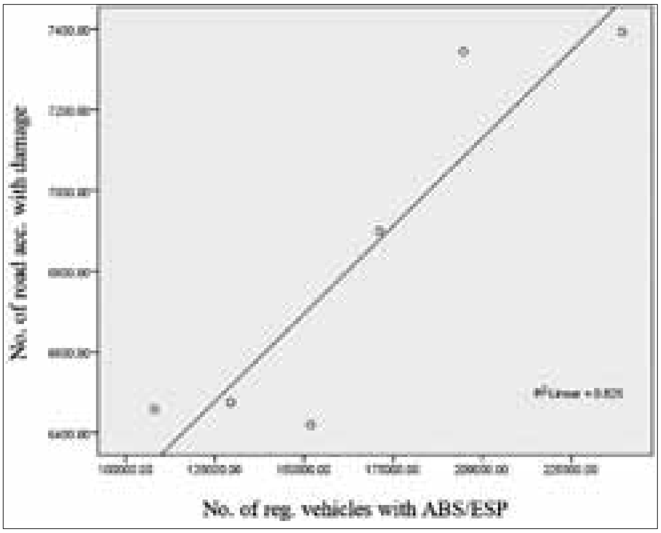


Figure 8. Dependence between the number SN with material damage and number of vehicles in the fleet which possess the braking systems with ABS and/or ESP

DISCUSSION

The obtained results may be explained with the fact that additional systems in the vehicles (ABS and ESP) have contributed to reduction of consequences of the traffic accidents in the respective period in the region of the Republic of Srpska. Namely, there is a statistical importance between the number of traffic accidents with lightly injured persons, number of lightly injured persons, number of traffic accidents with material damage and number of vehicles which have the braking systems with ABS and ESP and which passed the regular technical examination of the vehicle. Actually, the traffic accidents "have overflown", i.e. number of traffic accidents with the killed persons and severely injured persons have decreased, while the number of traffic accidents with lightly injured persons and material damage have increased. Normally, apart from this factor, consequences of the traffic accidents have reduced due to preventive and repressive actions of all structures of the traffic safety system in the Republic of Srpska in the spheres of the most significant factors of risk (speed, alcohol, use of the safety belt, etc).\

CONCLUDING REMARKS

Elements of active and passive safety of the traffic in vehicles considerably contribute to decrease of number of traffic accidents and their consequences. Application of the electronic systems in vehicles has been expanding and present vehicles have got dozens of these systems in order to provide for predictability of situations, accelerate reactions and minimize mistakes of drivers. The driver as a human being has certain performances and being like that he cannot follow the traffic which is rapidly carried out today. In that case, the risk of occurrence of the traffic accidents is very high. That is why the automobile industry tends to develop electronic systems in order to increase the performances of man, namely of the vehicle, because the man and vehicle makes a compact unity participating in the traffic. Communication with the environment (sensors detect vulnerable traffic users, traffic signs and other structures, vehicles) is achieved by development of the advanced systems, providing a driver with a possibility to have as much information as possible.

Having in mind that man tends to mistakes, electronic systems try to minimize the mistakes (e.g. detection of vehicles in the traffic course which brake earlier, detection of monitoring of the appropriate traffic lane, detection of sudden obstacles, etc). Huge representation of these systems resulted in commencement of using these systems with mechanical systems of reliance, detection of bumps on the road and similar, everything for the purposes of increase of comfort while driving.

Representation of these and similar systems in the Republic of Srpska has a growth trend caused by a level of export of vehicles with minimum prescribed EUR 4 norm, which involve, minimum, the following systems: ABS, ESP, ASR, AIRBAG and similar). Apart from that, a share of vehicles equipped with these systems annually is increased for about 5% which considerably contributes to reduction of traffic accidents with deaths and severe consequences. Of course, the increase of vehicles with contemporary systems is the result of type-approval of vehicles at the Bosnia and Herzegovina level, because it ensures a level of interchangeability of the fleet in the Republic of Srpska and reduction of the average age of the fleet from 18.5 years in 2012 to 16.5 years in 2017.

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ORIGINAL SCIENTIFIC PAPER

Road Traffic Accident Mortality and Economic Development: The Case of Bosnia and Herzegovina

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Abstract: This paper examines the relationship between the relevant parameters of traffic safety and the most important parameter of economic development, gross domestic product. In particular, the paper estimates the effects of the model of the rate of motorization and road traffic mortality in relation to the number of inhabitants and the number of motor vehicles, which are further used for the projection of mortality and the number of motor vehicles by 2030.

Keywords: Traffic Accidents, Mortality, Eeconomic Development, Roads.

INTRODUCTION

The road transport system of Bosnia and Herzegovina (hereinafter B&H) comprises of 21,678 km of classified roads. The rate of motorization, number of motor vehicles per 1,000 inhabitants, is influenced by economic status of the country and its population and the availability of other mode of transportation. This rate in B&H, as of 2016 was, 283.7 motor vehicles registered per 1,000 inhabitants. Every year, more than 11 thousand traffic crashes occur on B&H roads in which more than 300 people lose their lives (312 in 2016), and more than 11 thousand people were injured. Therefore, about 30 traffic crashes happened every day in B&H, and on average one person loses his/her life and about 29 persons were injured every day. These are very devastating and worrying data, and what is particularly worrying is the fact that young people (age 19-29) are the most affected in these crashes. What is also worrying is the fact that individuals and government institutions, responsible for traffic safety in B&H, are still talking about the causes of traffic accidents in very general way, and very often make conclusions about traffic safety based on superficial observations that are not based on expert analyses and serious professional or scientific work.

The economic development of each country contributes to the improvement of the conditions for a quality life of people in all segments, and therefore in the health segment and in the decline in mortality rates. However, the mortality of people in traffic accidents on the roads is a notable exception. In many developing countries, traffic deaths are increasing when compared to the number of people. The situation in the developed countries is somewhat different. In these countries, for some longer periods of time, mortality per capita has declined significantly, so this downward trend, which started in the OECD countries in the 1970s, continues today. As far as B&H is concerned, the situation cannot be consistently described even by examples of developing countries, and especially not by examples of high-income countries. The reason for this is the specificity of this country in terms of its government structure, and in which the state of confusion, controversy and inconsistency of economic and transport policy measures has lasted more than twenty years. This paper examines the relations between the relevant parameters of traffic safety and the most important parameter of economic development, gross domestic product. In particular, the paper estimates the effects of the model of the rate of motorization and road traffic mortality in relation to the number of inhabitants and the number of motor vehicles, which are further used for the projection of mortality and the number of motor vehicles by 2030.

RESEARCH BACKGROUND

Several economic studies have analyzed the relationship between economic development and road traffic fatality rates. Some of those studies concluded that traffic fatality rates tend to increase in initial developing phase, and then decrease as the countrys economy expands. As an example, Elizabeth Kopits and Maureen Cropper [1] , in their article titled "Traffic Fatalities and Economic Growth" supported by The World Bank (2003), examined the impact of income growth on the death rate due traffic fatalities. They also examined impact of income growth on fatalities per motor vehicle and on the rate of motorization (number of motor vehicles per population) using panel data for 88 countries. They estimated fixed effects models for fatalities per population, vehicles per population, and fatalities per vehicle, and use these models to project traffic fatalities and motor vehicle fleet. They found that the relationship between motor vehicle fatality rate and per capita income at first increases with per capita income, reaches a peak, and then declines. This is because at low income levels the rate of increase in motor vehicles outpaces the decline in fatalities permotor vehicle. At the levels of higher income, the opposite happens. They also found that projections of future traffic fatalities will grow by approximately 66 percent between 2000 and 2020. The authors also predict that fatality rate will rise to approximately 2 per 10,000 persons, while it will fall to less than 1 per 10,000 in high income countries. Van Beeck, et al (2000) examined nonlinear relationship between traffic fatalities and economic growth [2]. They found that traffic fatalities in industrialized countries have decreased as income has increased. They partly atributed this reduction to declines in mobility growth (growth in vehicle per capita). Mobility growth tends to increase rapidly at the onset of industrialization, and then tends to level off. Also Wang, et al (2003) have similar findings in their time series analysis of economic growth and traffic fatalities in China. This study found that China has seen a rapid rise in the absolute number of traffic fatalities. Schuffham and Langley (2002) similarly examined the time series relationship between real gross domestic product (GDP) and traffic fatalities in New Zeland [3]. They found real GDP per capita and automobile crashes to be negatively correlated. They think that this trend was potentially caused by "supply side effects", such as better road infrastructure. Hasselberg and Laflamme (2004) also found that Swedish children from families with higher disposable incomes were likely to experience traffic accidents than their lower income counterparts. Schuffham (2003) in his work [4] analyzed the impact of the unimployment rate on traffic fatalities in New Zeland. However, he found that reductions in unemployment were associated with increases in the number of traffic fatalities. He believed this could be attributed to the reduction in vehicle miles traveled for work and leisure associated with unemployment. It is not clear which of these factors is dominant. Bishai et al. (2006) in their work [5] explored why traffic fatalities increase with GDP per capita in lower income countries and decreases with GDP per capita in wealthy countries. They concluded that at a treshold of around 1,500-8,000 dollars per capita economic growth no longerleads to additional traffic deaths, although crashes and traffic injuries continue to increase with growth. The negative association between GDP and traffic deaths in rich countries may be mediated by lower injury severity and post-injury ambulance transport and medical care.

FATALITY RISK, RATE OF MOTORIZATION AND GDP PER CAPITA

Road traffic fatality rates (F/I – number of fatalities per number of inhabitants) are the product of the rate of motorization (V/I – number of motor vehicles per number of inhabitants) and fatalities per vehicle (F/V – number of fatalities per number of motor vehicles):

$$(F/_I) = (V/_I)\ x\ (F/_V)$$

In order to estimate statistical models relating to these ratios to the GDP per capita it is useful to examine how these quantities change depending of income. It is widely recognized that the rate of motorization rises with income implying that one should find large differences in number of vehicles per capita accross contries at different stages of development and within countries as per capita income grow [1].

Table 1. presents data on rate of motorization and GDP in B&H and its changes. Figure 1. plots the road traffic accidens fatalities trend in B&H and its two entities, Federation of B&H (FB&H) and Republic of Srpska (RS) in the period 2004-2016 and Figure 2. shows rate of motorization per GDP per capita. In the observed period, the rate of motorization in B&H increased about 42%, while GDP increased about 87% (Figure 3.) At the same time, the road traffic accident fatalities fell from 424 to 312, a decrease of 27% (Figure 1.). There is a strong trend correlation with polynomial function for the motorization rate depending on GDP per capita values. This correlation shows that motorization rate grows faster at lower GDP values, and then grows slower at higher GDP values. In our case, the average growth of the motorization rate for the GDP per capita values between five and eight thousand dollars, was 14.3%, and for the GDP per capita values between eight and eleven thousand dollars, the average growth was 1.5%.

Table 1. Rate of Motorization and GDP in B&H and its changes

Year	Number of Motor Vehicles (000)	Rate of Motorization (Number of Motor Vehicles per 1000 Inhabitants)	Cumulative Relative Changes (%)	GDP (USA $ per capita)	Cumulative Relative Changes (%)
2004	673.8	195.4	-	5049	-
2005	688.6	199.7	2.2	6192	22.6
2006	717.4	208.1	6.4	7141	37.9
2007	750.5	217.7	12.8	8758	60.5
2008	769.6	231.0	18.6	10676	82.4
2009	816.4	236.8	21.1	9865	74.8
2010	818.7	237.5	24.0	10038	92.3
2011	830.3	240.8	25.4	9971	91.6
2012	857.5	248.7	28.7	9873	90.6
2013	885.1	256.7	31.9	10211	94.0
2014	910.4	264.1	34.8	9666	88.7
2015	936.9	271.7	37.7	9245	84.3
2016	978.2	283.7	42.1	9523	87.3

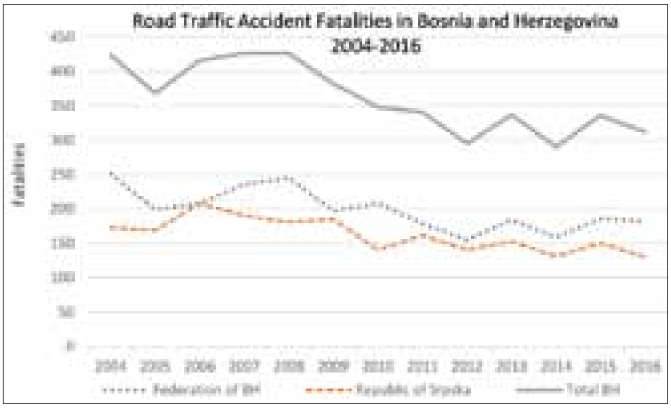

Figure 1. Road traffic fatalities in B&H

Figure 2. Motorization rate and GDP per capita in B&H

We carried out an assessment of the equations for mortality in traffic accidents in relation to the number of inhabitants, to the number of motor vehicles and in relation to the degree of motorization, depending on the GDP per capita using the following polynomial forms:

$$(F/I) = A_1(GDP)^2 + B_1(GDP) + C_1$$
$$(V/I) = A_2(GDP)^2 + B_2(GDP) + C_2$$
$$(F/V) = A_3(GDP)^2 + B_3(GDP) + C_3$$

Also, we made an estimate of the equations for cumulative relative changes in the number of motor vehicles and the changes in GDP per capita in the observed period, using the following logarithmic forms:

$$CRC_{mv} = A_4 ln(GDP) + B_4$$
$$CRC_{GDP} = A_5 ln(GDP) + B_5$$
$$CTAF_{mv-GDP} = A_6 ln(GDP) + B_6$$

where:

(F/I) – traffic accident mortality per100 000 inhabitants

(V/I) – number of motor vehicles per 1000 inhabitants

(F/V) – traffic accident mortality per 10 000 motor vehicles

GDP – gross domestic product (dollars per capita)

CRC_{mv} – cummulative relative changes of number of motor vehicles

CRC_{GDP} – cummulative relative changes of GDP per capita

$CTAF_{mv-GDP}$ – changes of traffic accident fatalities per motor vehicles depending of GDP

A, B, C – coefficients

For the analyzed period (2004-2016), given the changes in GDP values were rounded ranging from a minimum of 5 to a maximum of 11 thousand dollars, and for the purpose of simpler calculation and clearer graphic representation the following replacement for GDP values was made:

$$GDP = \frac{GDP_{max} - GDP_{min}}{(n)\,x1000} + i$$

where:

GDP_{max} – maximum value of GDP in analyzed period (11,000)

GDP_{min} – minimal value of GDP in analyzed period (5,000)

n – number of intervals in analyzed values of GDP in 1,000 (n = 6)

i = 0, 1, ….., n

For example, for an actual value of GDP of 8,000 in given equations, the following number is used:

$$GDP = \frac{11\,000 - 5\,000}{6\,x\,1000} + 3 = 4$$

After the calculation we obtained the values of the coefficients A, B, C for the equations set, and the proportions of the variance (R^2) of dependent variable that are predicted from the independent variables. These values are presented in Table 2.

