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- Promote and exchange information and knowledge in the transportation research arena and its application
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EDITOR'S WORD

Dear readers and associates,

It is my pleasure to announce the eight issue of the Traffic and Transport Theory and Practice – TTTP magazine, which is no available in both electronic and printed version. For the second year in the row, the magazine is being published with two editions, which is expected from serious scientific magazines. This eight issue has eights titles that have passed through double review with the highest level of anonymity between the author and the reviewer. Without reviewers there are no scientific magazines. We are well aware of that and therefore we chose those with representative papers from the scope of the paper being reviewed. Members of the editorial board are excluded from the paper review process. Aware that good and timely review process contributes to the quality of the magazine. Dedicated to intensive increase in the quality and ratings of the magazine, the publisher particularly stimulates the reviewers, paying them feed for each individual review.

The interest for cooperation by potential authors is growing, which enables us to increase the level of quality of published papers. As before, the magazine is open to cooperation by publishing your scientific, expert and research papers in the "Traffic and transport Theory and Practice – TTTP" Magazine.

On behalf of the editorial staff and in my own name, I thank you for your cooperation.

Editor-in-Chief
Prof. Danislav Drašković, PhD

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ORIGINAL SCIENTIFIC PAPER

TTW (Tank to Wheel) and WTW (Well to Wheel) Analysis Using Electric Buses on the Line Eko 1 in Belgrade

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Abstract: The bus subsystem is the holder of the public transport function in many cities with a dominant representation of diesel-powered buses. In the last few years, electric buses (E-bus) have been increasingly used in many cities around the world (China, Europe, South America), making them the main alternative to conventional buses (diesel, CNG). The main advantages of using electric buses compared to conventional buses are higher energy efficiency, zero pollution emitted at the local level, more favorable carbon dioxide emissions observed at the regional or national level depending on the method of obtaining electricity, lower noise level. Since 2016, five electric buses have been operating in Belgrade on the EKO 1 line (Vukov spmenik-Belvil). The paper will present the environmental benefits of the use of electric buses observed through TTW (Tank to Wheel) and WTW (Well to Wheel) analysis, compared to diesel and CNG buses.

Keywords: E-bus, TTW (Tank to Wheel) and WTW (Well to Wheel) analysis.

INTRODUCTION

The transport sector has an important role in meeting the needs of society in the transport of passengers and goods and is a significant generator of greenhouse gas emissions and carbon dioxide as the major cause of the environmental damage. Emissions from the road vehicle (passenger cars, busses, coaches, trucks), the principal source of emitted hazardous substances in the urban environment [1]. The products of combustion in the vehicles equipped with an internal combustion engine, which exhaust system are discharged into the atmosphere, harmful substances comprise a plurality of which are usually: carbon monoxide (CO), unburned hydrocarbon radicals (CxHy), nitrogen oxide (NOx) and particulate matter with diameters: PM 2.5 PM5, PM10, sulfur compounds, aldehydes, benzene, etc.

In 2012 according to a report of the World Health Organization (WHO) announced that 3.7 million people worldwide die each year as a result of air pollution. According to the same report, more than 5600 people die prematurely in the Republic of Serbia as a result of air pollution [2,3].

Buses used in public city transport are mostly represented with diesel engines. Diesel engines emit large amounts of suspended particles and nitrogen oxides, especially during cold engine operation, at full load, and subsequent fuel injection into the engine. Numerous studies conducted worldwide have shown that the impact of suspended particles as a result of air pollution is directly related to the higher likelihood of lung cancer in humans [3,4] as well as the increased rate of morbidity and mortality due to cardiovascular and respiratory diseases [3,4,5].

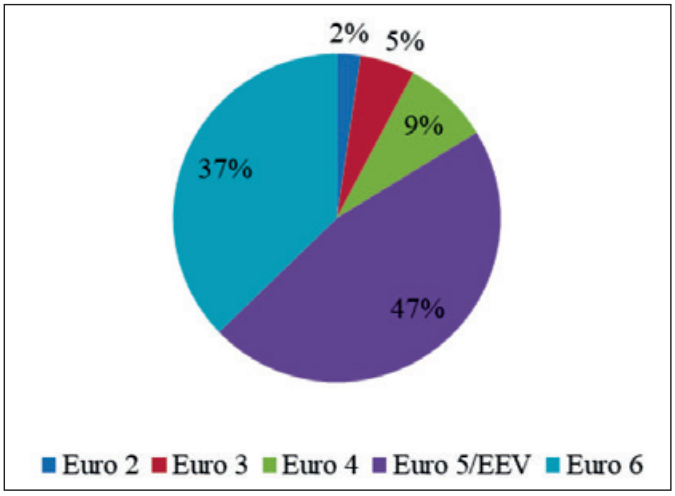

Figure 1. The structure of the bus fleet in JKP GSP Beograd (31/12/2020) [6]

In Belgrade the bus subsystem is the holder of the function of public transport. There are 1040 diesel buses in operation on week days. Buses of the largest carrier JKP GSP "Beograd" participate with 640 buses on week-

days and use about 31.29 million liters of Euro-diesel fuel for the realization of the planned annual transport work [6]. In the last 3 years, a significant modernization of the bus subsystem was performed with 244 new buses that meet the EURO 6 norm. Observed according to the emission norms (EURO), the structure of the bus fleet is shown in Figure 1.

The reduction of air pollution in Belgrade from the impact of traffic can be significantly improved by energy, environmental and technical-operational measures in the bus subsystem of public city transport, and as one of the most efficient ways is the substitution with electric buses. For these reasons, the bus subsystem of public urban passenger transport is gaining in importance as the main promoter of new technologies in the implementation of the city's sustainable development strategy.

EKO 1 (Vukov spomenik-Belvil) E-BUS LINE

In Belgrade the first line of public transport EKO 1 (Vukov spomenik-Belvil), where traffic only fully electric buses, put into operation on 1 September 2016. The introduction of five fully electric buses Higer KLQ-6125GEV3, in regular traffic is a significant development project of the expert team of JKP GSP "Belgrade" which is supported by the City of Belgrade and represents the beginning of using a new concept of environmentally and energy-efficient vehicles in public transport. passengers. City line EKO1 is a new line that is purposely designed and adapted for the operation of fully electric buses Higer KLQ6125GEV3, to maximize the energy and environmental benefits of E-buses in the central city area of Belgrade.

Line EKO 1 is a diametrical city line that connects the old part of Belgrade with New Belgrade, passing through the central city zone. The spatial position of the route of the EKO 1 line is shown in Figure 2.

Figure 2. Spatial position of the line EKO 1

The average length of the EKO 1 line is 7.995 m. Observed by directions, the length of the route in the direction "A" is 7.477 m, where there are 15 stations with an average inter-station distance of 534 m. In the direction "B", the length of the route is 8.513 m, where 17 stations are positioned with an average inter-station distance of 532 m [7].

The fully electric bus Higer KLQ6125GEV3 is a modern low-floor solo city bus that meets all technical requirements in accordance with European Commission Directive 2007/46 (Directive EC /2007/46) and Regulation 136/2014 (Regulation EU 136/2014) which refers to the fulfillment of technical conditions for buses for public urban passenger transport, including electric buses. The e-bus uses a supercapacitor to store electricity with a capacity of 20 kWh [8]. The E-bus charging system is with fast charging which is performed at the initial-final stops (terminals) where 150 kW chargers are installed.

Electric bus Higer KLQ6125GEV3 in the charging phase is shown in Figure 3. The basic technical characteristics are shown in Table 1.

Figure 3. E-bus Higer KLQ6125GEV3

Table 1. Technical characteristics E-bus

Type	Electric KLQ6125GEV3
Length/width/ height	12000/2550/3680 mm
Curb weight	12540 kg
Passengers	82+1
Max.speed	70 km/h
Charging time at the terminus	5-10 minutes
Supercapacitor	AOWEI 20 kWh
Traction motors	Siemens (x2) 1PV5135
Power	2x90 kW (peak) 2x67 kW (nominal)
Torque	2x430 Nm
Traction control	Siemens 10DT6

RESULTS OF TTW (TANK TO WHEEL) AND WTW (WELL TO WHEEL) ECOLOGICAL PERFORMANCES E-BUS COMPARED TO DIESEL AND CNG BUSES ON LINE EKO 1

Electric buses are classified in the category of zero-emission vehicles, since they use electricity for propulsion. In this sense, aspects of the environmental impact of the immediate environment can be analyzed, where vehicles are in operation (local level), which in the literature is called "tank to wheel", TTW (Tank to Wheel) and en-

vironmental impact on the wider environment that is a region or country known as a ''source to wheel'' analysis, WTW (Well to Wheel). In the case of TTW analysis, the electric bus propulsion system has no emissions: carbon monoxide, nitrogen oxides, hydrocarbons, and microparticles [8].

The environmental impact at the local level is minimal, as the only negative impact on the environment comes from the formation of microparticles and dust due to contact of tires and roads, from the friction of brake linings and evaporation of working fluids (transmission lubricating oil, antifreeze, etc.). which can be ignored. The TTW analysis of electric buses can be viewed in the context of the environmental effect achieved by replacing buses using diesel fuel or CNG, by quantifying the amount of pollutants that will not be emitted into the atmosphere as a result of vehicle substitution.

The method of production and transmission of electricity is essential when analyzing the impacts of the environmental performance of electric buses on a regional or national level, or WTW analysis. Analysis of WTW carbon dioxide emissions is important to consider and compare the emission levels emitted by buses with different propulsion systems, including purely electric buses. The aspect of carbon dioxide emissions that occur in the phase of electricity production is especially important here, considering that electricity is obtained from various sources. In the Republic of Serbia, most of the electricity is obtained from thermal power plants with a share of about 70% [9].

The Higer KLQ6125GEV3 electric buses operate exclusively on the city line EKO 1. Measurement of fuel consumption for buses of standard length using diesel fuel and compressed natural gas (CNG) was done based on monitoring the results of diesel fuel consumption on buses IK-112N (EURO 4) and CNG on buses MAZ-203 CNG which are performed in the period 12.08.-5.10.2017. year, when due to infrastructural works in Roosevelt Street, the operation of electric buses was temporarily replaced with buses with diesel fuel and buses with CNG [8]. Example of comparison of estimated emissions of harmful gases and carbon dioxide from the point of view of TTW and WTW analysis on line EKO 1 of electric bus Higer KLQ6125GEV3, the bus with diesel fuel IK-112N (EURO 4) and bus with compressed natural gas MAZ-203 CNG in which the Cummins ISL G powertrain, which meets the 2010 EPA/CARB and EURO 6 exhaust emission standards, is installed, is shown in Table 2 on an annual basis [8].