Table 2. Equations coefficients and variance values

Equation	Coefficients			Variance (R^2)
	A	B	C	
(F/I)	A_1 = - 0.1442	B_1 = 0.6197	C_1 = 11.2670	0.6758
(V/I)	A_2 = - 0.6155	B_2 = 17.4630	C_2 = 173.860	0.9779
(F/V)	A_3 = - 0.0552	B_3 = - 0.0789	C_3 = 6.2097	0.8993
(CRC_{mv})	A_4 = 15.8690	B_4 = - 2.6235	-	0.9499
(CRC_{GDP})	A_5 = 28.4090	B_5 = 28.2650	-	0.8470
($CTAF_{mv-GDP}$)	A_6 = - 6.8140	B_6 = 18.8990	-	0.9666

Based on the values of the variances given in Table 2, we can notice that the strongest correlation exists between the motorization rate - number of motor vehicles per inhabitant (V/I) and GDP, R^2 = 0.9779 (Figure 2.), and, in accordance with this, there is a cumulative change in the number of motor vehicles per number of inhabitants and GDP per capita, R^2=0.9499 (Figure 4.). The second strongest correlation is between changes in mortality in road traffic accidents in relation to the number of motor vehicles and GDP, R^2=0.9666. The average change in road traffic mortality rates on roads in B&H, depending on GDP, amounted to 9.4 percent per 1,000 dollars of GDP, and the average annual change in GDP was $ 428 (Figure 5). The weakest correlation is between mortality in road traffic accidents in relation to population (F/I) and GDP, R^2=0.6758.

Based on previous research, the review of which is given in section two of this paper, and based on the results of our research, it can be concluded that there is a logical correlation between the level of income in one country (GDP) and mortality in traffic accidents on the roads. This statement can also be accepted in the case of Bosnia and Herzegovina, bearing in mind the specificity of the overall economic situation in this country, especially the fiscal policy, which can have a significant impact on certain data on the real value of GDP compared with other countries

Namely, since the domestic currency exchange rate (convertible mark - KM) is fixed and is not dependent on the conditions and trends in the money market or economic trends, it is necessary to pay attention to the comparison of data presented in this paper with data from other environments. In this respect, a more thorough research is needed with real valorization and other economic indicators, such as production, productivity, consumption and employment.

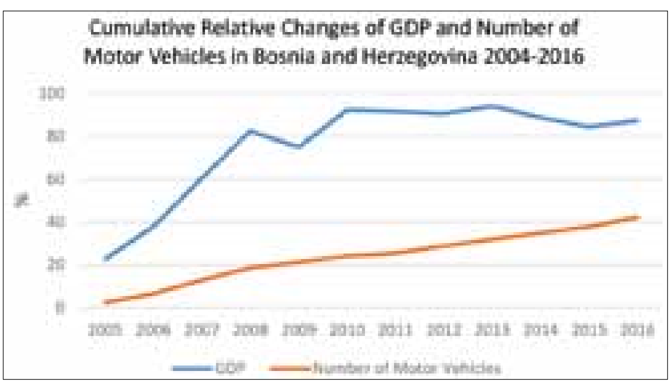

Figure 3. GDP and number of motor vehicle cumulative relative changes

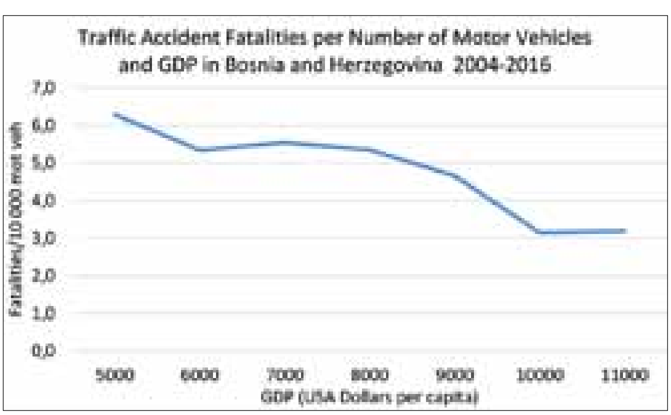

Figure 4. Road traffic accident fatalities and GDP per capita in B&H

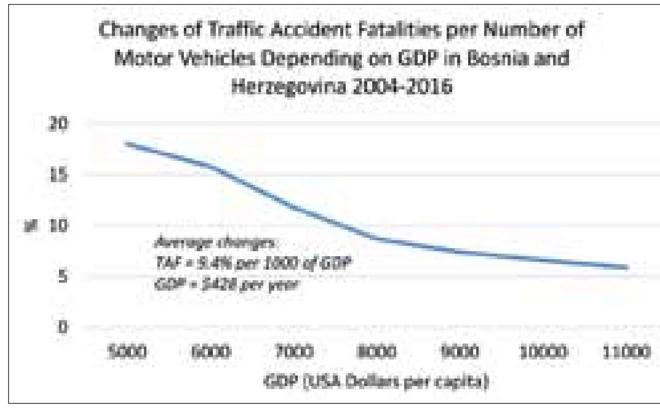

Figure 5. Road traffic accident fatalities depending of GDP per capita

PROJECTIONS TO 2030

Based on the equations presented in the previous section we projected the values of some indicators related to road traffic accident mortality and B&H economy for 2030. This projection and its realtion to base 2016 year is shown in Table 2. Projection of indicators related to traffic accident mortality and economic development of B&H for 2030 shows that the number of motor vehicles will increase by 56 percent and it will reach the amount of over 1.5 million, while GDP per capita will double, related to 2016. Traffic accident mortality related to number of inhabitants will decrease by 8 percent, and by 28 percent, related to the number of motor vehicles.

Table 2. Projection of some indicators related to traffic accident mortality and economy in B&H

Indicator		2016	2030	2030/2016
Number of motor vehicles		978 229	1,525925	1.56
GDP (dollars/capita)		9523	19236	2.02
Motorization rate (motor vehicles/1000 inhabitants)		283.7	442.6	1.56
Fatalities	Number of fatalities/ 100000 inhabitants	9.0	8.3	0.92
	Number of fatalities per 10000 motor vehicles)	3.2	2.3	0.72
	Total number of fatalities per year	312	286	0.92

Therefore, the total number of road traffic accident mortality in 2030 is projected to be 286. These projections and estimates of the income level assume that the new policy will take place in B&H because of the country's aspiration to become a candidate for the EU membership in 2018, and a member of this Union by 2025.

CONCLUSIONS

The paper analyzes the relevant parameters of traffic safety on roads and the most important parameter of economic development - gross domestic product (GDP) per capita in Bosnia and Herzegovina. It was noted that the number of motor vehicles in the analyzed period increased by about 42%, while GDP increased by around

87%. At the same time, the number of those killed in traffic accidents has been reduced by around 27%. Also, it was noticed that there is a significant correlation with the polynomial functional dependence between motorization and GDP per capita. This correlation shows that the degree of motorization is growing faster at lower GDP values and then grows slower at higher GDP values per capita.

The average increase in the degree of motorization at GDP values between five and eight thousand dollars in B&H was about ten times higher than for values of GDP per capita over eight thousand dollars. Regarding the territorial representation or administrative units, it can be concluded that there is a distinct similarity between the economic and participation in mortality in traffic accidents on roads. Projection of indicators related to traffic accident mortality and economic development of B&H for 2030 shows that the number of motor vehicles will increase by 56 percent, while GDP per capita will double, in comparison to 2016. Traffic accident mortality related to number of inhabitants will decrease by 8 percent, and by 28 percent, related to the number of motor vehicles.

FUTURE WORK

The paper points to the need for cautious use and interpretation of the presented data and the results of the research due to the fact that the course of the local currency (convertible mark - KM) is fixed, and it is not dependent on the state and movements on the money market or on economic trends. In this regard, the paper emphasizes the need for further research, and recommended evaluation other economic indicators, such as production, productivity, consumption and employment

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PRELIMINARY COMMUNICATION

The Use of Cell Phones While Driving - A Case Study in Serbia

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Abstract: Recording the data about the use of cell phones as one of the possible factors that contribute to accidents is not often conducted in practice. All the world's research indicate that the use of cell phone affects negatively the attention of the driver and his ability to safely operate the vehicle. In the literature, the most frequently mentioned is the increasing risk of a traffic accident, four times when using the phone and also that when reading or texting messages the driver takes his eyes off the road for almost 5 seconds. This means that at a speed of 50 km/h, during these 5 seconds while looking at his phone, the driver exceeds 70 m, and does not look what is happening in front of him, or around the vehicle. This paper describes the world experience in terms of analysing accidents and the use of cell phones in accidents. Also, an analysis was conducted of the legislation about the use of cell phones while participating in traffic in Republic of Serbia, as well as the domestic experience about the use of cell phone. Based on the above analysis, a research about attitudes of citizens of Serbia has been made, in order to give at least an approximate picture of the problem.

Keywords: cell phone, traffic accidents, traffic safety.

TELEMATICS GPS DATA

Nowadays we can't imagine our life without using a cell phone. All generations use a cell phone, in all kinds of situations. The discovery of cell phone has brought numerous benefits to humanity. It has provided that a person can be reached in any place, anytime. All the world's research indicate that the use of cell phone negatively affects the driver's attention and his ability to safely operate the vehicle. In the literature, the most frequently mentioned is the increasing risk of a traffic accident, four times when using the phone [10] and also that when reading or texting messages the driver takes his eyes of the road for almost 5 seconds. This means that at a speed of 50 km / h, during these 5 seconds while looking at his phone, the driver exceeds 70 m, and does not look what is happening in front of him, or around the vehicle. Even a distraction for just one second, while driving at same speed, makes the driver exceed 14 m and not look at the road.

LEGISLATION IN SERBIA

Law on Road Traffic Safety of the Republic of Serbia provides regulations which prescribe penalties referring to use of cell phones while driving. Law on Road Traffic Safety, provides punishment for using cell phones while driving. The driver commits an offense if he uses some of the communication devices while driving, even when the vehicle is in a traffic que or at the crossroad. The only allowed form of communication is to have some kind of special equipment that allows the phone to be used without holding it in your hand. Therefore, with the help of hands free devices.

Law on Road Traffic Safety of Republic of Serbia prescribes restrictions related to the official use of phone [9], excepting the members of those professions where for the execution of duties is necessary to use radio or telephone, and those are firefighters, members of the ambulance, police and other services. States provide different penalties relating to the use of cell phones while driving. From a complete prohibition on the use of cell phones while driving (for example in Switzerland); through a partial prohibition, allowed with the use of hands free devices, as the case in many countries, including the United States and Serbia; to the unregulated status, or permitted use of cell phones while driving.

ACCIDENTS AND CELL PHONES – WORLDWIDE EXPERIENCE

Recording of data about the use of cell phones, as one of the possible factors that contribute to the traffic accident, is not often in practice. In cases where the data is recorded, the collection of data is usually not systematic, which makes the evaluation of danger of cell phone usage in the vehicle even more difficult.

In most countries the presence or use of a cell phone in the vehicle is not even recorded [13]. One of the main ways of collecting data related to the use of cell phones while driving, as the reports after the accident and in a variety of researchs that are conducted, is the testifying of drivers themselves. This is also one of the most unreliable ways, because you can't be sure that drivers are telling the truth. Anyway, due to the lack of systematic collection of data on the use of cell phones while driving, for now we can analyze the situation of cell phone use in several countries.

The USA

In the USA, a special system for the analysis of traffic accidents (Fatality Analysis Reporting System (FARS) which is used by the National Administration for Safety in Traffic (National Highway Traffic Safety Administration NHTSA) began to record the use of cell phones by drivers in 1991. In 1995 a second system, National Automotive Sampling System (NASS), began to record the use of cell phones as a possible influential factor to traffic accidents. At the time, Oklahoma and Minnesota were the only two states whose police reports on traffic accidents contained specific questionnaires aimed to gather this kind of data. Oklahoma had standardized parts of the report in form of questions, with the possibility to reply with a yes or no ("check-box") made for the police to identify the presence and / or the use of a cell phone.

Anyway, only the cell phones that were noticed by the investigators were recorded, which means that in situations where phones were used but not noticed, weren't recorded. Analysis of data obtained by FARS system for year 1994 shows the most common factors that contributed to road accidents, as a result of cell phone use while driving: inattention, speeding, yaw movement. In most cases, cell phone users are the drivers of the vehicle that crashed into another vehicle or object, and this crash usually happens during the call and not at the stage of dialing a number. This is in contrast to the results obtained from studies in Japan.

JAPAN

In June 1996, Japanese National Police Agency performed a study to evaluate [3,7] how big and what kind of impact the use of cell phones has on a motor vehicle accident. From 129 analyzed accidents, 76% was the collision with the rear of the vehicle, 2.3% were traffic accidents with only one vehicle, 2.3% was knocking down pedestrians, and 19% were categorized as "other". In contrast to the results obtained in the United States, the highest number of accidents was related to the phase [4,1,6] of 'phone usage "(32% to dial a number, 42% answering a call, 5.4% ending calls) compared to only 16% of drivers that were talking when the crash happened. At 42% of drivers who were answering a call at the time of the accident, the behavior was described as "looking to the side, trying to reach the phone," and "careless driving at the time when the phone rings."

FINLAND

Out of the 2200 traffic accidents that occurred on the roads of Finland from 1991 to 1998, the use of a cell phone was the risk factor in 26 accidents (0.9%). The majority of drivers [2,5], (14 of 26) were talking at the time of the accident and a cell phone was handheld type in 23 (out of 26) of cases.

ACCIDENTS AND CELL PHONES - EXPERIENCES OF THE REPUBLIC OF SERBIA

When it comes to the use of cell phones in Serbia, the situation is similar to everywhere in the world [13]. According to surveys conducted by the Republic Institute of Statistics a few years ago, the number of households owning a cell phone is increasing, as shown in diagram 8.1. In 2006, in Serbia without Kosovo and Metohija we had a little more than 70% of households with a cell phone, but that number is now over 82%.

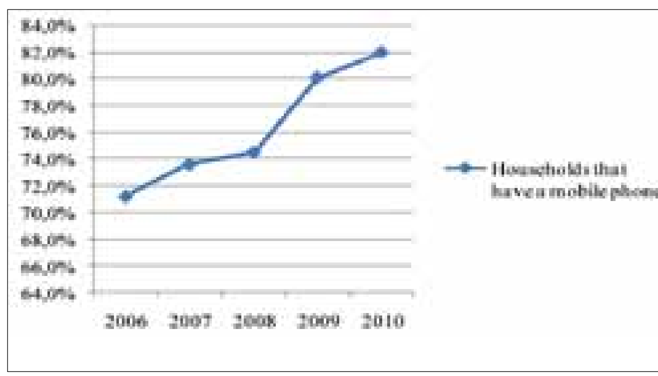

Figure 1. Representation of a cell phone in households in Serbia in the period from 2006 to 2010

Today, according to the information given by cell phone operators in Serbia, there are over 10 million cell phone [12] users. Also, it should be noted that these 10 million users compared to the 6 million inhabitants of Serbia, indicates that a number of residents actually own more than one cell phone or number, which further confirms the increasing expansion of cell phone usage in Serbia. Data on the use of cell phones in Serbia are consistent with those from abroad, the trend of growth is evident, there are more young users than the old ones, and there is little difference between men and women.

SURVEY OF ATTITUDES OF CITIZENS OF THE REPUBLIC OF SERBIA ABOUT THE USE OF CELL PHONES WHILE DRIVING

Survey

Considering that there are no official studies [8] about using a cell phone while driving in Serbia, neither research on the attitudes of drivers about it, this paper contains a survey of Serbian citizens, in order to give at least an approximate picture of the problem. Below is the more detailed description of the survey and then the analysis of the obtained data. The survey contains only a certain group of the population of Serbia. These are the drivers who own a cell phone. A total of 350 drivers were surveyed, of which 344 surveys were filled out correctly and used for further analysis. The survey was conducted in October and November of 2016, by written filling of surveys, with the note that the survey could only be filled by drivers who own a cell phone.

Questions

The survey consists of 20 closed type questions (for each question one of the offered answers is elected). The questions are divided into four groups. The first group consist of general questions (gender, age and driving experience). The second group refers to the frequency of phone use while driving and driver's attitudes about the dangers of using the phone while driving.

ANALYSIS OF THE RESEARCH RESULTS

Frequency of Cell Phone Usage While Driving

The survey covered 242 men (70,3%) and 102 women (29,7). Table 1. provides an overview of respondents by gender and age.

Table 1. Structure of surveyed drivers by gender and age

Gender/Age	17-30	31-45	46-60	61-more	Total
male	86	73	68	15	242
female	56	33	11	2	102
total	142	106	79	17	344

Table 2. Cell phone usage by the gender of respondents

Do you use a cell phone while driving?	Gender		
	Male	Female	Total
Yes	194 (80.2%)	57 (55.9%)	251 (73%)
No	48 (19.8%)	45 (44.1%)	93 (27%)
Total	242 (100%)	102 (100%)	344

It can be concluded that males, significantly more, use cell phones while driving than females and these results are consistent with global statistics, which also shows that more men than women use the phone (Table 2 and Figure 2).

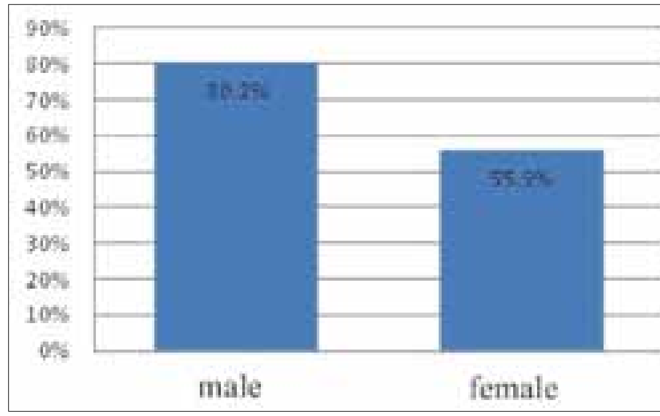

Figure 2. *Percentage ratio of cell phone use by gender of respondents*

More than half of respondents use the phone while driving (73%).

Table 3. Using a cell phone while driving by age of respondents

Do you use a cell phone while driving?	Age				
	17-30	31-45	46-60	61-more	Total
yes	118 (83%)	82 (77%)	47 (59%)	4 (23%)	251 (73%)
no	24 (17%)	24 (23%)	32 (41%)	13 (77%)	93 (27%)
Total (100%)	142	106	79	17	344

It can be concluded that the majority of those who use the phone while driving are among drivers between 17 to 30 years old (Table 3). Around 40% of drivers, of the total number who use a cell phone while driving are under 31 years, while the situation is completely different when it comes to people older than 61 years, 17 of those surveyed, 4 uses a cell phone while driving. However, this result may be due to a small sample of respondents older than 61 years (Image 3.)

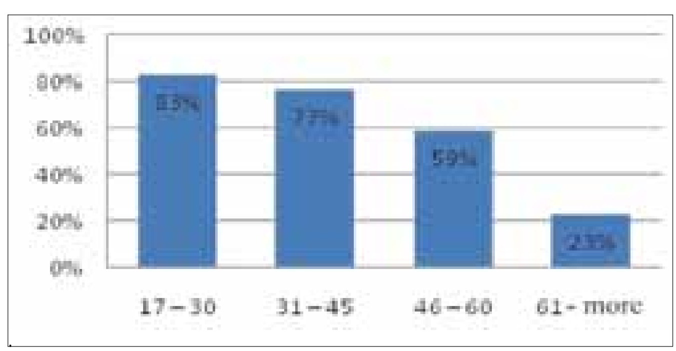

Figure 3. Percentage ratio of respondents regarding the use of cell phones while driving by age structure

Table 4. shows the answers to the question "How often do you talk on the phone while driving?", in total and by gender, as graphically shown (image 4 and 5). Every second a respondent_uses a phone while driving, occasionally or often, while one in eight said that_they never do that. Men make phone calls while driving more often than women - men 25.2% more often compared to

13.7% of women, and occasionally to 34.7% compared to 21.5%, respectively. 22.5% of women declared never to use the phone while driving compared to 8% of men.

Table 4. Frequency of phone conversations while driving by gender and total

How often do you talk on the phone while driving?	Gender		
	male	female	Total
often	61 (25,2%)	14 (13,7%)	75 (22%)
occasionally	84 (34,7%)	22 (21,5%)	106 (31%)
rarely	78 (32,1%)	43 (42,3%)	121 (35%)
never	19 (8%)	23 (22,5%)	42 (12%)
Total (100%)	242	102	344

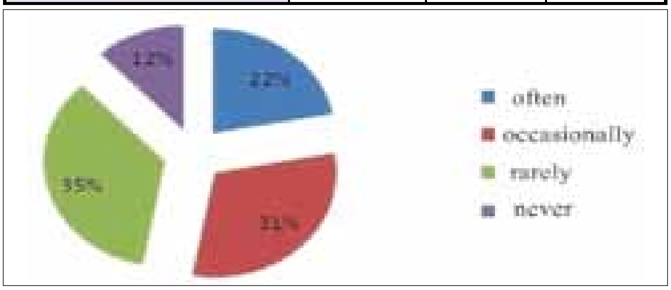

Figure 4. Frequency of using the phone to talk while driving, expressed in percentages

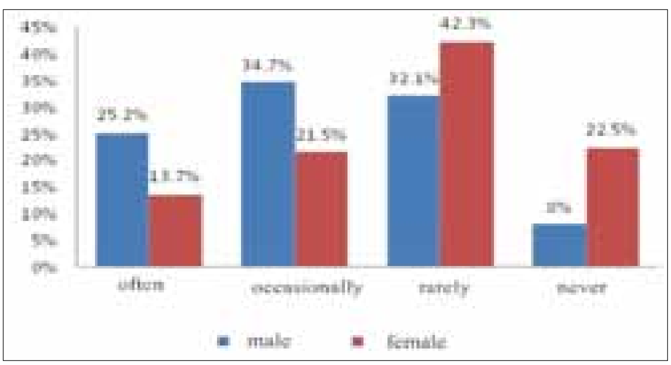

Figure 5. Frequency of phone conversation while driving by gender, percentage

When it comes to sending and reading messages while driving, there is no significant difference between genders. 49% of all respondents use the phone for messaging while driving (Table 5).

Table 5. Frequency of sending and /or reading messages while driving by gender and total

How often do you send and/or read messages while driving?	Gender		
	male	female	Total
often	15 (6,2%)	9 (8,8%)	24 (6,9%)
occasionally	37 (15,3%)	19 (18,6%)	56 (16,1%)
rarely	58 (24,5%)	31 (30,4%)	89 (26%)
never	132 (54%)	43 (42,2%)	175 (51%)
Total (100%)	242	102	344

In the population under 45, the youngest use the phone for calls and messaging equally, while older are more likely to use the phone for calls and less for messages. Older than 45 rarely use the phone for calls, and even rarer for messages. Also from the table 6. and 7. we notice that as the age of the respondents increases, the percentage of respondents who talk or send/read messages while driving decreases.

Table 6. Frequency of using the phone to talk while driving, according to age structure

How often do you talk on the phone while driving?	Age			
	17-30	31-45	46-60	61-more
often	20 (14%)	28 (26%)	27 (34,2%)	0 (0%)
occasionally	49 (34,5%)	30 (28%)	25 (31,6%)	2 (11,8%)
rarely	63 (44,4%)	37 (35%)	13 (16,4%)	8 (47%)
never	10 (7,1%)	11 (11%)	14 (17,8%)	7 (41,2%)
Total (100%)	142	106	79	17

So usually middle aged men make calls during driving, while messages are typically sent by younger people, regardless of gender.

Table 7. Frequency of sending and / or reading messages while driving by age structure

How often do you send and/or read messages while driving?	Age			
	17-30	31-45	46-60	61-more
often	10 (7%)	9 (8,5%)	5 (6,3%)	0 (0%)
occasionally	23 (16%)	19 (18%)	14 (17,7%)	0 (0%)
rarely	36 (25%)	37 (35%)	14 (17,7%)	2 (12%)
never	73 (52%)	41 (38,5%)	46 (58,3%)	15 (88%)
Total (100%)	142	106	79	17

Attitudes on Dangerous Impact of Cell Phone While Driving

The survey shows that most drivers think that using a cell phone while driving is dangerous. Although the majority of surveyed drivers think it's dangerous to use the phone while driving, they still do it, regardless of the danger. From Table 8 it can be seen that 87% of those who use a cell phone think it is dangerous 54.4% of those who think it's dangerous to use the phone, talk on the phone while driving frequently to occasionally (Table no. 9), while the 23.3% often to periodically sends messages (Table 10). Therefore, it is necessary to influence the drivers to change their behavior in accordance with their attitudes, so that their true views are against the use of cell phones while driving, because it is possible that the attitudes that they listed in the survey are actually responses which respondents thought it was right to give.

Table 8. Using a cell phone while driving and attitudes about the dangers

Do you think that using a phone while driving is dangerous?	Do you use a cell phone while driving?	
	yes	no
yes	220 (87%)	76 (81,7%)
no	9 (3,6%)	5 (5,4%)
in some situations	19 (7,6%)	11 (11,8%)
I don't know	3 (1,8%)	1 (1,1%)
Total (100%)	251	93

Table 9. Frequency of use of cell phones for conversations while driving and attitudes about the dangers

How often do you talk on the phone while driving?	Do you think that phone use while driving is dangerous?			
	yes	no	in some situations	I don't know
often	65 (24,2%)	1 (7,1%)	7 (23,3%)	2 (50%)
occasionally	90 (30,4%)	7 (50%)	8 (26,6%)	1 (25%)
rarely	104 (35%)	4 (28,6%)	12 (40%)	1 (25%)
never	37 (10,4%)	2 (14,3%)	3 (10,1%)	0 (0%)
Total (100%)	296	14	30	4

Table 10. Frequency of use of cell phones for messages while driving and attitudes about the dangers

How often do you send and/or read messages during driving?	Do you think that phone use while driving is dangerous?			
	yes	no	in some situations	I don't know
often	21 (7,1%)	2 (14,3%)	1 (3,3%)	0 (0%)
occasionally	48 (16,2%)	3 (21,4%)	5 (16,7%)	0 (0%)
rarely	72 (24%)	7 (50%)	8 (26,7%)	2 (50%)
never	155 (52,7%)	2 (14,3%)	16 (53,3%)	2 (50%)
Total (100%)	296	14	30	4

Interestingly, among drivers from 1730 years old almost 83% (Table 11) are those who think that using a phone while driving is dangerous, and yet also in this age group are most people who often and/or occasionally talk on the phone while driving. This points to the paradox that although they think that it is dangerous they still use cell phone while driving, which makes them an especially risky group which should be influenced. On the other hand, the drivers of this age are young people/ drivers with whom we need to work in terms of education. On the other hand, as far as the respondents from 31-45 years old are concerned, almost 82% of them think that using a phone while driving is dangerous, and even 61.5%, still use the phone for messages while driving.