The UITP Environmental methodology was used to calculate CO, CxHy, CH_4, NOx, PM_{10} emissions from diesel and CNG buses [10]. The emission calculation was obtained on the basis of input data on diesel fuel consumption expressed in $L \cdot (100km)^{-1}$, CNG consumption in $kg \cdot (100km)^{-1}$, maximum emission values of CO, CxHy, CH_4, NOx, and PM_{10} expressed in $g \cdot kWh^{-1}$ depending of the level emission norms of engine, according to the ETC TEST test (Directive 2005/55/EC, European regulation no.595/2009) and the specific fuel consumption expressed in $g \cdot kWh^{-1}$.

Carbon dioxide (CO_2) emissions for diesel-powered buses and CNG buses according to TTW analysis were obtained using equation 1.1 [8,9].

Table 2. Summary analysis of the TTW and WTW for buses of different propulsion systems on line EKO 1 in Belgarde, (annual period of operation) [8]

Line EKO 1	Unit	E-bus Higer KLQ6125GEV3	IK-112N	MAZ-203 CNG
Number buses in operation		5	5	5
Mileage	km	62750	62750	62750
Average electricity consumption	kWh·km-1	1.493		
Average consumption of diesel	L·(100km)-1		47.05	
Average consumption of CNG	kg·(100km)-1			49.84
Emission CO	kg	-	2183.6	2347.1
Emission CxHy	kg	-	300.2	93.9
Emission CH4	kg	-	-	293.4
Emission NOx	kg	-	1910.6	158.5
Emission PM10	kg	-	16.4	5.8
Emission CO2, TTW	t	-	388.2	397.1
Emission CO2, WTW	t	389.5	443.3	465.9

$$m_{CO_2} = m_{fg} \cdot g_c \cdot \frac{44}{12}, \quad (1)$$

m_{CO_2} - mass of formed carbon dioxide, g,
m_{fg} - mass of fosil fuel that burns, g,
g_c - carbon content in the fuel, %,
44 - molar mass of carbon dioxide, g·mol^{-1},
12 - molar mass of carbon, g·mol^{-1}.

The value of carbon dioxide (CO_2) emissions, if calculated according to the WTW analysis, was obtained by increasing the carbon dioxide emission value obtained by TTW analysis by an increase factor of 14.2% for diesel fuel and 17.3% for CNG, which are the most realistic for the Republic of Serbia. In the case of electric buses, the calculation of CO_2 emissions according to the WTW analysis was obtained using equation 1.2 [8]:

$$CO_{2_{WTW}} = \frac{E_{ebus_L}}{\eta_{ch}} \cdot LCA_{co_2} \cdot f_{gpee}, \quad (2)$$

CO_{2WTW} - carbon dioxide emissions acording to WTW analysis, g·km^{-1},
E_{ebusL} - electricity consumption of E-bus, kWh·km^{-1},
η_{ch} - charger efficiency coefficient (~0.95),
LCA_{CO2} - emmision factor of the total cycle of electricity production in Republic Serbia, adopted 774 g·(kWh)$^{-1}$ [8,9],
f_{gpee} - coefficient of loses in electricity transmission.

CONCLUSION

The introduction of electric buses in regular operation is a significant development step in the improvement of the public city transport system in Belgrade. The analysis of the environmental performance (TTW, WTW) of the E-bus on the EKO 1 line compared to diesel and CNG buses have proven the advantages of using this new bus concept. It is obvious that the mentioned emissions of harmful exhaust gases are not present during the operation of the electric buses on the EKO 1 line in Belgrade. Although the environmental performance of conventionally powered buses (diesel, CNG) has been significantly improved, the presence of harmful emissions is still present and the best way to reduce the environmental impact of the bus subsystem is to replace it with electric buses. Compared to the carbon dioxide emission from diesel buses, the annual level (WTW analysis) of 443.3 tons can be concluded to be 12.1% lower for electric buses. Compared to CNG-powered buses, the annual CO2 emission of electric buses is lower by 16.4%. The city of Belgrade attaches great importance to this issue and the next step will be the introduction of a new line EKO 2, on which 10 E-buses will work, which is planned for the end of 2021.

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ORIGINAL SCIENTIFIC PAPER

Models of Organization and Management of Passenger Public Urban Transport Systems

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Abstract: The paper gives an overview of the model of organization in the management of public urban passenger transport systems (JGTP), which are applied in world cities as well as in some cities in the region. These are complex systems with components of economic, technical, technological and organizational nature, as well as elements of planning, arrangement and organization of space and impact on the environment and its protection, at the same time, as a public service, it is a specific network of various organizational and spatial entities. Systems are open transport systems with stochastic state change.

Keywords: system, organization, management, public urban passenger transport.

INTRODUCTION

Public urban passenger transport systems (JGTP), according to the principles of the European Commission [5] have a key role in achieving the goal of sustainable development and sustainable transport in cities. Regarding the goals and interests of the JGTP system, the following are imposed: ensuring high mobility of residents, opening of the market of services, needs for higher production efficiency and lowering of operating costs of carriers, enabling mobility of certain social groups under favorable conditions, realization of efficient and regulated mechanism (management), revenue, prices and financing of the system, harmonization of service prices with real transport costs, investment and development of the system, etc.

In most of the world and European countries, JGTP is understood as a social interest, whose advantages are measured not only in terms of the number of transported passengers and the price of transportation, but also in terms of factors such as:

- reduction of traffic congestion,
- increasing traffic safety,
- improvement of the environment,
- increasing the mobility of the population, etc.

The advantages of JGTP are transferred indirectly to the city's income, which is the main argument for the city authorities to participate in the ticket price through active financial support, which enables an increase in the offer of public transport and improved service quality. This means that the policy of active financial support to JGTP by the socio-political community for its faster improvement and development, which is accepted in all developed countries in the world, is the basic lever by which the city government can influence the overall significant improvement of conditions of (time losses due to congestion and irregularities) traffic in the city, as well as the improvement of the environment.

The importance of the public passenger transport system is reflected in:

1. The public transport system enables a large number of inhabitants to realize one of the basic needs, the need to move.
2. The quality of transport service of this system affects the effectiveness and efficiency of all production, supporting processes and other activities of people in the city.
3. Indirectly, it affects the rational use of urban areas, traffic congestion, speed and capacity, safety and environmental pollution in the entire urban area.
4. For a large number of residents, given their financial capabilities, as well as certain social groups (pupils, students, the disabled, pension-

ers, the elderly, the unemployed, etc.) JGTP is often the only option for the realization of transport needs.

5. The public transport system is also an activity that engages large funds invested in resources: vehicles, employees, facilities and equipment, energy, etc. so it is in the interest of the economy of cities or every country that every JGTP company functions and works efficiently.

The key trends in the field of public urban passenger transport [5] today are:

- Obligation and concern of local communities to ensure the mobility of residents with limited use of passenger cars in accordance with the strategy of "sustainable development" and "quality of life",
- Opening the market of services for all carriers and all types of ownership,
- Development of intermodal transport (which implies the systematic use of two or more modes of transport in order to increase the overall efficiency of the transport system),
- Full integration: transport networks (physical integration), tariff integration and logical - information integration,
- The need to increase production efficiency and lower the operating costs of carriers, and
- Citizens' pressure on local self-government bodies to achieve a higher level of quality with an acceptable price of public transport services, and a single ticket for all carriers and modes of transport.

Obligations, responsibilities and tasks of local city administration bodies in an integrated environment with several carriers are: defining the model of organization of the market of services in public urban passenger transport (entry, exit and working conditions of carriers, management at strategic and tactical level), planning of service quality elements , timetables), planning and organization of functioning of the whole system-integration system, defining conditions for acquiring and distributing income to carriers, control of functioning and supervision over defined quality of service and income, determining costs of public urban transport system for desired level of service quality.

WORLD EXPERIENCES [9]

There is almost no city in the world in which public urban and suburban passenger transport (JGPP) is not a basic activity and a basic precondition for a large number of urban activities.

Depending on the importance of JGPP in the transport system of the city and region, as well as the economic potentials of local, regional and state institutions in charge of monitoring the work and supporting the performance of public transport activities, the models of organizing and managing the JGPP market vary. In general, there is no formula for the optimal model of connection of local companies for performing the activities of JGPP, in the field of organization, management, current operations and development, in the technical-technological and economic-financial sense.

Although the organizational forms (models) of the JGPP system differ from city to city, they also have several common characteristics [7]. These common characteristics are based on the coordination of transport services in urban and suburban areas, competition between carriers, physical, tariff, management, control and information integration of systems, secure sources of financing their current operations and reliable sources of financing the development of JGPP functions.

Based on the available literature and based on a large number of published papers in the world, it can be concluded that there are three basic concepts, ie groups of models for organizing the market of the JGPP system.

1. Regulated mode model [5] (classic model)

The model of a regulated public monopoly regime in JGPP mainly dominates in JGPP systems where the carrier is owned by the city. Within the same, certain modalities are possible. It is used in most European countries (Austria, Belgium, Germany, Spain, Luxembourg, Greece, Italy, the Netherlands, Portugal, Serbia and Montenegro). Regulated system regime - management of the JGPP system can refer to «public» but also to «private» carriers.

2. Model of restricted competition regime

There are two variants of this model: on different forms of tenders at the line level and with the most common choice of carriers with the lowest price (Denmark, Finland, Sweden so-called Scandinavian model) or on contracts for line network management (France, Norway so-called French model).

3. Model of deregulated JGPP system

This is a free market model based on competition between carriers for individual lines. These models have been applied mainly in the United Kingdom (outside London).

The three basic forms of the JGPP market organization model are:

1. Scandinavian model
2. French model
3. The British model

1. The Scandinavian model is based on a minimum of subsidies and contracts with minimal costs for a certain number of lines.

This model refers to the situation of a clear division between the transport policy set by the authorities and the functioning of the JGPP system, public and private carriers that are under contract with the competent administration. Public carriers are represented by a public regional transport company (RTK) formed by a regional administrative body with the aim of organizing and managing the transport services market on its behalf and for its account. This company is actually a key factor in the transport market of public transport services and is not a regional administration body, and according to the type of business it deals with, it belongs to public activities. The tariff system remains integrated through all subsystems of JGPP, and through different carriers, while the operation of public bus transport is contracted with different carriers, through tenders. In the contract, based on the total (gross) costs, the government specifies the transport service and determines the size of the bus fleet (number of vehicles) and then selects bids for the costs of fleet maintenance. The income generated on the bus lines belongs to the authorities, and the entire tariff system is under their control. Carriers do not assume any individual risk and have only the obligation to rationalize production costs (performing transport services). In the case of contracts based on net costs, the carrier declares the amount of costs for the provision of transport services and then at the same time retains the income generated by ticket sales. The single tariff system remains integrated for subscription tickets, and the income from the sale of single subscription tickets belongs to the competent body of the city administration [2]. This means that this type of contract transfers part of the risk to the carriers**.**

The tender selects the carrier that offered the most favorable conditions [3], ie. the carrier that offered the smallest amount of grants. The tender is usually announced for one line or a certain number of lines, and the period of validity of the contract is different.