Table 11. Attitudes about using the phone while driving according to the driver's age structure

Do you think that using cell phone while driving is dangerous?	Age				
	17-30	31-45	46-60	61-more	Total
yes	124 (87%)	87 (82%)	68 (86%)	17 (100%)	296 (83%)
no	3 (2%)	6 (5,7%)	5 (6%)	0 (0%)	14 (4%)
in some situations	13 (10%)	11 (10,4%)	6 (8%)	0 (0%)	30 (8,7%)
I don't know	2 (1%)	2 (1,9%)	0 (2,1%)	0 (0%)	4 (4,3%)

Also, three of four drivers think that making a call with a "hands free" device is safer than without it. All the world's research indicates that this device does not contribute significantly in reducing the negative influence of the phone, and therefore we should work on raising awareness of drivers about the negative impact of the phone, regardless of whether they used any of the auxiliary devices or not. Such cogitation of respondents can be correlated with the permitted use of "hands free" devices in Serbia.

Table 12. The frequency of accidents and incidents in the use of cell phones while driving

How many times have you participated in a traffic accident?	Have you ever been in a situation to suffer a traffic accident while using your cell phone?			
	No, never	Yes, once or twice	Yes, several times	Total
Never	136 (41,8%)	0 (0%)	0 (0%)	136
Once/Twice	172 (53%)	10 (58,8%)	0 (0%)	182
Three times or more	17 (5,2%)	7 (41,2%)	2 (100%)	26
Total (100%)	325	17	2	344

Every thirtieth driver was in a situation (once or twice) that his traffic accident occurred while using cell phone (Table 12), and almost 94.4% of respondents were not in such situation. However, this information can be questioned, given the possibility that drivers simply did not want to admit they have ever been in a situation like this. On the other hand, if this information is correct, it may indicate that drivers often use cell phone while driving, just because they have not yet experienced the incidental situation while doing it. From table 12 we can see that most of the drivers who have participated in the same number of traffic accidents with the number of incidents when using a cell phone. This can be attributed to personality characteristics, and preferences of individual drivers to aggressive driving, including the use of phones while driving.

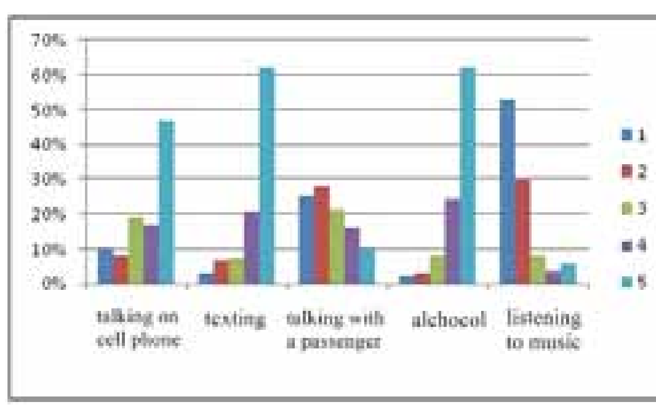

Figure 6. Estimated influence of valuated actions on driving

When the drivers evaluated the influence of individual actions on driving, they evaluated on a scale of 1 to 5, where 1 indicates that the given action has no effect, while 5 means that it has a very strong influence (Image 6). Actions that were listed in the survey were talking on cell phone, sending/reading messages, talking with the passenger, drunk driving (0.3 mg / ml of alcohol in the blood - the legally permitted maximum) and listening to music. Reading and sending messages was rated as equally influential as alcohol, over 62% of respondents rated these actions as very influential to driving (the average score for these two actions, in the sequence provided was 4.31, and 4.4). Talking on the phone was estimated in average with 3.81, a conversation with a passenger 2.58, while listening to music occupies the last place with 1.8. Therefore, the drivers considered talking on a phone slightly less influential than the messages and alcohol, while listening to music and chatting with a passenger received the highest score 1 (no influence) compared to all the others. The graph 6 gives a picturesque view of these data. From these studies, matches with the results of global research are revealed, according to which most of the drivers considered cell phone usage while driving dangerous, on the other hand they still admit they use it. Also, drivers are under the misconception that the use of cell phone with a "hands free" device is significantly safer. Drivers evaluated using cell phone as equally dangerous as drunk driving, in our country and in the world.

CONCLUSION

Cell phone has become one of the most commonly present device in vehicles today, with more than two-thirds of the drivers who use it at least sometimes while driving. In parallel with the increase in number and more intensive use of cell phones in traffic, the concern about their potential negative effect on traffic safety is also growing with a significant number of research focused on the consequences of the use of cell phones while driving. Overall, the conclusion of all the behavior research is that the use of cell phones while driving has a negative impact on various aspects of the driver's driving performance. Reaction time at traffic signals is slower, braking reaction is also slower with shorter braking distances, drivers miss more traffic signs, have a tendency to risky behavior, which could be proven by their acceptance of shorter distances between vehicles at detours or turns, or make minor speed changes while adapting to road conditions. These negative effects on driving performances are a result of physical, visual, sound and mental distraction that arise from the use of a cell phone. Although physical distraction may be reduced or limited with a variety of technical accessories such as hands-free equipment, speed dial, voice activation, etc., mental distraction remains a major problem in the use of cell phones. This is why hands-free phones do not have significant advantages in terms of security over handheld cell phones. The intensity of negative effects of using cell phones while driving depends on the complexity of the conversation and the complexity of the current traffic situation. The more complex the conversation, the more expressed are the negative effects on driving performance. The survey showed the following: most phone calls while driving are made by men from 17-30 years old, while the younger send messages regardless of gender; most drivers think it's dangerous to use the phone while driving, but still admit that they use it; sending and reading messages while driving are equally dangerous as driving drunk; most drivers support a ban on using the phone without auxiliary devices, with the fact that the more they use the phone while driving, drivers are less likely to support a ban. The special risk group are young drivers, who have a combination of inexperience, overestimation of their abilities and frequent use of cell phones; which makes their risk of traffic accidents when using a cell phone while driving higher than the risk for other drivers.

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PRELIMINARY COMMUNICATION

Passive Road Safety Systems - Case Study Of Road Section Banja Luka - Prnjavor (M16, M16.1)

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Abstract: In this paper, the authors will show the influence of roadside objects on road safety on the Banja Luka- Prnjavor section. Roadside objects have a major impact on the weight of a traffic accident because they represent direct obstacles to the wandering vehicle, which in most cases will be stopped by a collision in one of them in the immediate vicinity of the road. Roadside objects can be of different types and constructions, concrete poles, public lighting poles, trees, inadequately installed rebound fences and unprotected petrol stations are only some of them. Therefore, the essence of this paper is to spot possible roadside objects on the observed road section, categorize them, and make suggestions for short, medium and long term improvements.

Keywords: roadside objects types – RSI analysis – proposal of the solution for the observed road accident type – short, medium and long term improvements.

INTRODUCTION

INTRODUCTION

In the world, and especially in the underdeveloped countries and developing countries, 1.3 million people per year die in traffic accidents, and more than 50 million people remain permanently immobile or suffer injuries. In this "black" statistics Bosnia and Herzegovina contributes with at least 400 dead and 11,000 injured persons per year. The traffic death rate in BiH is three times higher than in Western European countries, according to official statistics over 10 people have been killed per 100.000 inhabitants. This difference can be even bigger if you take into account accidents that have not been recorded. The actual number of people killed in traffic accidents in the Republic of Srpska is higher than the registered number in the official statistical data. About 160 persons die on roads in Republic of Srpska, while over 3.200 persons get injuries. [1]

The economy of Republic of Srpska, due to traffic accidents, loses over 174 million KM, or about 90 million euros per year, when considering the costs of treatment, material damage, the costs of judicial and administrative procedures and loss of productivity. Total losses, damages and costs amount to over 2% of Gross Domestic Product (GDP). According to reports from the Ministry of Internal Affairs (hereinafter: the MIA), in the past five years, 850 persons died in Republic of Srpska, while 16.800 persons were injured or permanently incapacitated. The economy of Republic of Srpska has lost over 880 million KM (over 430 million euros). No economy can afford to have such high losses that are repeated year after year. It is therefore necessary to undertake urgent activities to reduce losses in people and the listed economic costs. [2]

DIRECTIVE 2008/96/EC OF THE EUROPEAN PARLIAMENT

The directive 2008/96/EC of the European Parliament on road infrastructure safety, dictates four points that all member states must undertake to improve safety on existing and future roads. Therefore, under this directive, member states should introduce and implement procedures relating to road safety inspection (RSI), road safety audit (RSA), the management of road safety aspects and the control of road safety. [3]

This directive applies to roads that are part of the trans-European road network, regardless of whether these roads are only designed, built or already in use. Bosnia and Herzegovina is a member of countries that have implemented this road safety directive.

Four points of the 2008/96/EC directive [3]:

- Infrastructure assessment projects impact on road safety;
- Road Safety Audit and Inspection on road infrastructure projects;
- Ranking of shares with a large number of traffic accidents and security ranking within the network;
- Data to be entered in a traffic accident report.

The Haddon matrix

The Haddon Matrix is the most commonly used paradigm in the injury prevention field. Developed by William Haddon in 1970, the matrix looks at factors related to personal attributes, vector or agent attributes and environmental attributes; before, during and after an injury or death. By utilizing this framework, one can then think about evaluating the relative importance of different factors and design interventions. [4]

Category	Before Crash	In Crash	After Crash
Human	Information, attitude, impairment, police enforcement	Use of restraints, impairments	First-aid skills, access to medics
Vehicle	Roadworthiness, braking, lighting, speed management	Occupant restraints, crash-protective design, other safety devices	Fire risk, ease of access
Road	Road design and layout, speed limit, pedestrian facilities	Crash protective roadside objects	Rescue facilities, congestion

Figure 1. The Haddon matrix

ROAD SAFETY INSPECTION ANALYSIS (RSI)

RSI is a systematic field study conducted by qualified experts. It consits in doing a safety check on existing roads in order to identify any dangerous points, mistakes and defects that can lead to serious traffic accidents. Following the "better to prevent than treat" principle through RSI analysis, the existing road facilities and infrastructure can be improved and this can reduce the percentage of serious traffic accidents.

The basic principles of RSI analysis are [5]:

- Interdisciplinary detailed analysis of road and road environment;
- Identification of possible accidental risks;
- An analysis of the state of the driver's perception and the quality of driving;
- Checking the performance of roadside equipment such as rebound fences and others;
- Compliance of the local situation with norms and guidelines.

CASE STUDY (BANJA LUKA - PRNJAVOR)

This case study presentes the analysis of passive road safety. The impact of roadside objects on road safety along the road section Banja Luka - Prnjavor is showed. In February 2017, the entire research-relevant stock was recorded with a camera placed in a cockpit of a passenger car. Analyzing the snapshots, additional field research was not necessary, given that the output information from the camera, or video recording, was of very good quality and could fully represent the real state of the road. Considering that the observed section contains two categories of road in its route, passing through inhabited and uninhabited places, the number of observed roadside objects was generally quite large. Such a result, looking at the state of the road and the environment, was not surprising. The roadside object impact factor for the consequences of a traffic accident was somehow always viewed as a secondary and not so important thing. But the fact is that an adequately set front rebound fence or an adequately protected concrete pole can significantly reduce the consequences for the persons and the vehicle involved in an accident, changes significantly the thinking about this topic. One of the aims of this case study is to precisely prove this claim. The vision of the competent authorities for the safety of traffic in the Republic of Srpska has to be enlightened to the extent that investing in the safety of transport is not a cost but a profit. Why profit? Well, if we look at the annual cost of traffic accidents based on the parameter from 2012, which "Economic Institute a.d. Banja Luka" in cooperation with Swedish experts calculeted, we will come to a simple conclusion that investments in adequate equipment for the protection of roadside disturbances are far less than the total cost of traffic accidents. Adequately protected roadside disturbances reduce the consequences of traffic accidents and reduce their costs for the Republic Of Srpska's budget analogously.

The cost of a traffic accident only with pecuniary damage, based on the "readiness to pay" calculation process, which represents the minimum economic loss, is 3.258 convertible marks (hereinafter KM). If we compare this amount with the cost of a traffic accident with severely injured or dead persons we will have 66.683KM or 620.618KM. We can conclude that the difference between economic losses is enormous depending on the severity of the traffic accident. Therefore, if the consequences of traffic accidents are reduced to a greater extent, the costs of this will decrease. [2]

The starting location begins at the exit from the Banja Luka city area on the road reserved only for the traffic of motor vehicles (M16). In the town of Klašnice, the road reserved only for the traffic of motor vehicles (M16) stops and crosses to the road M16.1 Klašnice - Prnjavor. During the observing period, this section was constantly under heavy load throughout the day due to the construction of the section of the Prnjavor-Banja Luka freeway parallel to this route. This means that the percentage of heavy vehicles in the traffic flow was big. There are a lot of smaller connecting roads that only these vehicles use, the newly constructed freeway-related facilities are in no way protected from the upcoming traffic. All of these factors additionally pose a danger to an already insufficiently safe road from the aspect of roadside disturbances.

Roadside disturbances identification

The identification of roadside disturbances was done by a detailed overview of the video material. Each roadside disturbance was marked by using the hours, minutes, and seconds on the recording. Categorization was done for easier data processing and because the number and the type of roadside disturbances was quite large. Each category of road was primarily dominated by one category of roadside disturbances with a smaller share of others.

Accordingly to that, lateral disturbances were categorized in:

- Concrete and iron poles of electricity distribution and public lighting;
- Open beginnings of the frontal rebound barriers;
- Approaches and fences on the bridges;
- New Jersey barriers;
- Unprotected approaches to the petrol stations.

Concrete and iron poles of electricity distribution and public lighting pose a problem to the greatest extent. The present poles, in most cases, are located in the immediate vicinity of the edge of the driveway, where they pose a serious threat to road users if a wandering vehicle hits one of them.

Observing the our case, especially on the main road M16.1 Klašnice - Prnjavor, the distance of roadside disturbances is roughly 2m from the edge of the driveway. In some segments of this road, the poles are located at a distant distance, somewhere even on a smaller one. The point is that these poles are not adequately protected in any way and pose a direct danger to traffic participants in case a wandering vehicle hits some of them.