Since the first such contract was made in London in 1985, this type of contract has been very present in the large metropolises of Western Europe.

2. The French model, unlike the Scandinavian model, is based on contracts for the management of the line network of one or more JGPP subsystems, with additional incentives / sanctions provided for in the contract.

In this model, two entities (city/regional government and carrier) coexist and work together:

- The administrative body (authority) that sets the transport policy is responsible for the area of functioning of the JGPP system, sets the index of return of financial resources of the carrier and parameters for evaluating the work of the carrier ie same as with the Scandinavian model,
- The carrier is responsible for the operation and maintenance of vehicles, production efficiency and management of employees, which is regulated by the contract with RTK.

Responsibility for the marketing strategy, in some cases relies on the competent administrative body and in some cases on the carrier itself. The key feature of this model is that there is no competition in a particular transport area (network of lines) so that if more than one carrier provides transport service, then they do so only in one transport area (with different passenger characteristics) or using different subsystems through which make it less significant to compare the performance of each JGPP subsystem. Carriers work under a contract (license), and by type of ownership they can be a public company, a semi-public or a private company.

3. The British model is this model of competition in the transport market (or imperfectly competitive market), and public administration interventions are limited to setting safety standards for transport services and other institutional regulations.

This model has not been applied in any metropolis of Western Europe (including London), but it is applied in about 85% of subsystems in the UK (including those registered on the outskirts of London). Public city passenger transport is deregulated and is performed through private bus companies, but there is a possibility of subsidizing unprofitable lines (primarily suburban and local).

EXPERIENCES OF CITIES IN THE REGION

Model of organization and management in Kragujevac[4]

Numerous problems that accompanied the public urban and suburban passenger transport in Kragujevac were overcome by the introduction of two carriers on the complete network of urban and suburban lines, in December 2005. Until then, the transport was performed by one carrier - «Autosaobraćaj Kragujevac».

This was preceded by the preparation of the Study of public urban and suburban passenger transport in Kragujevac by the Faculty of Technical Sciences from Novi Sad. An integrated tariff system has been introduced, ie single tickets so that users of public urban and suburban transport services can use the transport services of several carriers. In addition, the system of payment, ticket sales, user - passenger control, carrier control, as well as JGTP management has been improved**.**

The precondition for the introduction of a new organization and management of the JGTP system was the establishment of the City Transport Agency, which unites all jobs related to JGTP.

The main scope of work of such an institution is to perform entrusted tasks, for and on behalf of the City, as follows:

- planning the development of public transport with the market in the integration of all subsystems,
- setting up and continuous correction of the line network,
- making timetables,
- traffic control,
- introduction of priorities and other measures to increase the speed of public transport,
- passenger control,
- issuing and selling tickets,
- concluding contracts with carriers,
- control of contract execution,
- distribution of revenues from sold tickets for the use of transport services of several carriers,
- charging for services from other bodies and institutions for categories of passengers with preferential prices,
- providing additional funds for the development of JGPP,
- monitoring and analysis of costs and revenues of the carrier,
- tasks related to monitoring and improvement: tariff system, payment system, ticket system, etc.

As a result of the introduction of such an organization and management of the JGTP system, not only a shorter travel time was obtained, but also a reduction in the total cost of operating the system, through the use of unique transport tickets. Unified printing and distribution of tickets, functional dispatch service, installation and maintenance of stop signs and informing passengers about the exact timetable, control of the work of carriers and vehicle documents in the vehicle, payment of additional tickets, as well as distribution of jointly realized income.

Model of organization and management in Niš [4]

The JGTP system in the city of Niš has undergone drastic changes in recent years, both in the level of service quality and in the way of organization, monitoring and planning process. Until 2005, the only carrier in the city of Niš was Nišekspres, and the way of organizing JGPP was completely entrusted to this company, which resulted in certain disagreements between the City and the mentioned company. In accordance with the new situation where the level of quality of public passenger transport was obvious (disrespect of the timetable, reduction of the number of vehicles at work from 190 to 80, obsolete vehicle fleet, etc.), the city management decided to introduce new operators in the JGPP system. However, the basic problem of the concept of such a multi-operator system is the need for the best possible control and manner of organization that requires a special body, which would deal exclusively with matters in the field of JGPP.

At a certain moment, in the city of Niš, passenger transport was performed by seven operators:

1. Nišekspres,
2. Veritimo,
3. Konvoj travel,
4. Transprodukt,
5. Lekon,
6. Ćurdić i
7. Aerodrum.

Due to the fact that the city was not ready for this way of functioning of JGPP, and due to the lack of a relevant institution for management, control and monitoring of such a system, there was an unregulated market which resulted in the withdrawal of some carriers and chaotic situation on public transport lines.

The Administration for Communal Activities, Energy and Transport of the City of Niš tried to apply certain measures in such a system, by accepting the principles of organization of JGPP set by Niš Ekspres in previous years (zone-tariff system, city and suburban lines remain unchanged, carrier collects revenue from sold individual tickets and monthly stamps, etc.). In such a system, the development of the timetable was entrusted to the carrier itself, and the only control consisted of the Directorate for Inspection Affairs and the later established sector of control at the city Airport.

CONCLUSION

In recent years, in all cities in the world, even in the region that have an organized JGTP system, the Model of Regulated Public Monopoly Regime in JGTP has been applied so far (where the only carrier in the system is owned by the city), model of restricted competition regime in this system has been introduced (with two or more carriers - operators in the system). Although the organizational forms (models) of the JGTP system differ from city to city, they also have several common characteristics. These common characteristics are based on the coordination of transport services in urban and suburban areas, competition between carriers, physical, tariff, management, control and information integration of systems, secure sources of financing their current operations and reliable sources of financing the development of JGTP functions. The inclusion of all selected carriers (regardless of the ownership structure: public company, private company, joint stock company, etc.), through a public tender (tender), is preceded by the procedure of preparing the JGTP Study.

Based on the research conducted in the Study [1], the calculation of real income and costs of the system is performed, in order to determine the balances of needs for necessary grants and subsidies from the city budget. Based on the obtained balances, Agreements are concluded between the City (local authorities) and selected

carriers, which regulate the rights and obligations of each participant in the system.

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ORIGINAL SCIENTIFIC PAPER

Traffic Accident Expertise in Civil Procedure

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Abstract: In the process of compensation for the damage suffered by the aggrieved party as a result of a traffic accident, it is often necessary to provide expertise to determine the cause of the accident, the aggrieved party's contribution to the accident, or increase in the amount of damage. Formally and legally, it is necessary to observe the institute rule of shared responsibility. Shared responsibility is an institute rule that marks the contribution of the aggrieved party to cause damage or to be greater than it would otherwise be. Within the framework of this paper, the model of traffic accident expertise in civil procedure is investigated, primarily from the aspect of the contribution of the inadmissible action of the aggrieved party in the occurrence of the accident or increase of the damage.

Keywords: Traffic accident; Dangerous situation; Cause of traffic accident; Shared responsibility; Contribution to the occurrence of an accident; Increase of the damage.

INTRODUCTION

Liability for damage [4] in traffic is a topic that is always actual, given the number of traffic accidents, the degree of motorization and the number of cases, both judicial and extrajudicial, in regular procedures for damages with insurance companies. The importance of the responsibility of the perpetrator for the damage is highly emphasiszed for the incurred damage in terms of the contribution of the aggrieved party to the damage, observed through the institute of the contribution of the damaged party to the occurrence and/or size of the damage. These are the most common dilemmas in court procedures, which are expressed by judicial authorities when deciding, after the procedure of proving the cause of the traffic accident and the contribution to the occurrence and magnitude of the damage. It is evident that there is a disproportion that can occur in relation to the basic cause of the accident and the contribution to the occurrence and magnitude of the consequences of the accident or the damage suffered by the aggrieved party.

Any guilt established in the previous criminal procedures, does not represent the one and only assumption of liability for the damage caused, when it comes to civil procedures. The court is bound by the provisions of Article 12 of the LCP to the decision of the criminal court regarding criminal liability, but this does not prevent the perpetrator (his insurer) from proving the contribution on the part of the aggrieved party in the civil procedures. The established responsibility in the misdemeanor procedure does not bind the civil court, but it shifts the burden of proof from the aggrieved party to the perpetrator.

In cases when it is necessary to analyze the existence of several causes that lead to the accident, ie when it is not possible to determine with certainty which of the actions primarily led to the accident, and which contributed to the accident, ie the damage was greater than it would otherwise be, a correct analysis of the dynamics of the course of the accident performed by a traffic expert is of crucial importance. The analysis of the behavior of the participants in the accident will give us the answers on the basis of which the court will determine the legally relevant facts and correctly determine the contributions to the occurrence of the accident.

LIABILITY FOR ACCIDENT

Liability for the occurrence of a traffic accident is regulated by the provisions of Article 178 of the Law on Obligations, as a special kind of liability in our law. Although motor vehicles are considered as dangerous things, the law stipulates that liability is determined by the rules on subjective liability based on presumed guilt (Articles 158 to 163 of the Law on Obligations). Guilt exists when the

perpetrator has caused the damage intentionally or negligently.

The general presumptions of civil liability for damage are considered to be: the existence of damage, the inadmissible act of the perpetrator and the causal connection between the act and the damage that occured.

The questions that the court can answer only after the traffic expertise has been conducted concern the inadmissibility of the behavior of traffic participants and the casual connection between such behavior and the consequences. Here it is important to mention the theory of adequate causality, according to which of all possible existing facts related to the specific cause of damage, legally relevant is only that fact, that cause that is adequate to the damage, and as such (from the Latin Adaequare - equalize) only the cause that matches and corresponds to the specific damage. Which cause will be adequate, typical and expected will depend on each specific situation, and there will be a situation that the one same cause in the case has a legally relevant meaning, and another it will not, but nevertheless the most important thing in evaluating each case is to compare specific behavior of the participants in an accident with behavior that is proper, permissible and customary in the normal course of the events, abstracting any extravagance and irregularity. [6]

Law on the Principles of Traffic Safety in BiH indirectly prescribes the principle of trust [10], as a general principle. First, by a general provision in Article 3, the legislator defines that traffic participants are obliged to respect the provisions of this Law and other regulations in the field of road safety, to develop humane relations between people to protect the health and lives of others, especially children, the disabled, the elderly and helpless persons, and to take care of the protection of the environment, and that they must not obstruct traffic, damage roads, facilities and equipment on the road. According to the traffic rules, starting from Article 25, the law singles out certain groups of traffic participants (children, the elderly, persons with disabilities ...) according to which, due to their characteristics, drivers must pay special attention, ie the principle of distrust or limited trust. Also, the legislator singles out certain traffic situations (access to the pedestrian crossing, on the part of the road where children are moving, vehicles moving next to public transport vehicles, when vehicles are moving behind vehicles transporting children ...) in which an exception is made of the principle of trust. With this kind of separation, the legislator emphasized when the driver must pay special additional, ie when special attention is necessary (defensive driving). Argumentum a contrario, in all other cases drivers can be sure that all participants will act in accordance with the law (principle of trust).

The Law on Traffic Safety on the Roads of the Republika Srpska, in Article 4, explicitly prescribes the obligation to avoid dangerous situations caused by improper behavior of other participants in traffic.

Based on the above legal provisions, we can see what questions we have to answer during the trial, and thus the task of a traffic expert in civil procedures is defined.

The task of the expert should be to, based on the available documentation in the file and possible visit to the scene of the accident, perform an analysis and declare the participants in the accident; road, traffic signals and weather; possible injuries to the participants; vehicle damage; traces of a traffic accident; vehicle speed and dynamics; and to make a time-space analysis of the possibility of avoiding the accident (immediately before and at the time of the accident); as well as to analyze the manner of occurrence of the accident and the compatibility of the collision process and the resulting damage.

From the task set in this way, for determining the guilt and shared responsibility that is the topic of this paper, the most important factor is certainly the temporal-spatial analysis in which the expert has his essential role during the procedure. The expert witness is the one who, based on the available documentation in the file (in accordance with the principle of the parties), will first determine how one of the participants in the accident has behaved, and then he will make an analysis of the possibility of avoiding the accident.

Starting from the definition of a dangerous situation, on this occasion it is necessary to emphasize that the action by which the driver creates a dangerous situation must be impermissible. As an example of this case, it may be best to cite the collision of a left turn in relation to the impermissible speed of a vehicle moving from the opposite direction.

The provisions of the Vienna Convention also define the obligation of drivers to pass other vehicles, ie not to continue driving or maneuvering if this would force drivers of other vehicles (moving in accordance with the law) to suddenly change the direction or speed of their vehicles. This solution is also accepted by our law. [5] Thus, the priority to the right is not an absolute right, but is, in accordance with the principle of trust, limited to situations in which the driver invoking that right moves in accordance with the law.

The action of the aggrieved party can be the cause of the harmful event, the contribution in the occurrence or the contribution in the consequence.

SHARED RESPONSIBILITY

Shared responsibility is regulated by the provisions of Articles 192 and 205 of the Law on Obligations of the RS/FBiH.

Shared liability means the liability of several persons for the occurrence of a harmful event or for a contribution in the amount of damage. An aggrieved party who has contributed to the damage occurring or to be greater than it would otherwise be, is entitled only to a proportionately reduced compensation.

When deciding in procedures for compensation for damage from traffic accidents, it is necessary to assess which behavior of the aggrieved party is improper from the point of view of the occurrence of the harmful event and/or increase in the damage he suffered.

Shared responsibility must be distinguished from joint and several liability. Joint and several liability is the liability of several persons for the same damage in which those persons are liable to third parties on the principle of all for all, and then in possible recourse litigation regulate their mutual relations and contributions in the making. Joint and several liability can be shared, but also the exclusive responsibility of one of the participants. Solidarity is manifested outwardly and does not go down the inner relationship of the person.

In the case of shared responsibility in civil procedures, the relationship between the aggrieved party (plaintiff) and the perpetrator is primarily important, ie the contribution of the aggrieved party to the occurrence or amount of damage. The perpetrator cannot invoke the contribution of third parties, but as a rule such persons should, as joint and several debtors, be invited as interveners in the litigation. Such a decision also arises from the provisions of Article 178, paragraph 4 of the Law on Obligations.

TRAFFIC ACCIDENTS TYPE: VEHICLE-PEDESTRIAN

In a collision between a vehicle and a pedestrian, the rules on strict liability apply because the vehicle is considered a dangerous thing in relation to the pedestrian (Articles 173 and 174 of the Law on Obligations). The burden of proving the existence of elements for release from liability is on the owner of the motor vehicle (Article 177 of the Law on Obligations). The pedestrian proves only the causal connection between the damage and the dangerous thing (vehicle).

When determining the responsibility and possible shared responsibility, it is primarily necessary to analyze the admissibility of the actions of all participants in the accident.

The provisions of Law on the Principles of Traffic Safety in BiH stipulate that pedestrians are allowed to cross the road at a distance of more than 100 meters from the pedestrian crossing, overpass or underground crossing, provided that the pedestrian is obliged to cross the road carefully and by the shortest route, after making sure that it can do it in a safe way, that is, to miss vehicles moving on the road.

The driver has an obligation to pay attention to a pedestrian who is on the road or steps on the road or expresses an intention to step on the road, but he has no obligation to expect that the pedestrian will not miss him. The pedestrian has no right to expect the driver to miss him. If visibility or clearness is reduced or disabled, the driver is not obliged to expect pedestrians to enter or cross the road. [10]

When the claim of the injured pedestrian or the claim of the family of the injured pedestrian is observed, then it is necessary to determine by using the traffic expert procedure in civil procedures:

- admissibility of actions of participants in the accident,
- responsibility for the occurrence of a dangerous traffic situation that preceded the traffic accident,
- individual contributions to the occurrence of a traffic accident,
- the possibility of avoiding a traffic accident.

It is first necessary to observe the micro location of the traffic accident and the modes of movement of vehicles and pedestrians at the time of the dangerous situation or traffic accident.

- direction of vehicle movement,
- direction of pedestrian movement,
- mode of movement of vehicles and pedestrians,
- vehicle and pedestrian speeds,
- positions of vehicles and pedestrians in time-space analysis.

In order to perform a quality analysis of a traffic accident, in the expert procedure, it is necessary to keep in mind the criteria defined on the basis of mutual trust [1] between drivers and pedestrians, in accordance with the provisions of Law on the Principles of Traffic Safety:

1. if the traffic at the marked pedestrian crossing is regulated by light traffic signs for pedestrians, the pedestrian is obliged to act according to these signs,
2. if the traffic at the marked pedestrian crossing is not regulated by light traffic signs, but the vehicle traffic is regulated by light traffic signs for vehicles or signs given by authorized persons, pedestrians may cross the road only as long as they are allowed to cross the road with a given sign,
3. if the traffic at the marked pedestrian crossing is not regulated by light traffic signs or signs given by an authorized person, before entering the pedestrian crossing, the pedestrian is obliged to pay attention to the distance and speed of the approaching vehicle.
4. if the traffic at the marked pedestrian crossing is not regulated by light traffic signs, or signs given by an authorized person, the driver is obliged to stop the vehicle in front of the pedestrian crossing, to pass pedestrians crossing or entering the pedestrian crossing, or unequivocally show intention to cross the pedestrian crossing.
5. before entering the pedestrian crossing, the pedestrian is obliged to pay attention to the dis-

tance and speed of the vehicle [2] approaching him.

With the proper movement of pedestrians (1-5), his contribution to the occurrence of a traffic accident is excluded, especially having in mind the fact that the vehicle is a "dangerous thing" in the hands of the driver.

In the case of improper behavior of pedestrians in the above circumstances (1-5), which basically caused the accident, the driver's contribution to the resulting consequence is measurable in the amount of difference between the possessed or collision speed and the safe or allowed speed of the vehicle in a particular traffic situation.

The consequence of a traffic accident is directly proportional to the product of the mass and square of the speed of the vehicle consumed in the collision, or the amount of kinetic energy in the collision with a pedestrian:

$$E_K = \frac{mV_S^2}{2}$$

The relationship between vehicle collision speed and the probability of pedestrian death is shown in Table 1.

Table 1. Dependence of pedestrian mortality and speed

Collision speed km/h	Pedestrian mortality%
30	10
40	20
50	40
60	80
80	100

In the presented case, the consequences for pedestrians are directly dependent on:

- collision characteristics,
- shape and construction of the vehicle;

In the case of traffic accidents with pedestrians outside the pedestrian crossing, there are different approaches in expertise, and therefore court judgments are different. In these cases, there is no harmonized position, primarily of the traffic profession. The practice of the competent courts is also different.

Accordingly, it is necessary to emphasize the following legal norms [5] of Law on the Principles of Traffic Safety:

Article 9, Paragraph 1

- item 15) road is a part of the road surface intended primarily for vehicle traffic,
- item 74) a sidewalk is a specially arranged traffic area intended for the movement of pedestrians, which is not at the same level with the driveway, or is separated from the driveway in another way,

Comment: All others (including pedestrians) have to behave in a legally prescribed manner. The legislator separates the areas intended for the movement of vehicles and pedestrians.

Article 28

1. the driver is obliged to pay attention to pedestrians who are on the road or entering the road during driving.
2. when approaching a marked pedestrian crossing, the driver must drive the vehicle with special caution and drive at such a speed that he can stop the vehicle in front of the pedestrian crossing if necessary.
3. on the part of the road on which children move, or on which traffic signs on children's participation in traffic are placed, the driver is obliged to drive with special caution and with such speed that he can stop the vehicle in case of need.

Comment: With this article, the legislator limits the principle of trust towards pedestrians moving on the road, in the immediate vicinity of the pedestrian crossing and towards children as a special category of participants.

Article 105

1. As a rule, pedestrians must not move and stay on the road.
2. If a pedestrian moves on the road, he must move as close as possible to the edge of the road, and very carefully and in a way that does not interfere with or prevent vehicle traffic.

Comment: With this provision, the legislator explicitly obliges pedestrians to pay special attention in cases when they move on the surface intended for the movement of vehicles.

Article 108

1. A pedestrian is obliged to cross the road and the bicycle path carefully and by the shortest route, after he is convinced before entering the road that he can do so in a safe manner.
2. While driving on the road, a pedestrian must not use a mobile phone or have headphones in both ears.
3. On a road that has marked pedestrian crossings or specially built crossings, ie pedestrian crossings, when crossing the road, the pedestrian is obliged to move through these crossings or passages, if they are not more than 100 meters away from it.

Article 110

1) A pedestrian who intends to cross the road in a place where there is no marked pedestrian crossing must not enter the road if by doing it he interferes vehicle traffic.

Comment: Having in mind the stated provisions [5] of Articles 105, 108 and 110 and the definition from Article 9, paragraph 1, item 15, it can be concluded that the driver or vehicle outside the pedestrian crossing is on the road with priority of movement [1] in relation on the pedestrian.