In Figure 3. we can see an example from a real life situation. That even if the speed limit is 80km/h the poles are located very close to the edge of the driveway and extend on the right and left side of the road to the entire length of the segment of the specified speed limit. [7]

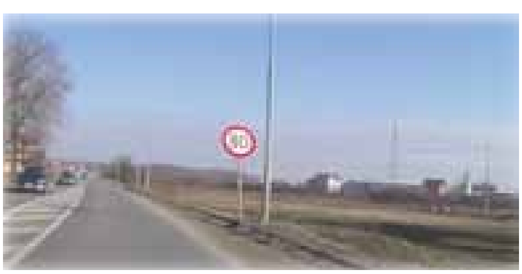

Figure 2. Iron poles in the speed limit zone of 80km/h (M16.1).

It should be noted that in such cases even if the speed limit is 80km/h the speed of the vehicles is predominantly higher than permitted for as much as 30km/h in some cases. For such segments of the road, it is necessary to protect the roadside disturbance (poles) by the setting of the rebound fences, so that the poles are not in the working width of the same fence or completely replace the existing poles with passive safety poles where this is possible.

On the road reserved only for the traffic of motor vehicles M16 Banja Luka - Klašnice, the poles of electricity distribution and pubblic lighting are adequately protected by a rebound fence. But there are some places on the exit ramps as in Figure 4. where the poles are completely exposed to the external traffic impact.

Figure 3. Pole exposure (M16)

In this road section, vehicle speeds exceed 100km/h, making this a relevant hazard. And if so far there have been no cases that a vehicle hit that unprotected pole, that does not mean that tomorrow will not happen. Therefore, it is necessary to react preventively and not wait for a serious traffic accident to happen, and then only apply certain measures that will be corrective in this case.

The frontal open beginnings of rebound fences pose a major problem in the entire observed section. The example from Figure 5. shows the open start of the rebound fence on the road section Klašnice - Prnjavor (M16.1).

Figure 4. Open start of the rebound fence (M16.1)

The open start of the rebound fence acts as a kind of blade when the vehicle in motion hits it, so we have an opposite effect of the fence here. Instead of turning away the wandering vehicle that hits the fence back on the driveway or in an another case safely stopping it along the length of the fence, the vehicle hits directly the metal structure which, at that speed, becomes a "blade" that breaks through the chassis of the vehicle. In addition to the open beginnings and endings of the rebound fences, they're mostly in a bad state. Primarily because of previous vehicle accidents and insufficient fixing after accidents. In some places the fences are not placed at the appropriate height and are not connected in an adequate way with the attachments of other fences. The explanation for this situation lies in the fact that these fences when first placed were adequately furnished. But because of insufficient maintenance of infrastructure and poor remediation after traffic accidents they've lost all their functional aspects in time and now they have almost no effect on reducing the consequences of a traffic accident. In some cases they can act contrary to what they are intended for and increase the consequences for passengers in the vehicle and for the vehicle itself.

Figure 5. Poor maintenance (M16.1)

The approaches and the fences on the bridges are also one of the critical points on the observed section. There are openings between the protective fences on the bridges and the frontal rebound fences. And in this case, the ending of the rebound fence is in most cases open. As far as the protective fences on the bridge are concerned, they are mostly in poor condition or not present on one or both sides. The approaches to the zones of the bridges are not adequately protected. The rebound fences, if any, do not protect vehicles from possible landings in slopes in the zone from 20 to 50 meters before the bridge. They are placed before the beginning of the bridge or are not at all positioned.

As can be seen in Figure 8, this frequency of the defective fence barrier before the bridge is quite constant throughout the observed section.

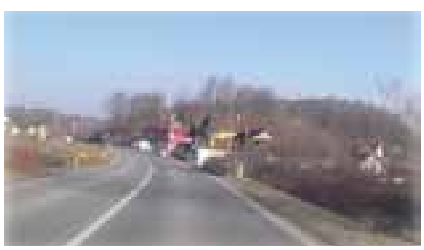

Figure 6. Unprotected approaches (M16.1)

New Jersey barriers are present only on the road reserved only for the traffic of motor vehicles M16 Banja Luka - Klašnice. Their function is to physically separate the driveways. In the majority of cases, one line of these barriers is enough but there are two lines on the M16 path for reasons that are not defined. Roadside disturbances on this section are largely adequately protected, but the beginning of the new jersey barriers are a problem if a moving vehicle hits one of them. Any beginning is not protected in any measure, and it also represents a sort of a catapult for a vehicle in case of a collision.

Figure 7. Unprotected new jersey barrier (M16.1)

An additional indispensable item on this section of the road are the paytoll booths that are not in operation and currently present, in such a state, only an obstacle and endanger the safety of traffic due to their inadequate protection against possible vehicle collisions.

Figure 8. Paytoll booths (M16)

Unprotected petrol stations are a subcategory because there is only one unprotected station in the speed limit zone of 80km/h. Other gas stations on the whole observed section of the road are located in zones where the speed limit is 50km/h. Therefore even if they have similar characteristics to the gas station in question, no further changes are needed. The curbs set up at the access road do not represent any kind of protection against collision and can not prevent the vehicle from passing. An advertisement with fuel prices is placed very close to the edge of the driveway, with its foundation of concrete structure, which in most cases expands so it poses additional danger. Also, the iron poles of lighting are in the immediate vicinity of the structures.

Security risks analysis

The observed section of the road M16.1 contain a mixed function of local and remote traffic, which indicates different speeds of allowed movement. Pedestrians and bikers also use this route, but are present mostly in liner settlements and villages than in rural areas. Tractors and other transport vehicles used by farmers are most often present in rural areas. The presence of connecting roads, without traffic signalization and without asphalt cover, from various private estates is quite large. Mixed road users with varying speed and safety requirements make these a high-risk road sections. On the other hand, if we look at the road reserved only for the traffic of motor vehicles M16 these listed characteristics are not present. Driveway directions are physically separated, working machines and tractors are not present in the traffic flow, no connecting roads and the speed of movement is quite constant without sudden changes. But there are other issues that need to be addressed, such as: inadequately protected beginnings and endings of New Jersey barriers and toll booths that are not in function. [6]

Identified safety risks for the observed road sections

Function and road environment:

- Along the observed sections there are connecting roads without traffic signalization and without built-in asphalt cover;
- In some segments there are "wild" bus stops that are not illuminated and properly marked;
- Speed limit signs on certain parts of the road are not placed in appropriate ways, causing drivers to not respect them.

Cross-sectional profile:

- The driveway is divided by a central line, the edge lines that are in poor conditions (damaged and with poor retro-reflection);
- The edges of the driveway are damaged, the soft shoulders are not in the same level with the driveway (especially on section M16.1) and do not have enough width;
- The ruts made of car tires are visible, which prevents drainage from the driveway. This factor will cause aquaplanning when it rains;
- The driveway surface, especially on the road section M16.1, is smooth and slippery with a low adhesion coefficient, especially in rainy conditions;
- There are no transverse inclinations on the carriageway in some segments and where they are present they're not properly directed.

Passive safety features:

- Raised sidewalks are present along the road section M16.1. Raised both by the driveway and by the soft shoulders;
- Unprotected drains, electricity and public lighting poles;
- Lack of rebound fences in most of the curves;
- Existing rebound fences are not long enough and do not have safe endings and beginnings;
- Unprotected beginnings of the New Jersey barriers on the road M16.

Proposal of safety solutions

After the identification of roadside disturbances and security risk analysis on the observed sections of the road, this chapter will show the possible solutions for the improvement of roadside disturbances protection. Short,medium and long term solutions will be displayed.

Short term solutions are a type of solution that can be implemented in a short period of time. It is especially important to have stable goals and ideas regarding short-term measures for further implementation of medium and long-term measures. Therefore, through the short-term measures within this report, the following items are recommended:

- Replacement of concrete and iron poles with passive safety poles where possible;
- Where the replacement of existing poles is not possible, it is necessary to protect the poles with appropriate crash cushions especially for zones 50km/h and zones over 70km/h;
- Fixing the rebound fences in general with a special emphasis on the correct ways of their beginnings and endings;
- Protecting the beginnings of "New Jersey" barriers with End-Terminals on the road section M16 Banja Luka - Klašnice;
- Installation of rebound fences before and after the bridges and removal of the existing voids between the end of the rebound fence and the beginning of the protective fences on the bridge.

Medium term solutions

- Removal of a large number of unshielded connecting roads on section M16.1 and creation of a pair of collecting paths by segments.

Long term solution

- Permanent removal of all roadside disturbances where possible.

Passive safety poles and crash cushions

Poles must comply with the requirements of EN-40 and/or EN 12899 for traffic signs in terms of carrying capacity for certain types of road equipment (portal and semi-portable constructions, traffic signaling constructions as well as public lighting poles). In order for such pillars to be passive and safe, they must comply with EN 12767. [8]

EN 12767 differs three categories of poles in terms of energy absorption during a vehicle impact:

- HE - high energy absorption;
- LE - low absorption;
- NE - without energy absorption.

Areas of use of these poles are very wide and can easily be applied to solve the observed problems in this case study. Poles must be passively secure on [8]:

- All roads outside the inhabbitated areas, where the speed limit is higher than 50 km/h and where the poles are not protected by a rebound fence;
- All roads, where the speed limit is less than 50 km/h and the poles are less than 4m from the driveway surface and are not protected by a rebound fence;
- Always when the pole is behind the rebound fence but is in the area of its working width.

Figure 9. Example of the behavior of a passive pole

In case the replacement of the existing poles with a passive safety ones is not possible, there is an another method of protection against vehicle impacts. SMA Tree crash cushion is the best solution for this. Originally designed to protect trees from possible vehicle impacts, it can be applied with the same analogy for poles as well. Figure 11 shows the technical characteristics of the SMA crash cushion. Note that this system is 80% re-usable after an impact of a vehicle. The absorbent cells can be replaced and the crash cushion can again perform its full function. [9]

Figure 10. Technical characteristics

The green zone is the area where the tree or pole is located and can be in the width of 1m to 1.5m. The kinetic energy produced during the impact is gradually absorbed from this system by preventing serious injuries on the passengers in the vehicle.

Protection of the beginnings of New Jersey barriers

On the road reserved only for the traffic of motor vehicles M16 there are several New Jersey barriers whose beginnings are not protected in any measure and some of them have already traces of vehicle imapcts. Since speeds on this road are more than 100km/h, adequate protection and prevention of catapulting vehicles in the event of a collision is a must have thing. [11]

Figure 11. M16 example situation

Blue arrows indicate the direction of movement of the vehicles while the orange arrows indicate the possible directions of movement of the vehicles during an impact with the SMA end terminal.

There are two types of these structures [11]:

- SMA T2 for speeds up to 80km/h;
- SMA T4 for speeds up to 110km/h.

SMA end terminals are a really innovative product on the market because they are double sided which means that they absorb the energy of the impact from both sides and therefore can be installed both in front of the roadside barrier, and in front of the median barrier. Also bi-directional, they absorb the energy of the impacting vehicles coming from both directions of the driveway. For this reason, they can be installed both at the begin and at the end of the barriers. [11]

The behavior of SMA End Terminals during the impact is similar to the behavior of Crash Cushions because of their similar absorbing system. SMA T2 and T4 are different from the competitor's end terminals because they have an enery absorbing system made of collapsing beam with controlled deformation, patented from Industry A.M.S. srl. . They avoid any possibility to have an unpredictable behaviour – especially in case of out-of-norm impacts – in order to adequately protect the passengers from serious injuries. SMA end terminals are tested to absorb the impact of a vehicle with a mass between 900 and 1500 kg. Thanks to their structure in steel, SMA T2 and T4, after the impact do not release debris on the road because they don't break but become more compact by reducing their lenght. SMA end terminals guarantee the maximal protection for the passengers of the impacting vehicles and other road users. Like the SMA crash cushion absorber, this system can be used again after the impact, by only changing the damaged parts of the terminal, that is the modular system. [11]

Correct execution of the beginnings and endings of rebound fences and their maintence

As shown, the beginnings and endings of rebound fences are not executed in the right way and pose a serious threat in case of a vehicle impact. Many fences have not been repaired after the earlier accidents and can not perform their function in the right way. So the only possible solution to the problem in this case is:

- Fixature or replacement of the rebound fences that have been damaged during vehicle collision;
- The beginnings and endings of fences must be executed out in the right way so that they do not have a sharp beginning and end that can break through the front of the vehicle. The beginning must not be in such a form to catapult the vehicle into the air during collision.

Rebound fences before bridges and fences on the bridges

Before and after the bridge, there are no rebound fences that would prevent the possible landing of the vehicle into the slope before the passage. It is necessary to install a rebound fence of an adequate length before the passage and after the passage, so that possible exit of the vehicles in that zones are prevented. Rebound fences should be connected with the fence on the bridge, the pedestrian zone if present, should be protected from the external influence of traffic of motor vehicles. Fences on bridges are in a catastrophic state in most cases or do not exist at all, so this aspect should be solved by placing adequate certified protective fences.

CONCLUSION

One of the tasks of this case study was to determine the safety risks of the observed road sections from the aspect of passive road safety. The ultimate goal of the research basically offers a solution to modernize the road and remove and protect roadside disturbances in order to create the prerequisites for reducing traffic accident consequences. By implementing measures to eliminate potential security threats, it is possible to get a road that forgives driver errors. Therefore, it is necessary to create a roadside ambient amplitude that will not bring participants into a dangerous or fatal situation.

All this being said, investment in traffic safety should not be considered a cost, but vice versa. It is a gain in terms of more saved lives, minor serious bodily injuries and minor material damage in the aftermath of traffic accidents.

In addition to the implementation of this measuers, there is a need for them to be maintained regularly. By investing in equipment and financing future projects in the area of traffic safety it is possible to reduce the consequences of traffic accidents and increase the overall level of safety on Republic of Srpska's roads. By reducing the consequences, spending of the budget will reduce, social situation in the society will improve, which is evident from the Study of the Economic Institute in Banja Luka in 2012.