Any change in the mode of movement of the vehicle (braking, acceleration, change of traffic lane ...) caused by the behavior or entry of pedestrians on the road, is caused by the consequences of pedestrian failure.

If a traffic accident occurs in the given circumstances, then it can be reliably concluded that the traffic accident occurred as a consequence of a dangerous situation caused by improper behavior of pedestrians. In this regard, from the aspect of traffic technical expertise, in the collision of vehicles and pedestrians outside the pedestrian crossing, the dangerous situation that precedes the collision is always caused by the impermissible behavior of pedestrians.

If the speed of the vehicle is within the allowed limits, then the traffic accident is basically caused by the behavior of pedestrians, who are entering the road and thus causing a dangerous situation. An exception to this rule occurs when traffic participants are children, the disabled, the blind, the elderly and the helpless perons, which the law classifies as a special group of road users to whom the "principle of limited mutual trust" applies. In these cases, it is necessary to analyze whether the driver paid special attention, because there may be the fault of the driver even in the cases when he was moving at the allowed speed and if he could notice the movement of pedestrians from those groups in time. The legislator decided to limit trust due to the special characteristics of these participants.

If the speed of the vehicle is higher than allowed, then the driver's contribution to the accident can be discussed. Namely, if the speed of the vehicle at the moment of the dangerous situation is higher than allowed, and the safe speed is lower than allowed, then there is a contribution of the driver of the traffic accident, the size of which is significant in litigation.

If the speed of the vehicle at the time of the dangerous situation is higher than allowed, and the safe speed is also higher than allowed, then there is a shared responsibility that depends on the amount of speeding. [9]

In order to make a correct court decision, in the event of a collision between a vehicle and a pedestrian outside a pedestrian crossing, it is assumed that the vehicle is always in an advantage over the pedestrian [5].

Within the stated statement, it is possible to form different forms of opinion:

- If the speed of the vehicle is within the allowed limits, then the traffic accident is basically caused by the behavior of pedestrians, entering the road and thus causing a dangerous situation that led to the occurrence of a traffic accident. On the driver's side, the possibility of avoiding an accident should be appreciated.
- If the speed of the vehicle at the time of the dangerous situation is higher than allowed, and the speed at which it could avoid an accident is less than or equal to the maximum allowed, then the existence of the driver's contribution to the consequences of the accident should be determined.
- If the speed of the vehicle at the time of the dangerous situation is higher than allowed, and when moving at the maximum speed on the road section the accident could be avoided, then there is a shared responsibility, which depends on the size of the speed.

These rules must be respected when making a decision for the sake of legal certainty and equality in the judiciary. It is especially important to look at the real state of affairs in the right way, devoid of emotion towards any of the participants. Law is most just when it is in its pure form. As soon as we start leaning to one side, be it a pedestrian or a driver, we will lose the purpose of the right.

If we blame the driver because on the road surface where the law gives him the right of precedence, he hits a pedestrian whom he could not objectively foresee, whom he could not avoid and if he could not eliminate the consequences in any way, we will rudely deny the provisions of Article 177 Law on Obligations.

In situations where a pedestrian comes to the driver from the left side of the road, a dangerous situation does not arise at the moment when the pedestrian steps from the left edge of the road. If the moment when a dangerous situation occurs is taken into the consideration, as the moment when the driver sees a pedestrian on the left side of the road and then has the obligation to expect that the pedestrian may move incorrectly, it would mean that all traffic participants should expect improper behavior of all other participants, which would be contrary to the applicable principle of "mutual trust" for such situations. Traffic would be impossible under such conditions. For this reason, the moment of occurrence of a dangerous situation is the moment when it is indisputable that the pedestrian will step into the traffic lane in which the vehicle is moving, or when the pedestrian is (in cases of pedestrians walking) no more than 0.7 meters inside the traffic lane in which the vehicle is moving [7]. This interpretation of the term road is necessary for the normal flow of traffic. If we imagine a situation in which a driver in the far right lane brakes and stops to miss a pedestrian who enters the left lane outside the pedestrian crossing

in places where there are two or more lanes, it is clear why the legislature favors vehicles.

TRAFFIC ACCIDENTS OF TYPE: VEHICLE-VEHICLE

In traffic accidents involving two vehicles, liability for damage is assessed according to the rules of subjective liability (Article 178 of the Law on Obligations). The provisions of Article 154, 158 and 178 regulate guilt. As a rule, the guilt is on the side of the driver whose action was inadmissible and which preceded the collision, ie caused a traffic accident.

In a trials for traffic accidents in civil procedures, the contribution of the aggrieved party is determined as a contribution to the occurrence of the accident or a contribution as a result of a traffic accident (192. Law on Obligations).

In the case of a conflict of two demeanors, one of which is impermissible (deprivation of priority, non-compliance with the sign, movement on an impermissible surface, etc.). the expert witness should start from the situation that such an action is the cause of a dangerous situation, and that on the part of other traffic participants he appreciates the possibility of avoiding an accident (conflict of rights and wrongs). On the other hand, if two or more actions of the participants in the accident are allowed individually, then it is necessary to analyze which of the actions was started first.

On the example of the speed of the vehicle, it will be explained how the expert should analyze whether speeding is the cause of the accident, the contribution in the occurrence or the contribution in the consequence (increased damage).

During the time-space analysis of the traffic accident, the expert will primarily determine the collision speed of the vehicle, and then determine where the vehicles were at the time of the dangerous situation, ie when there is a possibility that the participants' paths intersect at the same time. If it determines that one of the vehicles was moving at a speed higher than the maximum allowed speed, it will perform an analysis of how the speed affected the accident, by using the maximum allowed vehicle speed for the section of the road instead of the speed. Therefore, the expert witness will compare the specific behavior of the participants in the accident with the behavior that is correct, permissible and usual in the regular course of events.

Depending on the results of the analysis, the expert may come to the following conclusions:

- speed is the cause of the accident, if at the maximum allowed speed, without the reaction of the driver there would be no conflict with another vehicle, or if another vehicle would complete its operation without coming to the conflict zone;
- speed is a contribution to the occurrence of an accident, if at the maximum allowed speed the driver could avoid the occurrence of an accident by braking (the court will assess the contribution according to all the circumstances of the case);
- speed is a contribution in the amount of consequences, if at the maximum allowed speed the driver could not avoid the accident by braking, and there is more damage than would occur when driving at the maximum allowed speed;

For example, if the aggrieved party's vehicle came into contact at a speed of 80 km/h and the maximum speed is 50 km/h, the question arises as to what extent the difference in kinetic energy of 30 km/h contributed to the resulting consequence.

The kinetic energy consumed in the collision is a direct consequence of the growth of the velocity square, which directly affects the consequences of the traffic accident, which is presented in Figure 2.

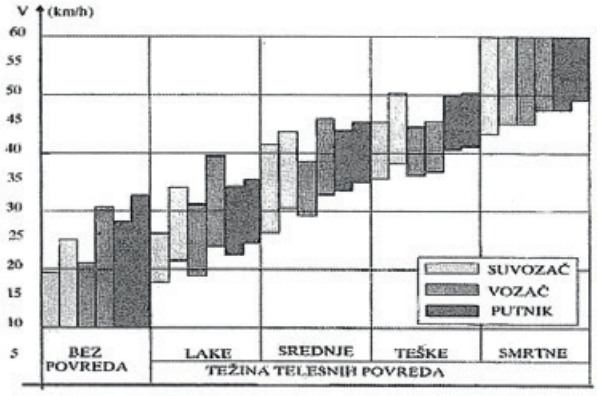

Figure 2. Consequences of a traffic accident depending on the collision speed of the vehicle;

Given that this is a complex consequence of material and non-material damage, such expertise should be combined or interdisciplinary, within the competence of a traffic, mechanical and medical expert.

As shown in the example of speed, the expert will act in the same way when analyzing any action that is a possible cause of the accident.

CONCLUSION

As part of determining the responsibility for the occurrence of a traffic accident, we must first determine the permissibility of the behavior of the participants and separate the causes of the accident and the consequences in the amount of damage. Each action of the participants needs to be analyzed individually and in connection with other actions. In assessing each case, it is necessary to compare the specific behavior of the participants in the accident with the behavior that is correct, permissi-

ble and usual in the regular course of events, abstracting from any extraordinary and irregularity.

Shared responsibility must be distinguished from joint and several liability. Joint and several liability is the liability of several persons for the same damage in which those persons are liable to third parties on the principle of all for all, and then in possible recourse litigation regulate their mutual relations and contributions in the making.

In the event of a collision between a vehicle and a pedestrian, the rules on strict liability apply. The burden of proving the causal connection is on the pedestrian, and proving the grounds for discharge is on the driver.

If a traffic accident occurs during the unauthorized movement of pedestrians on the road outside the pedestrian crossing, then the traffic accident occurred as a consequence of a dangerous situation caused by improper behavior of pedestrians. From the aspect of traffic-technical expertise, in the collision of vehicles and pedestrians outside the pedestrian crossing, the dangerous situation that precedes the collision is always caused by the illicit behavior of pedestrians. In order to make a correct court decision, in the event of a collision between a vehicle and a pedestrian outside a pedestrian crossing, it is assumed that the vehicle is always in an advantage of movement over the pedestrian.

Within the stated statement, it is possible to form different forms of opinion:

- If the speed of the vehicle is within the allowed limits, then the traffic accident is basically caused by the behavior of pedestrians, entering the road and thus causing a dangerous situation that led to the occurrence of a traffic accident. On the driver's side, the possibility of avoiding an accident should be appreciated.
- If the speed of the vehicle at the time of the dangerous situation is higher than allowed, and the speed at which it could avoid an accident is less than or equal to the maximum allowed, then the existence of the driver's contribution to the consequences of the accident should be determined.
- If the speed of the vehicle at the time of the dangerous situation is higher than allowed, and when driving at the maximum speed on the road section the accident could be avoided, then there is a shared responsibility, which depends on the size of the speeding.

In traffic accidents involving two vehicles, liability for damage is assessed according to the rules of subjective liability. In the trial for traffic accidents in civil procedures, the contribution of the aggrieved party is determined as the contribution in the occurrence of the accident or the contribution as a result of the traffic accident. In the case of a conflict of two behaviors, one of which is impermissible, the expert witness should start from the situation that such an action is the cause of the dangerous situation, and appreciate the possibility of avoiding an accident (conflict of rights and wrongs) on the part of other traffic participants. On the other hand, if two or more actions of the participants in the accident are allowed individually, then it is necessary to analyze which of the actions was started first.

Depending on the results of the space-time analysis, the expert may come to the following conclusions regarding the speed of the vehicle:

- speed is the cause of the accident, if at the maximum allowed speed, without the reaction of the driver there would be no conflict with another vehicle, or if the other vehicle would complete its action without coming to the conflict zone;
- speed is a contribution to the occurrence of an accident, if at the maximum allowed speed the driver could avoid the occurrence of an accident by braking (the court will assess the contribution according to all the circumstances of the case);
- speed is a contribution in the amount of consequences, if at the maximum allowed speed the driver could not avoid the accident by braking, and there is more damage than would occur when driving at the maximum allowed speed;

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ORIGINAL SCIENTIFIC PAPER

The Impact of the Age of the Vehicle Fleet on Traffic Safety - Vehicle as the Third Pillar of Traffic Safety

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Abstract: Traffic accidents are, today, accepted as a global problem and activities are being undertaken to adapt and transfer successful practices from the most developed countries to underdeveloped and developing countries. The impact of a road transport system is so significant that its safety or lack of safety affects a wide range of social needs. Road safety or mobility without risk of death or injury affects health, poverty, equality, the environment, employment, education, gender equality and the sustainability of communities. Many nations around the world have improved the effect of pillar interventions by applying them selectively and strategically in accordance with the principles of the safe system approach. The safe system approach addresses problems closer to their root cause and on a broader level than conventional methods. The five pillars of road safety identified in the Global Plan for the Decade of Action 2011-2020 include a set of evidence-based interventions that can measurably improve road safety. Preparation and adoption of strategic documents- a traffic safety system development policy and strategy is a great way to demonstrate traffic safety management. The most important common denominator for all successful traffic safety practices is science-based strategic traffic safety management, which has clear, honest and publicly expressed political support. The paper presents the analysis of the third pillar „safer vehicles" and its influence on the approach of the safe system from different aspects.

Keywords: traffic safety, motor vehicles, road traffic, decade of traffic safety, critical headway.

INTRODUCTION

Numerous characteristics of the vehicle affect the occurrence of the accident, and especially the severity of the consequences (vehicle weight, vehicle construction, vehicle equipment, vehicle age, technical correctness of the vehicle, etc.). Crash tests (NCAP - New Car Assessment Program) are a good way to research the safety characteristics of vehicles and the basis for further improving the safety properties of vehicles. Fleets are being renewed at both the national and local levels, reducing vehicle age and improving performance in terms of vehicle safety. Vehicle characteristics represent the third pillar of traffic safety. It is possible to present the characteristics of vehicles related to the vehicle fleet in different ways, such as the age of the vehicle fleet, the structure of the vehicle fleet and the safety characteristics of the vehicle. [1]

In the third pillar, as in the other pillars, the action should focus on the following areas, [2]:

a) Legislation - to have a clear basis for improving road safety as well as to designate responsible agencies for implementation, education and supervision

b) Implementation (including inspections and audits as necessary) - to ensure that rules, regulations and standards are respected and / or enforced

c) Education - ensure that rules and regulations are known and applicable

d) Technology - to supplement and strengthen other areas to increase system efficiency

e) International regulatory support - to provide an international legal framework and institutional platforms to support work in other areas.

The aim of the research is to investigate the extent to which the average monthly salary and older vehicles (passenger cars over 10 years of age) affect the participation of younger vehicles (passenger cars under 6 years of age) in the set of registered vehicles in one municipality. The sample corresponds to the some municipalities on the territory of the Republic of Serbia.

PREVIOUS RESEARCH STUDIES

The United Nations Agenda 2030 for Sustainable Development, adopted by all member states in 2015, provides a common plan for peace and prosperity for people and the planet, now and in the future. The agenda is based on 17 sustainable development goals and is presented as

an urgent call to action for both the public and private sectors in a global partnership. The goals of sustainable development cover a number of needs for the improvement and stabilization of both the human condition and the condition of our planet, recognizing the interdependence of these two goals. [3, 4]

The effectiveness of any United Nations operation in the field is related to its mobility, which in turn correlates to the vehicle fleet. This includes the quantity, quality, condition and types of vehicles available in relation to the condition of the roads and the type of terrain in the operational area.

The following recommendations are offered by the Academic Expert Group for inclusion in the Stockholm Declaration and for use by political, corporate and civil society leaders and practitioners around the world. The recommendations are aimed at 2030 and aim to build on those previously set out in the Moscow Declaration of 2009 and the Brasilia Declaration of 2015, as well as previous United Nations General Assembly and World Health Assembly resolutions.

Recommendation No. 6 of this group applies to safe vehicles around the world. Vehicle safety technology has proven to be effective both in preventing collisions and in saving lives when accidents occur. Vehicle safety systems play an important role in the safe system approach by addressing these basic principles: 1) Accommodating human error, 2) Limiting crash forces to levels within human injury tolerance, and 3) Pursuing a commitment to proactive improvement. [4]

Recommendation No. 9 of this group refers to technology. The question of whether new in-vehicle technologies could be developed in the coming decades that could be suitable for use in low- and middle-income countries could almost certainly be answered in the affirmative. However, realizing that potential will require the commitment of both the public and private sectors. Automotive technology is changing at an unprecedented rate, so it is very likely that there will be candidates for safety devices in the coming years. Technologies outside the vehicle can also make a difference in low- and middle-income countries. One example is post-collision care.

Figure 1 shows countries applying priority UN vehicle safety standards. The 2018 Global Status Report on Road Safety identifies eight critical safety vehicle standards and indicates that while 40 countries have implemented 7 or 8 of these standards, 124 countries worldwide have implemented none or just one of these requirements. [5. 6]

Improvements in the secondary safety characteristics of vehicle design (reduction in the severity of collision injury outcomes) are responsible for much of the reduction in casualties observed worldwide over the last thirty years. These characteristics are increasingly relevant for the protection of vulnerable road users. [7]

Vehicles are designed and regulated to minimize the occurrence and consequences of collisions. Making vehicles safer may include installing „active" safety measures, which can prevent collisions, such as autonomous emergency braking or „passive" safety measures, which protect passengers in the event of a collision, such as seat belts and airbags. Roads and vehicles will increasingly be managed within an intelligent transport system that relies on increasingly autonomous vehicles and smart infrastructure. As safety becomes embedded in vehicle technology and road design, there is the potential to fur-

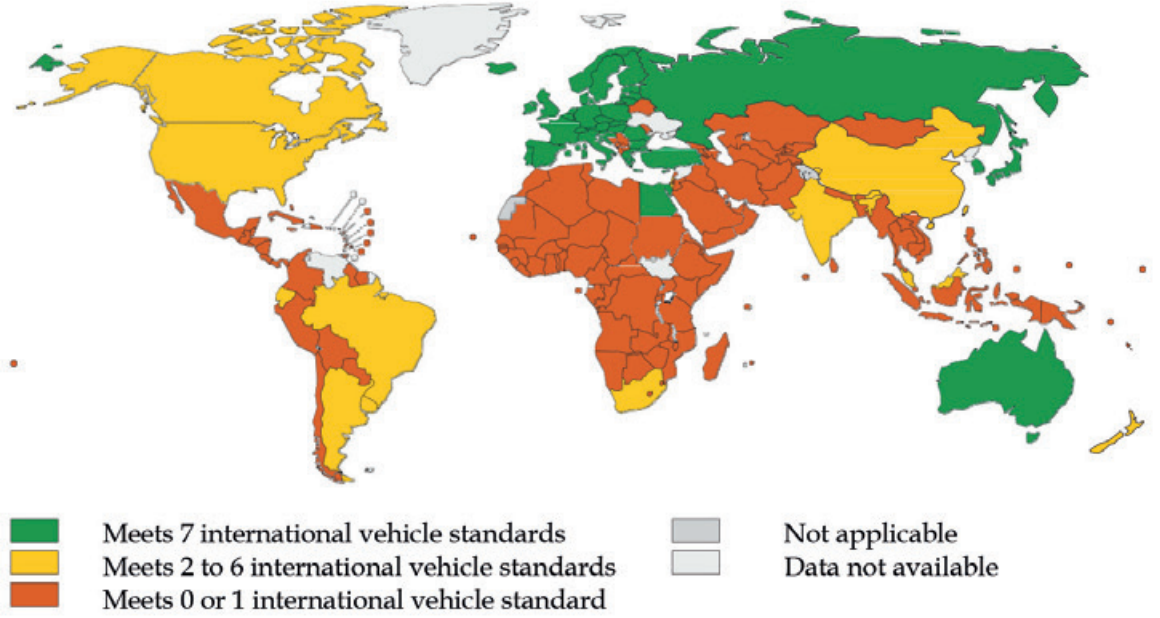

Figure 1. Countries applying priority UN vehicle safety standards
Source: https://www.who.int/violence_injury_prevention/road_safety_status/2015/Section_3_GSRRS2015.pdf

ther reduce the number of casualties and deaths on the roads. The third pillar includes encouraging the universal application of improved vehicle safety technologies for passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the adoption of new technologies. [8]

Important actions under the third pillar of the Global Plan for the Decade of Action for Traffic Safety, [9, 10]:

- implementation of UN vehicle safety regulations and New Car Assessment Programmes (NCAPs), recommendations for inclusion of technologies such as ESC (Electronic stability control) and ABS (Anti-lock Braking System),
- discouragement of import and export of new or used cars that have inferior safety levels increased research into safety technologies designed to reduce risks to vulnerable road users,
- encouragement of managers of governments and private sector fleets to purchase vehicles,
- that offer advanced safety technologies and high levels of occupant protection.

According to the strategy [11], one of the goals related to the third pillar is that 100% of new vehicles (defined as manufactured, sold or imported) and used vehicles will meet very high safety standards, such as the United Nations Regulations or the Global Technical Regulations recommended as priority, or national performance requirements recognised as equivalent by 2030.

The traffic safety indicator related to the age of the vehicle fleet can be observed in different ways. The average age of the vehicle fleet is the first and basic indicator of the vehicle fleet. The second approach considers the percentage of vehicles that are younger or older than some predefined limit.

Based on the two approaches [12], key traffic safety indicators related to vehicles can be defined: average age of all vehicles (fleet),

- average age of passenger car fleet,
- % of passenger cars under 6 years of age and
- % of passenger cars older than 10 years.

Influence of vehicle age on the occurrence of vehicle defects are investigated in paper [13] and the results showed that the average results of the assessment of the technical roadworthiness of vehicles in individual states differed diametrically from each other and did not depend on the average age of the vehicle fleet in a given state.