Having examined all the information presented in this paper and the possible solutions that exist and are implemented in the world, through the precise visions and goals it is possible to significantly change the condition of the roads in question and remove or adequately protect the roadside disturbances.

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PROFESSIONAL PAPER

Safety Aspects of Freight Traffic in the Republic of Srpska

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Abstract: This paper tries to present the state of traffic safety in the Republic of Srpska based on a statistical sample of traffic accidents involving freight motor vehicles on roads of the Republic of Srpska and Bosnia and Herzegovina. Besides statistics, survey and statistical sample analysis methods were used, as well as analyses of indicators of road worthiness testing station inspections of vehicles in the Republic of Srpska. The indicators of non-regular preventive inspections of roadworthiness tests conducted on the roads by the Auto Moto Association of the Republic of Srpska are especially important. Bearing in mind the age and number of freight motor vehicles in the Republic of Srpska, in accordance with the indicators from chapter 3.4 (Consequence of Traffic Accidents) it is possible to continue the research with a special view on the injuries of the freight vehicle drivers and causes of traffic accidents. According to the data available, most of the fatalities and severe injuries were inflicted to drivers and passengers from vehicles that were involved in accidents with freight vehicles.

Keywords: freight motor vehicle, traffic accident, vehicle road worthiness test, road worthiness testing station.

INTRODUCTION

Freight transport is the dominant transport sector in the Republic of Srpska. As well as traffic itself, the freight traffic is represented in all spheres of our lives, thus occupying an important place in the structure of traffic flows on the roads of the Republic of Srpska. Its importance is also described by the number of registered cargo vehicles. The total number of registered cargo vehicles in 2014 was 28 279, in 2015 this number increased by 1 086 vehicles, amounting to 29 365. By the end of 2016, by statistical processing of data on the number of registered cargo vehicles, the highest increase in the number of registered cargo vehicles was present in the observed period. Data released show that 1 875 vehicles more were registered in the previous year than in 2015, or 2 961 more than in 2014, so in 2016 a number of 31 240 of freight vehicles were registered. The constant increase in registered vehicles shows that freight traffic is more and more present on the roads of the Republic of Srpska, and from the aspect of traffic safety it is necessary to create a clear picture of the safety of this type of transport. These data on the increase in the number of freight vehicles are quite acceptable, since Bosnia and Herzegovina/the Republic of Srpska is a developing country and has suffered great changes in the near past. This again says that traffic is involved in all spheres of our lives and that it plays a major role in the development and progress of the country. At the assembly of the UN, the period 2011-2020 was declared the decade of traffic safety on roads. In 2010, the World Health Organization (WHO) released the data on global safety at which it is clear that 1.24 million people were killed in traffic accidents annually and that traffic accidents at that time occupied the eighth place in the cause of mortality in the world with a tendency to become the fifth cause by 2030. Our country as a member of the UN, along with other members, signed the Declaration of the Assembly of the United Nations, thus accepting the action plan of the systematic solving of this problem. Therefore, multi-sectorial efforts must be invested and a strategy created which will integrate individuals and institutions of the system. For systematic action, we first need to analyse and investigate traffic accidents in a quality way so as to have a clear picture of its participants, consequences and causes of its occurrence. This means that it must be determined which group of drivers are participants, when and where traffic accidents occur, the number of persons who have died, the number of persons who have suffered serious body injuries (SBI), the number of persons who suffered minor body injuries (MBI), as well as material damage.

From the aspect of the safety of freight traffic, technical safety of the vehicles should be considered, that is, the correctness of the active and passive systems of the vehicles themselves. Also, for these parameters, a period of three years should be analysed, that is for 2014, 2015 and 2016. Inspections of technical safety of vehicles are done through regular annual inspections, regular six-month, and extraordinary inspections of vehicles. The malfunction of some of the active systems can lead to an accident. When all these parameters correlate, the level of safety of freight traffic in the Republic of Srpska is obtained.

RESEARCH METHODS

Analysing the statistical sample of traffic accidents, the participation of freight vehicles in traffic accidents, its characteristics, time and place, etc. is evident. In order to evaluate the level of safety of freight traffic, it is necessary to put the existing values into a mathematical relation, or to synthesise the relative indicators. In this way, already known absolute indicators of the number of traffic accidents and their consequences can be combined with other significant figures (population, number of vehicles, number of drivers, number of kilometres travelled, length of the road section, tons, kilometers ..).

Using the comparative method, conditions have been created for the comparison of certain parameters, that is, this type of traffic with other modes of transport, in order to evaluate the safety aspects of freight traffic.

In this paper, we have separately distinguished traffic accidents in which freight vehicles were involved with different consequences and the causes of its occurrence.

RESULTS OF RESEARCH

The objectives of this research are related to the assessment of the impact of technical safety of freight motor vehicles on the parameters of traffic safety. What is particularly significant is the sample of the number of road accidents involving freight vehicles and percentage in relation to the total number of traffic accidents, as well as the number of persons killed and injured in traffic accidents in the Republic of Srpska for the mentioned period.

On the basis of a sample of preventive inspections and verification of the technical safety of vehicles in 2014, data on the correctness of freight vehicles were obtained. There were 17 systems on-board examined, system of active and passive safety as well as other systems and devices on the vehicle itself.

In Table 1, the results of the technical safety of vehicles in 2014 are presented

Table 1. Control of technical worthiness in 2014

Control of technical regularity of freight vehicles in 2014 (verification, preventive and check of technical regularity)	
Number of registered vehicles in RS in 2014	324 691 (100%)
Number of freight vehicles in 2014.	28 279 (8.7%)
Total number of faults on the systems of freight cargo.	13 157

By testing and checking all the controlled systems of freight vehicles, 46% of vehicles had a fault on one of the systems. As already known as the cause of a traffic accident there can be some of the faults in the system of active safety of the vehicle, that is, the failure of the system itself. The active safety systems that were controlled through regular, preventive and extraordinary technical inspections had errors, malfunctions on 40% of the freight vehicles. Out of the total number of errors, i.e. 13 157, there were 4 934 or 37.5% errors on the braking system. On the management system, 750 or 5.5% errors were recorded. Lighting devices numbered 3 567 errors or 27.1% of the total number of errors. Devices that allow normal visibility had 585 errors or 4.4%. Elements of hangers, shafts and wheels comprise 1 625 or 12.3% errors.

Table 2 shows a fault/error pattern on the equipment and devices of active traffic safety systems.

Table 2. Errors of active traffic safety systems in 2014

Subject of technical testing	Number of errors	%
Braking system	4 934	37.5
Management system	750	5.5
Lighting and light signalling devices	3 567	27.1
Devices that allow normal visibility	585	4.4
Elements of hangers, shafts, wheels	1 625	12.3
IN TOTAL	11 461	86.8

The active safety systems number 86.8% of errors, and 13.2% or 1 714 errors some of the passive safety systems of other devices that are checked through verification, preventive inspection and verification of technical safety of freight vehicles of the N1, N2 and N3 categories.

During the inspections of the technical safety of cargo vehicles, which were performed in verification, preventive control and verification in 2015, the number of errors on 17 checked systems, their subsystems and other devices recorded 18 529 errors.

In Table 3, the results of technical vehicle safety in 2015 are presented.

Table 3. Control of technical vehicle safety in 2015

Control of technical safety of freight vehicles in 2015 (verification, preventive inspection and technical safety control)	
Number of registered vehicles in RS for 2015	335 775 (100%)
Number of freight vehicles in 2015	29 365 (8.7%)
Total number of errors in systems of freight vehicles	18 529

By testing and checking all the controlled systems of freight vehicles, a percentage error was found, of which 63% of the vehicles had a fault on one of the systems. Active safety systems make 54% of the vehicles involved in errors. Out of the 18 529 total errors, 6 235 or 33.6% were recorded in the braking system. There were 1 054 errors or 5.6% on the control system. Lighting devices had 5 519 errors or 29.7%. Devices that allow normal visibility had 880 errors or 4.7% and elements of hangers, shafts and wheels 2 328 or 12.5%.

Table 4 shows a fault/error pattern on the equipment and devices of active safety systems for 2015.

Table 4. Errors of active safety systems in 2015

Subject of technical testing	Number of errors	%
Braking system	6 235	33.6
Management system	1 054	5.6
Lighting and light signalling devices	5 519	29.7
Devices that allow normal visibility	880	4.7
Elements of hangers, shafts, wheels	2 328	12.5
IN TOTAL	16 016	86.1

Active safety systems had 86.1% of errors, and 13.9% or 2 513 errors were on some of the systems of passive safety and other devices that are checked through the control of technical safety.

In the previous year, i.e. in 2016, 17 778 errors were detected on the systems that were inspected as a part of the technical inspection of freight vehicles.

In Table 5, the results of technical vehicle safety in 2016 are presented.

Table 5. Control of technical vehicle safety in 2016

Control of technical safety of freight vehicles in 2016 (verification, preventive inspection and technical safety control)	
Number of registered vehicles in RS for 2016	351 754 (100%)
Number of freight vehicles in 2016	31 240 (8.8%)
Total number of errors in systems of freight vehicles	17 778

Observing the number of registered vehicles in 2016, the number of errors in verification, preventive control and verification of technical safety of freight vehicles is 57% for vehicles N1, N2 and N3. Active safety systems have participated with 48% in the faults of the vehicles examined. The braking system involved 6 101 errors or 34.3%, while the management system participated with 918 errors or 1.7%. Lighting and light signalling devices had 5 235 errors, i.e. 29.4%. Devices that provide normal visibility and elements of hangers, shafts and wheels had 868 errors or 4.8%, i.e. 2 119 errors or 11.9%.

Table 6 shows a fault/error pattern on the equipment and devices of active traffic safety systems in 2016.

Table 6. Errors of active safety systems in 2016

Subject of technical testing	Number of errors	%
Braking system	6 101	34.3
Management system	918	1.7
Lighting and light signalling devices	5 235	29.4
Devices that allow normal visibility	868	4.8
Elements of hangers, shafts, wheels	2 119	11.9
IN TOTAL	13 122	82.1

The active safety systems make 82.1% of the errors of the total errors of all systems and devices on the vehicle, which further implies that the passive safety system and other in-vehicle devices had their share with 17.9% of errors.

CONSEQUENCES OF TRAFFIC ACCIDENTS OF FREIGHT VEHICLES

As it is known, a person, a vehicle, the road and the environment can be the cause of a traffic accident. The errors of some of the active systems can lead to the occurrence of a traffic accident. Here we will integrate traffic accidents where one of the participants was a freight vehicle category N1, N2 and N3.

In the period January 1st - December 31st 2015, totally 15 760 vehicles participated in 8 581 traffic accidents on the roads of the Republic of Srpska, of which 1 623 heavy motor vehicles with material damage, minor and serious bodily injuries and dead persons.Freight vehicles accounted for 18.9% of the total number of traffic accidents in 2014. Out of the total number of vehicles that participated in traffic accidents, the freight vehicles made 10.29%.

The consequences of traffic accidents involving freight vehicles are known as follows:

- 1 364 traffic accidents with material damage
- 175 traffic accidents with minor injuries
- 62 traffic accidents with serious body injuries
- 22 people lost their lives in a traffic accident

Out of the 131 persons who lost their lives in traffic accidents on roads in the Republic of Srpska in 2014, 22 persons were in traffic accidents with a freight vehicle, or 16.7%

In 2015, there were 9 300 traffic accidents, which involved in total 17 219 vehicles, out of which 1 640 belonged to the N1, N2 and N3 category. Freight vehicles participated in 17.6% of traffic accidents, and 9.52% of participants in traffic accidents from the total number of vehicles were freight vehicles. The consequences of traffic accidents involving cargo vehicles are as follows:

- 1 340 traffic accidents with material damage
- 194 traffic accidents with minor injuries
- 81 traffic accidents with serious body injuries
- 25 people lost their lives in a traffic accident

The number of people killed in traffic accidents for 2015 amounted to 150 people, of which 25 persons were killed in accidents involving one of the participants a freight vehicle, which makes 16.6%, speaking in percentage.

The figures show that in the period January 1st – December 31st 2016, there was total of 9 783 of traffic accidents involving 18 419 vehicles, out of which 1 877 were freight motor vehicles. Cargo vehicles participated with 19.1% in traffic accidents, and there was 10.1% of freight vehicles involved in traffic accidents compared to the total number of vehicles that participated in it. The consequences of traffic accidents in the past year are as follows:

- 1 562 traffic accidents with material damage
- 208 traffic accidents with minor injuries
- 83 traffic accidents with serious body injuries
- 24 people lost their lives in a traffic accident

The number of people killed in traffic accidents for 2016 is 130 persons, out of which 24 persons lost their lives in traffic accidents where the participant was a freight vehicle, i.e. 18.46%

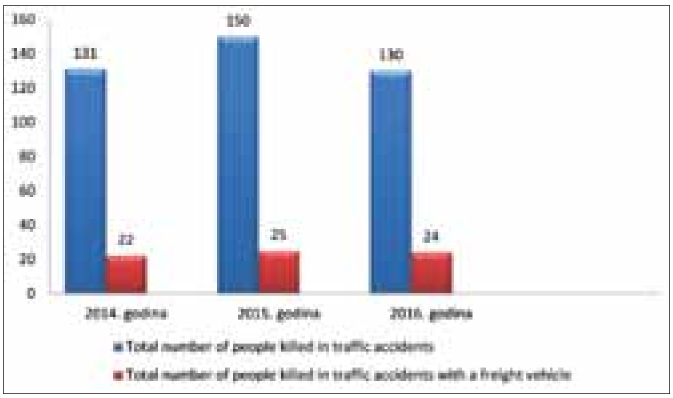

Chart 1. Number of dead persons

The diagram shows the number of persons killed in traffic accidents over the past three years, and particularly integrated is the number of persons who died in accidents with freight vehicles.

In order to assess and determine the safety or non-safety of this group of vehicles participating in traffic on the roads of the Republic of Srpska, it is necessary to determine the traffic risk for the period of the last three years. Traffic risk represents the annual number of people killed in traffic accidents per 10 000 registered vehicles.