OVERVIEW OF TRAFFIC SAFETY STRATEGIES IN THE REPUBLIC OF SERBIA

The Road Safety Strategy of the Republic of Serbia for the period from 2015 to 2020 envisages the adoption of the Action Plan for the implementation of the Road Traffic Safety Strategy of the Republic of Serbia for the period from 2015 to 2020, which will elaborate the goals of the Strategy. Specific measures and tasks, holders of activities, deadlines for the implementation of activities, monitoring of traffic safety, responsibilities and sources of funding are contained in the Action Plan. The Action Plan is a set of concrete measures and activities, systematized through five pillars listed in the Strategy. For each of the pillars, the Action Plan sets out the goals to be met. The objectives in the Action Plan for pillar 3. safer vehicles are: [14]

- Objective 1. Harmonization of regulations in the field of vehicle type-approval
- Objective 2. Improvement of the vehicle technical control system
- Objective 3. Technological improvement of vehicles and stimulation of the use of ecological fuels and ecological vehicles
- Objective 4. Development of intelligent transport systems in / on the vehicle in the function of traffic safety

According to the strategy [15], from the point of view of traffic safety, three groups of countries can be distinguished:

1. States that have accepted that traffic safety can be managed, have built an organized protection system and are successfully implementing management in practice, constantly reducing the number of casualties (Great Britain, Sweden, the Netherlands, Norway, etc.),

2. States that in principle accept the idea of the possibility of reducing the number of casualties in traffic, but have not built a strong protection system, fail to manage traffic safety, and record large fluctuations in the number of casualties (Serbia, Croatia, Macedonia, Montenegro, Bosnia and Herzegovina, Romania, Bulgaria, etc.)

3. countries that have not yet accepted the idea of traffic safety management (most countries from the African continent, India, etc.).

The basic guidelines in the field of action towards improving vehicle safety are: [15]

1) the vehicle must not be the cause of a traffic accident,

2) the vehicle should prevent a traffic accident when there is an error of traffic participants, a road error or other dangerous situation,

3) the vehicle should prevent or mitigate the consequences of a traffic accident.

Problems of traffic safety in the Republic of Serbia related to vehicle safety are: [15]

1) the average age of vehicles in the Republic of Serbia is more than 16 years, which is directly related to the economic standard of the population,

2) inconsistent implementation of regulations and procedures related to the control of technical correctness of vehicles,

3) production and placing on the market of non-homologated and low-quality parts and equipment of vehicles,

4) inadequate maintenance of technical correctness of vehicles,

5) a large number of unregistered and technically defective tractors,

6) a large number of unlit and unmarked vehicles in traffic (trucks, tractors, mopeds, bicycles, working machines),

7) small percentage of vehicles with sufficient elements of active and passive vehicle safety,

8) insufficient promotion of „clean" and energy efficient vehicles.

A REVIEW OF THE THIRD PILLAR OF TRAFFIC SAFETY

According to the paper [16], the third pillar of traffic safety (Safer Vehicles) is in the Development Phase, given that the percentage of performance in relation to the maximum performance is 66%. The third pillar of traffic safety is in the Development Phase, which represents a higher level of development status and implies that certain procedures have been adopted but are not systemically linked, and there is no systematic, planned and well-coordinated, synergistic contribution to strategic traffic safety goals. The third pillar (Safer Vehicles) is considered through the following eight areas: Legal Framework, Strategic Framework, Traffic Safety Financing, Data-Based Traffic Safety, Science-Based Traffic Safety, Safe system approach, Capacity and integrity of the most important stakeholders / institutions and Performance of the most important institutions. [16]

Having in mind the goals of the national traffic safety strategy, as well as the fact that Belgrade largely participates in achieving those goals, these will be the final goals (defined for 2020), but the so-called transitional goals (by years from 2017 to 2020), achieved by implementing measures and activities in key areas of work, which are systematized according to the pillars of the Global Plan of the Decade of traffic safety action [17]:

1. improving the organization and management of traffic safety,
2. improving road and street safety,
3. improving the safety properties of vehicles in traffic,
4. improving the behavior of traffic participants and
5. improvement of action after a traffic accident.

In order to improve the safety properties of vehicles in traffic, the City of Belgrade will establish regular field research on safety and other properties of vehicles in traffic, analyze the situation, inform the public about the results and conduct campaigns aimed at improving the safety properties of vehicles in traffic. mandatory equipment, especially in winter conditions, etc.). In the annual traffic safety programs, the city of Belgrade will implement support to the owners of agricultural machines, which use public roads, by purchasing and distributing appropriate rotating lights and appropriate campaigns. In order to better visibility and visibility of bicycles, the City will encourage the use of appropriate lights and retroreflective materials for bicycles. Appropriate campaigns will be conducted for motorized two-wheelers, in order to improve the visibility and technical correctness of these vehicles. [17]

The basic guidelines in the field of action towards improving vehicle safety are, [18]:

- improving the quality of technical inspections in the city,
- establishment and improvement of a system based on the concept that the vehicle must not be a contribution to the occurrence of a traffic accident,
- promoting a system in which the vehicle should prevent a traffic accident when there is an error of traffic participants, a road error or other dangerous situation,
- systematic planning of control and sanctioning of congestion of trucks on local roads
- improving the vehicle element in order to prevent or mitigate the consequences of a traffic accident.

Problems of traffic safety on the territory of the city in connection with vehicle safety are, [18]:

- insufficient knowledge of the driver about the importance of a safe vehicle, ie the magnitude of the impact of a faulty vehicle on the occurrence of a traffic accident,
- inadequate maintenance of technical correctness of vehicles,
- inconsistent implementation of procedures related to the control of technical correctness of vehicles, which characterizes the entire Republic of Serbia,
- a large number of unlit and unmarked vehicles in traffic (bicycles, trucks, mopeds, work machines),
- insufficient control of truck overload,
- small percentage of vehicles with sufficient elements of active and passive vehicle safety and
- insufficient promotion of „clean" and energy efficient vehicles.

Vehicle safety should be improved by improving existing procedures and harmonizing with relevant world standards and mechanisms, with the aim of faster adoption of new technologies that affect safety. Activities within the third pillar according to the strategy are

related to vehicle standards and vehicle technical inspection. Within the vehicle standards, activities related to the improvement of the vehicle and parts type-approval system, the improvement of the vehicle certification system, and incentives for the procurement of new vehicles are envisaged. Within the Check of technical correctness of vehicles, the following activities are envisaged related to:

- Improving procedures and updating the methodology of performing technical inspections,
- Improve the system of emergency control of technical correctness of vehicles,
- Publish the results of the control of vehicles sent for extraordinary technical inspection by the police along with the data on regular technical inspections,
- Publish statistics on technical inspections of vehicles,
- Improve supervision and enable supervisory bodies access to data from the information system for monitoring the work of vehicle technical inspection stations,
- Review the legal regulations regarding the issuance of approvals for the operation of technical inspection stations,
- Introduce procedures for technical inspection of vehicles after major repairs or alterations to the vehicle,
- Upgrading of standards when inspecting vehicles depending on age,
- Accreditation of technical inspections according to the ISO 17020 standard for inspection bodies,
- Technical inspection of the vehicle after a traffic accident.

METHOD AND RESEARCH RESULTS

The paper [12] presents the values of traffic safety indicators related to the vehicle fleet, which were collected within the project „Research of traffic safety performance indicators for 2018", implemented by the Traffic Safety Agency. The project collected data on the values of indicators according to the police administrations in Serbia, which are aggregated at the national level. By analyzing the age of passenger cars in Serbia, it was found that there are 133,051 cars under the age of 6, which is about 7% of the vehicle fleet. There are 1,450,501 passenger cars older than 10 in Serbia, which is 76% of the vehicle fleet. Passenger vehicles over 15 years of age were also analyzed, of which there are 682,801, ie. about 36% of the total number of vehicles. The average age of the vehicle fleet in Serbia is 17.1 years, with the lowest average age in Belgrade (13.3 years), and only in Belgrade is the double-digit percentage of cars under 6 years (13.2%).

The method used in this paper is multiple regression. A regression model that contains two or more explanatory variables is called a multiple regression model and is given in the following form, [19]:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + \varepsilon \quad (1)$$

Where Y is a dependent variable, and X_1, X_2, X_3,…, X_k are explanatory variables, while ε is a random error of a multiple regression model.

In this part of the paper, it is examined whether the percentage of older passenger cars than 10 years in the fleet of a certain city and the average monthly net salary at the same city affect the percentage of passenger cars younger than 6 years in the city under study. Table 1 provides data on the percentages of passenger cars younger than 6 years and older than 10 years in certain cities of the Republic of Serbia from the 2018 survey, as well as the average monthly net salary in dinars for 2020. [12, 20]

Let them be:

Y - % of passenger cars under 6 years of age in Republic of Serbia from the 2018 survey, [12]

X_1 - % of passenger cars older than 10 years of age in Republic of Serbia from the 2018 survey, [12]

X_2 - average net salary in RSD in Republic of Serbia from the 2020 survey. [20]

Table 1. Data for multiple regression equation

Observation No.	City	Age of cars < 6 years (%) (Y)	Age of cars > 10 years (%) (X_1)	Average net salary in RSD (2020) (X_2)
1	Beograd	13.2	73.0	74,296
2	Novi Sad	6.2	82.2	67,933
3	Subotica	4.4	87.7	55,686
4	Zrenjanin	3.8	87.7	57,228
5	Pančevo	3.7	87.3	59,357
6	Kragujevac	3.2	89.3	57,371
7	Sombor	3.2	89.6	53,622
8	Čačak	3.1	90.3	51,401
9	Kikinda	3.1	90.4	54,809
10	Sremska Mitrovica	3.0	90.5	55,000
11	Niš	2.9	90.1	54,640
12	Požarevac	2.9	90.2	60,310
13	Užice	2.6	90.4	56,980
14	Jagodina	2.4	91.5	48,883
15	Bor	2.1	90.7	69,459
16	Kraljevo	2.0	92.3	50,881
17	Šabac	1.9	92.9	53,452
18	Kruševac	1.9	93.0	50,442
19	Valjevo	1.8	93.4	53,520
20	Novi Pazar	1.8	93.5	45,461
21	Smederevo	1.7	93.1	56,930
22	Pirot	1.4	94.5	57,213
23	Leskovac	1.4	94.7	47,475
24	Zaječar	1.3	93.8	52,897
25	Vranje	1.3	94.8	49,828
26	Prijepolje	1.2	94.9	46,050
27	Prokuplje	1.2	95.4	51,055

The estimated regression equation is:

$$\hat{y} = 54{,}42 - 0{,}5445 \cdot x_1 - 0{,}000039 \cdot x_2 \quad (2)$$

The values of the standard regression error, the coefficient of multiple determination and the corrected coefficient of multiple determination are:

$$s = 0{,}504140; \quad R^2 = 95{,}76\%; \quad \overline{R}^2 = 95{,}41\% \quad (3)$$

The standard regression error is about 0.5. Value R^2= 95.76% shows that % of passenger cars older than 10 years and average net salary in RSD explain 95.76% of the variation % of passenger cars under 6 years of age. The value of 95.41% is the value of the coefficient of multiple determination corrected for the number of degrees of freedom. After correction, it follows that the mentioned two explanatory variables explain 95.41% of the variation of the dependent variable.