Firstly, the traffic risk for the total number of persons killed in traffic accidents in relation to the total number of all registered vehicles in the Republic of Srpska for the specified period was calculated, and then the traffic risk of freight vehicles.

Total traffic risk for 2014 amounts to 4.03, i.e. on 10 000 registered vehicles there were 4.2 persons dead. This means that the traffic risk for freight vehicles is 7.77, i.e. the number of 7.77 persons died on 10 000 registered cargo vehicles.

In 2015, traffic risk was 4.2 and for freight vehicles 8.51. For 2016, traffic risk amounted to 3.69 people per 10 000 registered vehicles. Watching only cargo vehicles, the traffic risk is 7.6.

$$Tr = \frac{Number\ of\ dead\ in\ traffic\ accidents \cdot 10\ 000}{Number\ of\ registered\ vehicles} \quad (1)$$

$$Tr\ freight\ vehicles = \frac{Number\ of\ dead\ in\ traffic\ accidents\ of\ freight\ vehicles \cdot 10\ 000}{Number\ of\ registered\ freight\ vehicles} \quad (2)$$

RESULTS DISCUSSION

By data processing and analysis, an image of the security aspects of freight traffic was created. If only the final results of this survey were observed, this picture of the security aspects of the freight vehicles would not fully describe the real situation. So, through the discussion of the results, the parameters that represent the real state should be considered. If we look at the technical safety of the cargo vehicles, and for this paper, we are particularly aware of the mistakes in the active vehicle safety systems, in 2014, 40% of freight vehicles reported a fault in the active safety system. In 2015, the faults of active systems of trucks were on 54% of vehicles, and in 2016 it was 48%. If we consider also the fact that several faults have occurred on one vehicle on some of the active safety systems, then there is a significantly lower percentage of freight vehicles errors, and consequently a more favourable picture and assessment of the safety aspects of freight traffic in the Republic of Srpska, which is the real situation.

The results show that 16.7% of people were killed in road accidents out of the total number of those killed in 2014. In 2015, the results show that 16.6% of dead people lost their lives just in traffic accidents with freight vehicles. This result for 2016 is 18.4%. According to the number of people killed in traffic accidents, freight traffic is in an unsettled position in relation to bus traffic, and in a better position than the traffic of passenger cars. By obtaining the ultimate results, it can be seen that freight traffic is a medium-sized traffic, where much effort must be made, and it will create methods that will lead to a downward trend in the number of deaths, but also participation in traffic accidents. Regarding the traffic risk of freight vehicles, the obtained results indicate that the largest number of persons is hit by 10 000 registered freight vehicles, and that it is far ahead of other types of traffic.

CONCLUSION

By observing the results, and in particular the number of dead persons in traffic accidents with freight vehicles, it can be concluded that there is no trend of decline in the number of killed in the very incidents. Traffic is a multi-sectorial science, and therefore, in order to solve this problem, and to create a model of solving known facts, it is necessary to include several scientific spheres and that through various case studies, a way to improve the current state and its applications is found. As far as technical safety of the vehicles, Bosnia and Herzegovina/the Republic of Srpska are among the underdeveloped countries in Europe, so the average age of vehicles itself is much higher than in developed countries and members of the European Union. Most freight vehicles used for local and regional transport are older and are in poor technical condition, while vehicles used in international transport meet the prescribed provisions by the European Union for transport within its borders.

So the example of the European Union should be followed, the level of safety of freight traffic in the Republic of Srpska increased by regulations and laws, where, through constant control by supervisory authorities, and by putting accent on this group of vehicles through various campaigns, the developed countries should be approached. Thus, the underdevelopment and poor performance of the supervisory authorities have also transmitted into the technical correctness of freight motor vehicles, where a large number of errors have been identified during the technical inspections. As already stated, this phenomenon is of multi-sectorial character and further research must determine the method of solution which is to be implemented in all spheres. The causes that lead to this state of traffic safety may be of a different nature and are reflected in the lack of certain finances, poor control of the business operations of the companies and their attitude towards employed drivers, etc., where, with the constant education of drivers and increased control of all relevant institutions of the system, this kind of transport is made safer.

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PROFESSIONAL PAPER

Passive Road Safety Systems – Case Study of Road Section Prnjavor- Doboj (M16.1, R474, R474a)

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Abstract: The European Parliament and the European Council have adopted the Directive 2008/96/EC relating to the safety of traffic infrastructure. This Directive binds the EU Member States to implement the guidelines on roads comprising the parts of the Trans-European traffic network, regardless of the stage those roads are in. EU Member States have a possibility to adopt the guidelines and regulations from the Directive and build them into the national regulations on parts of the roads that are not a part of the Trans-European roads. Based on the facts stated above, there is a research problem in a form of a question “Can the Directive 2008/96/EC be applied in the traffic in Bosnia and Herzegovina?” i.e. are its guidelines implemented as a manner of approximation with the EU regulations, and what are the effects of its implementation. This is a traffic problem in its nature, closely related to road traffic safety, and we find the answer to the research problem in theoretical and empirical research in this area.

Keywords: inspection, road, traffic safety.

INTRODUCTION

In the world, 1.3 million people per year die in traffic accidents, and more than 50 million people remain permanently immobile or suffer injuries. This statistics of Bosnia and Herzegovina shows that it contributes with at least 400 dead and 11,000 injured persons per year. The traffic death rate in BiH is three times higher than in Western European countries, according to official statistics over 10 people have been killed per 100.000 inhabitants. This difference can be even bigger if you take into account accidents that have not been recorded. The actual number of people killed in traffic accidents in the Republic of Srpska is higher than the registered number in the official statistical data. In modern conditions, the country’s traffic infrastructure has an extremely high significance, since it connects with other countries. However, the key problem that arises in the mentioned segment is the safety of the participants in the traffic. Bearing in mind that significant investments are made in transport innovations and the improvement of means of transport, which now have significant opportunities and acceleration, there are often traffic accidents with certain consequences for the participants in the traffic. Since the consequences are often devastating, with a fatal outcome or with serious injuries involving a degree of disability, it is necessary to draw attention and continuously work on the prevention of traffic accidents in the form of implementing measures to increase traffic safety.

On the basis of the above, the European Parliament and the European Council have adopted the Directive 2008/96 / EC concerning the safety of transport infrastructure. This Directive obliges Member States of the European Union to apply guidelines on the roads that form parts of the trans-European transport network, regardless of the stage in which the roads are located. Also, EU Member States have the possibility of adopting guidelines and regulations from the directive and as national regulations on parts of roads that are not part of the trans-European road segment, but parts of the roads are either fully funded by the European Union and its funds. In this regard, the EU Member States have an obligation to respond to the type requirements, whether the Directive 2008/96 / EC is applicable to roads in BiH, or whether its guidelines are applied or whether the regulations in this area are adapted to the regulations of the European Union, and what are the effects of its application. The problem is closely related to the traffic safety segment in road traffic, and the answer to the problem of research is found in the theoretical and empirical research in this segment.

DIRECTIVE 2008/96/ EC

Directive 2008/96 / EC is a Directive of the European Parliament and of the European Council [2] of 2008 on the safety of transport infrastructure. The Directive applies to the roads that form part of the trans-European transport network, regardless of whether the roads are in the design stage, whether they are under construction or are already in use. The Directive does not apply to tunnels, bearing in mind that they are covered by Directive 2004/54 / EC

In accordance with Directive 2008/96 / EC, EU members are obliged to implement procedures relating to:

- Giving assessment of the impact of certain elements on traffic safety,
- Audit of traffic speed,
- Management of safety aspects on the transport network, as well
- Continuity of safety on the roads.

EU Member States have the option of applying this Directive, as part of their national regulations, or for state transport infrastructure, which does not apply to trans-European transport networks. When carrying out appropriate works, Member States of the European Union must provide appropriate traffic signs in order to respond in a timely manner to the participants in the traffic. These signs must be visible both day and night, and they must be placed at the appropriate distance prescribed by the Vienna Convention on Traffic Signs and Signaling, signed in 1968. Member States should ensure that road users are adequately informed of stocks with a high number of traffic accidents.

In the segment of traffic safety control, Member States must:

- Ensure that safety checks are carried out on existing roads in order to determine the safety features of the roads and reduce the number of traffic accidents,
- Include occasional traffic network controls and analysis of the potential impact of traffic safety on traffic safety,
- Ensure that such occasional controls are carried out by the competent institution, at such time intervals to ensure the optimal level of safety on the transport infrastructure,
- Adopt guidelines on temporary safety measures in relation to road works, which must not be at the expense of the directive's directives,
- Conduct an appropriate control program to ensure the correct application of these guidelines.

Within the competent institutions, it is necessary to establish a regular compilation of reports on traffic accidents with fatal outcomes. Each country for its territory should calculate the average social cost of a fatal accident and the average social cost of an accident with severe consequences. There is also the possibility of further elaboration of these costs according to country initiatives independently, and they must be updated at least every five years. As of 19 December 2011, Member States were obliged [2] to adopt a training program for auditors for road safety, if such program has not already been adopted. States that use the services of auditors for traffic safety must provide initial auditor training, which includes issuing an adequate certificate of competence, and occasionally organize additional training courses for these auditors. Traffic safety auditors must also have a certificate of competence. Only acknowledgments received prior to the entry into force of this Directive shall be recognized.

Setting up an auditor [7,8] must take place according to the following conditions:

- The auditors should have the appropriate experience or qualification in designing roads, in the area of traffic safety, and in carrying out analyzes of traffic accidents,
- For the purpose of efficiency of the audit of the infrastructure project, the auditor should not be involved in the design or management of the infrastructure project during the audit period.

In order to provide additional security on roads within the European Union that are not included in the trans-European transport network, an adequate system for the exchange of positive experiences between member states should be developed, including, inter alia, existing projects to improve safety on infrastructure projects and proven technologies for improving traffic safety. Member States were required to adopt laws, administrative acts and regulations necessary to comply with this Directive by 19 December 2010. They were also required to provide the Commission with the text of those acts. Member States of the European Union are obliged to provide the text of the basic legal provisions to the Commission which they adopt in the field covered by this Directive.

The Republic of Srpska is the only institution in Bosnia and Herzegovina that fully implemented the Directive 2008/96 / EC with regard to the adoption of regulations and the implementation thereof.

CASE STUDY (PRNJAVOR- DOBOJ)

The analysis of passive road safety is presented in this case study according to the impact of roadside objects on road safety along the road section Prnjavor-Doboj. In February 2017, the entire research-relevant stock was recorded with a camera placed in a cockpit of a passenger car. Analyzing the snapshots, additional field research was not necessary, given that the output information from the camera, or video recording, was of very good quality and could fully represent the real state of the road. Considering that the observed section contains two categories of road in its route, main and regional roads, passing through inhabited and uninhabited places, the number of observed roadside objects was generally quite large. Such result, looking at the state of the road and the environment, was not surprising.

The roadside object impact factor for the consequences of a traffic accident was somehow always viewed as a secondary and not so important thing. But the fact is that an adequately set front rebound fence or an adequately protected concrete pole can significantly reduce the consequences for the persons and the vehicle involved in an accident, changes significantly the thinking about this topic. One of the aims of this case study is to precisely prove this claim and that the vision of the competent authorities for the safety of traffic in the Republic of Srpska have to be enlightened to the extent that investing in the safety of transport is not a cost but a profit.

Why profit?

Well, if we look at the annual cost of traffic accidents [9], we will come to a simple conclusion that investments in adequate equipment for the protection of roadside disturbances are far less than the total cost of traffic accidents. Adequately protected side disturbances reduce the consequences of traffic accidents and reduce costs in an analogous way, thus releasing budget funds for investments in other projects. The cost of a traffic accident only with pecuniary damage, based on the "readiness to pay" calculation process, which represents the minimum economic loss, is 3.258 convertible marks (hereinafter KM). If we compare this amount with the cost of a traffic accident with severely injured or dead persons we will have 66.683KM or 620.618KM. We can conclude that the difference between economic losses is enormous depending on the severity of the traffic accident. Therefore, if the consequences of traffic accidents are reduced to a greater extent, the costs of this will decrease.

So if the consequences of traffic accidents are reduced to a greater extent, the costs will also be reduced in analogy.

In Table 1. The categories of observed road shares are displayed.

Table 1. View of the observed section from the aspect category of the road

Banja Luka – Klašnice	Road reserved for traffic of motor vehicles (M16)
Klašnice – Prnjavor	Main road (M16.1)
Gornja Vijaka – Razboj	Regional road (R474)
Razboj – Rudanka	Regional road (R474a)

Identification of Sides

The identification of roadside disturbances was done by a detailed overview of the video material [1]. For the position of each significant point, that is, the lateral disturbance, the marking [6] of its place was used by hour, minute, and second on the record. Each category of road was predominantly dominated by one category of roadside disturbances with a smaller share of others.

Side disturbances are categorized [3] on the basis of common features:

- Concrete and iron poles of electricity distribution and public lighting;
- Open beginnings of the frontal rebound barriers;
- Approaches and fences on the bridges;
- Unprotected approaches to the petrol stations;

Concrete and iron poles of power distribution and public lighting pose a problem to the greatest extent on the main road M16.1 and the regional roads R474 and R474a. The present poles, in most cases, are located in the immediate vicinity of road, where they pose a serious threat [7,6] to road users if a wandering vehicle hits one of them.

Figure 1 shows the percentage of impact in the lateral disturbance, depending on its distance from the edge of the driveway.

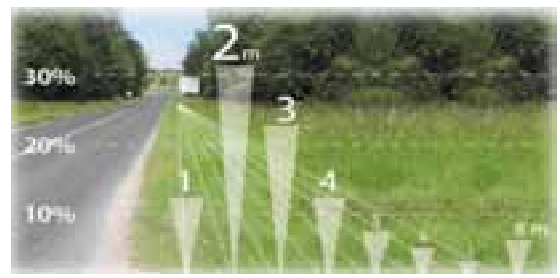

Figure 1. Percentage of impact rate in lateral disturbance

Observing the our case, especially on the main road M16.1 Klašnice – Prnjavor and road R474 Gornja Vijaka-Razboj, the distance of roadside disturbances is roughly 2m from the edge of the driveway. In some segments of this road, the poles are located at a great distance, somewhere even on a smaller one. The point is that these poles are not adequately protected in any way and pose a direct danger to traffic participants in case a wandering vehicle hits some of them.

Figure 2 shows an example of inadequately shielded poles of power distribution and public lighting from a real life situation.

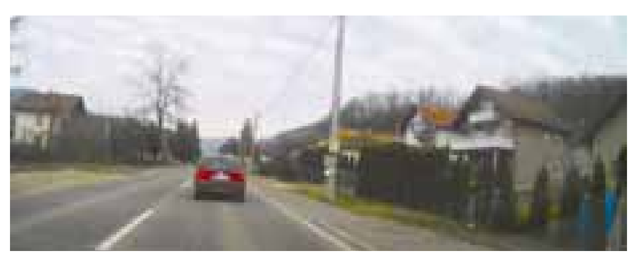

Figure 2. Inadequately protected pillars of electricity distribution and public lighting

For such segments of the road, it is necessary to protect the lateral disturbance, that is, the columns, the setting of the reflecting fences, so that the columns are not in the working width of the same fence or completely replace the existing poles with passive safety poles where possible.

The frontal open beginnings of rebound fences pose a major problem in the entire observed section. The beginnings and endings of the rebound fences are in most cases open, which poses a great danger for the passengers in case the vehicle impacts the fence.

The example from Figure 3. shows the open start of the rebound fence on the road section Gornja Vijaka-Razboj (R474).

Figure 3. The open end of the front reflecting fence

The open start of the front reflecting fence acts as a kind of blade during the vehicle's encounter, so the opposite effect of the reflecting fence is obtained here. Instead of turning the wandering vehicle that encounters at the beginning of a frontal reflecting fence from it and returning it on a cart track or, in the other case, safely stopping the fence length, it will in this case leak directly on a metal structure that at that speed encounters becomes "cutting edge" that breaks through the chassis vehicles. Apart from the bad condition of the reflecting fences in some places, they are not placed at the appropriate height and are not connected in an adequate way with the attachments of other fences. Insufficient maintenance of the infrastructure and poor remediation after traffic accidents has led to the loss offunctional aspect over time and now have almost no impact on reducing the consequences of a traffic accident, on the contrary they can act the opposite and increase the consequences for the passengers in the vehicle and for the vehicle itself.

Approaches and fences on bridges are critical points on the observed section. There are openings between the guardrails of the fences on the bridges themselves and the frontal reflecting fences.

Figure 4 shows the openings between the protective fence and the open end of the front reflecting fence.

Figure 4. The open end of the front reflecting fence

The gap that exists between the protective fence and the open end of the front fence is a problem of traffic safety [3] in the event of a vehicle in the area just in that zone. Additionally, the fence on the bridge is set up to protect pedestrians and vehicles from possible drops, but the question arises as to how it will behave when a vehicle is on the move on it, as it has not been tested in any way prior to its implementation.

Figure 5 shows a bridge on which a reflective fence is missing before it is often the case on the observed section of the road.

Figure 5. The lack of a protective fence on the bridge

Unprotected petrol stations on the observed section of the road are located in areas where the speed limit is 50km / h. The curbs placed at the access road do not represent any kind of protection against collision and can not prevent the vehicle from passing. An advertisement with fuel prices is placed very close to the edge of the carriageway, with its foundation of concrete structure, which in most cases expands so it poses additional danger. Also, the iron pillars of lighting are also in the immediate vicinity of advertising structures.

Figure 6 shows the unprotected construction of the gas station.

Figure 6. Unprotected steel structure of the gas station

Analysis of Safety Risks

The observed sections of the main road M16.1 and the regional roads R474 and R474a contain a mixed function of local and remote traffic, which indicates different speeds of allowed movement. Pedestrians and bikers also use the route, but are present mostly in liner settlements and villages than in rural areas. Tractors and other transport vehicles used by farmers are most often present in rural areas. The presence of connecting roads, without traffic signalization and without asphalt cover, from various private estates is quite large. Mixed road users with varying speed and safety requirements make these three high-risk road sections at risk from an accident.

Identified safety risks for the observed road sections:

- Function and the road environment
  - Along the observed sections there are connecting roads without traffic signalization and without built-in asphalt cover,
  - The signs of speed limits on certain parts of the road are not placed in the appropriate places, thus provoking drivers not to comply with the limit.
- Cross section
  - Road is divided by a central line, and there are also edge lines that are in poor condition (damaged and with poor reflection);
  - The edges of the carriageway are damaged, the banks are not in the same level with the cart track an they do not have enough width,
  - Ruts made of car tires are visible, which prevents drainage from the carriageway. This factor will cause aqua planning at a time when it rains,
  - The pavement surface is smooth and slippery with a small coefficient of adhesion especially in rainy conditions,
  - There are no crosswalks of the carriageway in some segments, which prevents drainage and where they are not properly directed.
- Passive safety features
  - The raised pavements, where they are present, are present on both sides of the bridges. Raised both by road and by the banks,
  - Unprotected drains, power poles and public lighting,
  - Lack of protective fences in most of the curves,
  - Existing frontal rebound barriers are not long enough and do not have safe ends and beginnings.

After the identification of lateral disturbances and security risk analysis on the observed sections of the road, in line with the guidelines of EU Directive 2008/96 / EC it is necessary to find solutions for improving the protection of lateral disturbances.

Improvements will be divided into three groups:

- Short-term improvement measures,
- Medium-term measures of improvement,
- Long-term improvement measures.

Short-term improvement measures are a type of solution that can be implemented in a short period of time. It is especially important to have stable goals and ideas regarding short-term measures for further implementation of medium and long-term measures.

As short-term measures within this report, the following recommendations are given:

- Replacement of concrete and iron pillars with passive safety pillars,
- Where replacement of existing pillars is not possible, it is necessary to protect pillars with appropriate impact buffers especially for zones 50km / h and zones over 70km / h;
- Rehabilitation of frontal reflecting fences with a special emphasis on the proper performance of the beginnings and endings that are the biggest problem,
- Installation of reflective fences before and after the bridge and removing the existing voids between the end of the reflecting fence and the beginning of the protective fence on the bridges.

Passive safety poles must comply with EN 12767.

EN 12767 differs in terms of energy absorption [3] in vehicle impact, through three column categories:

- HE - high energy absorption,
- LE - low absorption,
- NO - without energy absorption.

Areas of use of these pillars are very wide and can easily be applied to solve the observed problems in this case study.

Pillars must be passively safe:

- On all roads outside the settlement, where the speed is higher than 50 km / h and where the pillars are not protected by a reflective fence,
- On all roads, where the speed is less than 50 km / h and the pillars are far away from the running surface of less than 4 m and are not protected by a reflective fence,
- Whenever the pillar is behind the reflecting fence, it is in the area of its working width.

Figure 7 shows an example of the behavior of a passive safety pillar.

Figure 7. An example of the behavior of a pillar when a vehicle hits

In case the replacement of the existing pillar with a passive safety pillar is not possible, there is another method of protection against impact and impact of the vehicle on the same. SMA Tree Moisture Shock [3] is the best solution for this. Originally designed to protect the trees from possible vehicle accidents, it can be applied with the same analogy for pillars as well.

Figure 8 shows a shock absorber.

Figure 8. Smash hitter

Figure 9 shows the technical characteristics of the SMA Tree [3] shock absorber.

Figure 9. Dimensions SMA Tree (mm)

The SMA Tree system is 80% re-usable after the impact of the vehicle. The absorbent cells after the impact of the vehicle can be replaced and the shock absorber can again perform its function.

Correct execution of the beginnings and endings of the frontal fence rails and the rehabilitation of swinging is a serious procedure that will eliminate the security threat if there is a ride on some of them. Many fences have not been repaired after the impact of the vehicle and can not perform their function in the right way.

A possible solution to the problem in this case is:

- Repair or replacement of reflective fences that have been damaged during the vehicle's collision,
- The beginnings and ends of the front fenders must be carried out in the right way so that they do not have a sharp start and end that can break the front of the vehicle, the beginning must not be such a form to catapult the vehicle into the air when it comes to flight.

Medium-term improvement measures involve the removal of a large number of unshielded connecting lines on sections M16.1, R474 and R474a and the creation of a pair of collection paths by segments.

Long-term improvement measures involve the permanent removal of lateral disturbances where possible.

CONCLUSION

When making this case study, passing through and analyzing the observed shares through the lens of the camcorder, things that are not satisfactory from the aspect of traffic safety or the impact of lateral disturbances on the safety of the road have too many. When we look at the amount of vehicles that are driving the observed section of the road, things look very worrying if the landing vehicle arrives. For years, the road equipment was not working, the protection of lateral disturbances almost did not exist or was minimal. The pavement blind additionally increases the risk of landing because it is in decadent state, especially at a time of rainy weather and snow. The percentage of heavy goods vehicles in the traffic flow is high, especially at the time when this case study was conducted due to the construction of the Doboj-Banja Luka highway section.

Over the years, a lot of human lives have been taken on these road segments from Banja Luka through Prnjavor to Doboj, and they have brought a lot of budget costs. Adequately protected lateral disturbances can significantly reduce the consequences of a traffic accident and, in the same way, its costs. Of course, this is only the first phase in which the main goal is to mitigate the possible consequences of road accidents such as landing. Over a long period of time, equipment that protects lateral disturbances that cannot be removed should be maintained regularly and other disturbances should be permanently removed. To this end, especially on the main and regional roads M16.1 and R474, R474a it is necessary to carry out the re-arrangement of the connecting rural roads, which should be classified into smaller collection paths that will be correctly signaled by vertical and horizontal signaling.

One of the aims of this paper is to show how much the observed sections of the road are dangerous and do not forgive even the minimal mistake of the participants in the traffic. This situation should be the opposite; it is necessary to create an ambient of the path that falsifies mistakes [2], which will not lead the participants to a dangerous or fatal situation, even in case they exceed the allowed speed of movement.

Investments in traffic safety should not be considered a cost [5], but vice versa. It is a gain in terms of saving lives and avoiding serious bodily injuries (analysis: costs / benefits). The arrangement of connecting rural roads would be beneficial, which should be classified into smaller collection paths that are correctly signaled by vertical and horizontal signaling.

One of the essences and tasks of this paper is to show how much the observed sections of the road are dangerous and do not forgive even the minimal mistake of traffic participants. This situation should be the opposite, it is necessary to create an ambient of the path that fills the mistakes, which will not bring the participants into a dangerous or fatal situation, and if they exceed the allowed speed of movement. Therefore, investments in traffic safety should not be considered a cost, but vice versa. It is a gain in terms of saving lives and avoiding serious bodily injuries.

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TRANSPORTATION RESEARCH BOARD 97th ANNUAL MEETING WAS HELD IN WASHINGTON, D.C.

The Transportation Research Board (TRB) 97th Annual Meeting was held January 7–11, 2018, at the Walter E. Washington Convention Center, in Washington, D.C. This is the largest international conference in the world in the field of traffic and transport, which has been held since 1921, every year in month of January. This year, the information-packed program, attracted more than 12,000 transportation professionals from around the world. The meeting program covered all transportation modes, with about 4,500 presentations in nearly 800 sessions and workshops, addressing topics of interest to policy makers, administrators, practitioners, researchers, and representatives of government, industry, and academic institutions. A number of sessions and workshops has focused on the spotlight theme for the 2018 meeting: ***Transportation: Moving the Economy of the Future***

More information about this conference can be found at **www.trb.org/AnnualMeeting**

Photos from the Annual TRB Conference, Washington, D.C.

ODRŽANA 97. KONFERENCIJA ODBORA ZA SAOBRAĆAJNO-TRANSPORTNA ISTRAŽIVANJA

Devedeset sedma godišnja konferencija Odbora za saobraćajno-transportna istraživanje (TRB) održana je od 7. do 11. januara 2018. godine u Walter E. Washington Convention Centru u Vašingtonu, D.C., SAD. Ovo je najveća međunarodna konferencija u svijetu u oblasti saobraćaja i transporta koja se od 1921 godine održava u mjesecu januaru svake godine. Ovogodišnji, informativno prepun program, je privukao više od 12.000 stručnjaka iz oblasti saobraćaja i transporta iz cijelog svijeta. Program konferencije obuhvatio je sve vidove transporta, sa oko 4,500 prezentacija na skoro 800 sesija i radionica, obrađujući teme od interesa za kreiranje politike, administratore, praktičare, istraživače i predstavnike vlasti, industrije i akademskih institucija. Brojne sesije i radionice su se fokusirale na glavnu temu konferencije za ovu, 2018. godinu: ***Transport: Pokretanje ekonomije budućnosti***

Više informacija o ovoj konferenciji može se naći na **www.trb.org/AnnualMeeting**

Prof. dr. sc Mirsad Kulović

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TTTP provides conditions and positive environment for the new idea promotion, exchange research results and achievements accomplished by the scientific community from academia and transportation industry.

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The length of each paper, including the abstract and references may not exceed **7,500 words**; that is, a paper that is only text should contain no more than 7,500 words. Each figure, photograph, or table accompanying the text counts as 250 words. For example, if two figures and three tables are submitted, the text may be no more than 6,250 words.

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Following the abstract, about 3 to 5 **key words** that will provide indexing references to should be listed.

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For peer review of Papers, submit the manuscript in a single electronic file organized in the following sequence:

- Title page, including submission date, word count, and author names, affiliations, addresses, phone numbers, fax numbers, and e-mails (please indicate corresponding author);
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Table Titles and *Figure* Captions

TABLE 5 Effects of All Factors

(Insert title above the table; "Table" is all capitals; title is initial capitals; all type is boldface; extra space but no punctuation after number; no punctuation at end of title.)

FIGURE 3 Example of results.

(Insert caption below the figure; "Figure" is all capitals; caption is sentence case; all type is boldface; extra space but no punctuation after number; period at end of caption.)

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The **Introduction** should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of disciplines.

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Journal article [1]

[1] Zahavi Y. and Ryan, M. James. Stability of Travel Components Over Time. *Transportation Research Record*, 750 (1980), 70-75.

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Article in a Periodical [3]

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Acknowledgments

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