The value of b_1= - 0.5445 in the estimated regression model shows the change in y at a unit increase of x_1, while x_2 is constant.

The value of b_2 = - 0.000039 in the estimated regression model shows the change of y at the unit increase of x_2, while x_1 is constant.

In those cases, there is a negative relationship between the observed two variables (y and x_1, y and x_2).

Figure 2 shows histogram of residuals, normal probability plot of residuals, residuals versus fits and residuals versus order. One of the evaluation criteria is the least squares method. The method consists in taking the value for which the sum of the squares of the residual is minimal to estimate the parameter. Residuals (errors) should be approximately normally distributed, which is in accordance with Figure 2.

CONCLUSION

The age of the vehicle fleet is largely related to the economic situation in the local community. The local community has very little or limited opportunities to influence the condition of the vehicle fleet. The key parameters of action on the condition of the vehicle fleet, and thus on the vehicle safety indicators, are within the state competence. The fleet renewal policy brings vehicles with driver assistance systems, which can significantly contribute to the reduction of certain types of traffic accidents. The national fleet strategy must be based on a fleet renewal policy, in line with the vehicle's innovative safety features. Vehicle-related traffic safety indicators were considered in Republic of Serbia for the first time in 2018, which is why it is necessary to encourage similar research in the coming period. The limitations of the paper are in the fact that the analysis was done only on a sample of one year (data on the age of cars from 2018 (from paper [12]) and data on salaries from 2020) and that only the category of passenger cars was used.

The directions of further research would be turned to the calculation of traffic safety indicators by municipalities, such as the traffic safety indicator related to the vehicle fleet in the regional unit and the vehicle fleet indicator for the national level (Republic of Serbia) and their comparison for a period of 5 years.

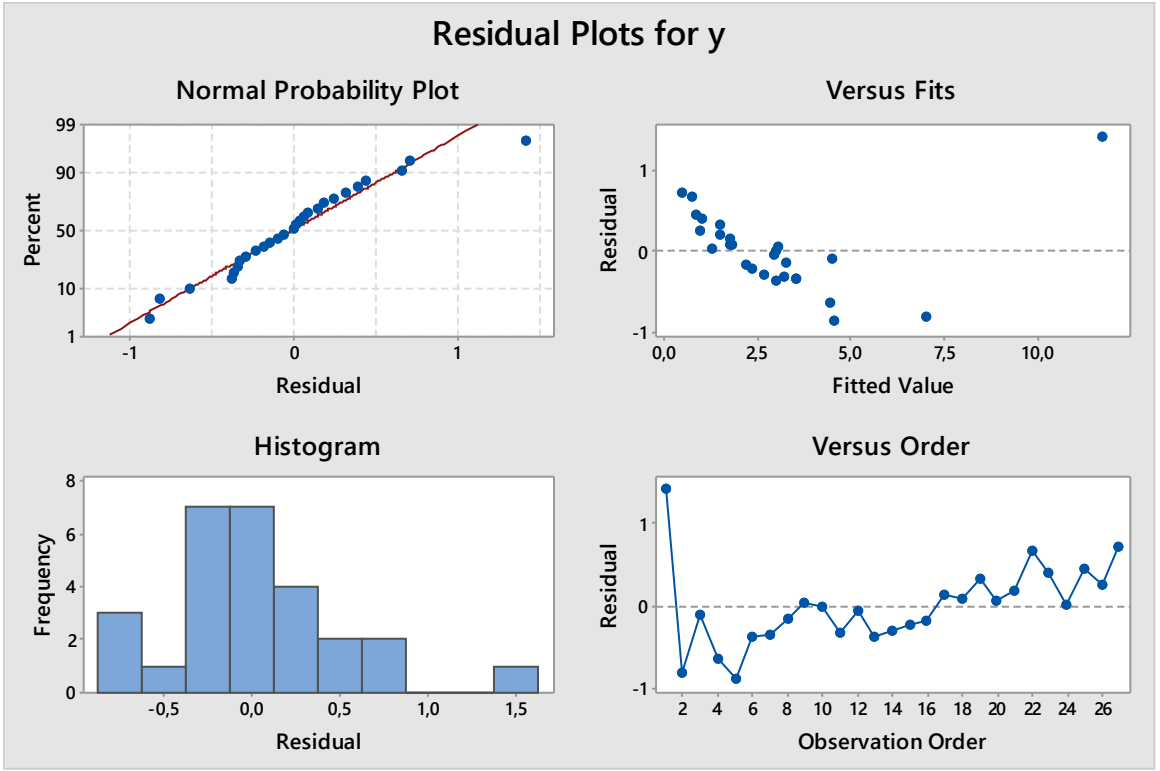

Figure 2. Plots of multiple regression equation

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PRELIMINARY REPORT

Analysis of Road Vehicles' Lifecycle Stages

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Abstract: The paper deals with the issue of lifecycle stages of motor vehicles. This topic is trending around sustainability issues, given the very unfavorable age structure, increasing import of used cars, which causes an increasing intensity of the number of waste vehicles. This situation creates problems with management of all kinds of waste. Optimal life of a motor vehicle is 10-15 years on average. Individual phases of lifecycle are indicated differently with multiple parameters. All phases are influenced by many factors, but this paper focuses on maturity and decline phases. Key findings suggest that different market, business and environment indicators define the key stages of the lifecycle-maturity and decline stages. Future research will expand the sample on other countries from the Balkans region.

Keywords: vehicle, lifecycle phase, transport.

INTRODUCTION

Motor vehicles function throughout their lifespan as the time of its use from the for-mation of the idea, design, and development of construction, production, placing the motor vehicle on the market - operation, its use, maintenance, obsolescence and until the very end of its use.

In [1] it is revealed that majority of research papers in top tier journals dealing with lifecycle of motor vehicles, have been published only in the last ten years, making this a topic of significant interest for any research dealing with sustainability. Papers are dealing mostly with environmental (or technology- i.e. related to engine technology) indicators influencing lifecycle phases of motor vehicles, but this research attempts to broaden the scope of indicators via empirical research. In [2] it reports that only one third of research papers includes a case study or empirical research.

Discussion about environmental issues concerning motor vehicles has been going on for 10 years in the EU Parliament. In 2000, the EU have adopted Directive 53, which provides a clear direction for all decision makers, to provide minimum amounts of reusable materials and vehicle parts, recycling and energy restored [3]).

It also included investigation of paradigm of sustainable growth as a consequence of recy-cling end of life vehicles, determining business decision, government support, and volume (number) of end of life motor vehicles, as critical enablers of success.

MATERIAL RESULTS FROM LITERATURE REVIEW

Maturity phase deals with the specific period of lifecycle when the peak moment of operational capability of a motor vehicle approaches. Very often, drivers (in case of pas-senger cars) or decision makers (in case of fleet management of commercial vehicles). Taking into account the fact that the market is already saturated with many kinds of new models of motor vehicles, which causes large pressure on further shortening of lifecycle of used cars.

Motor vehicle is declared obsolete by two means-market trends and technology/car manufacturing trends. Market trends are reflected through change in demand for a certain type of motor vehicle, and emerging trends are depicted through introduction of new types of engines, fuel technology, new functions and functionalities. Figure 1 displays key lifecycle stages in the case of motor vehicles.

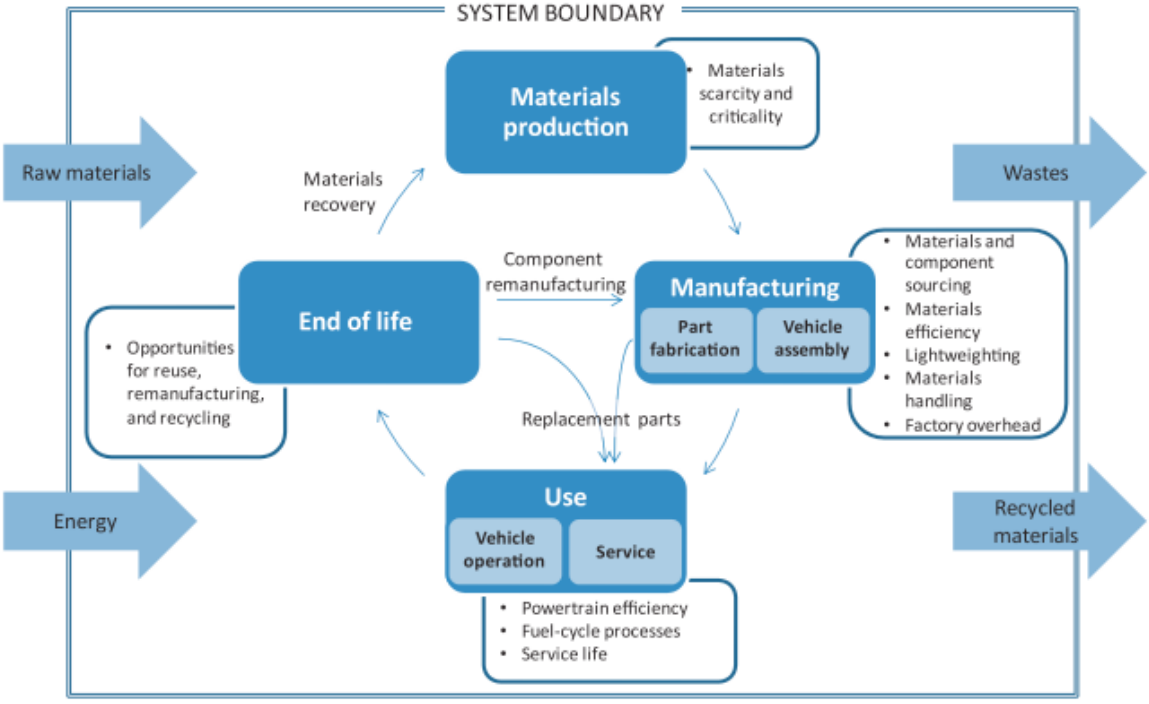

Figure 1. Lifecycle framework for a motor vehicle with reflection to environmental impact [4]

It can be concluded that decision about motor vehicle replacement represent a trade off between different impacts, which supports previous, older study performed [5].

Maturity phase is followed by decline phase, where all motor vehicles eventually become obsolete (otherwise called end of life phase), creating 1% of all waste in Europe [6], investigated decline phase of lifecycle in the case of commercial trucks and found that light duty trucks enter the decline phase when emissions of greenhouse gases drastically increase (compared to average emissions during the whole lifecycle).

Now follows a display of potential key indicators for distinguishing between lifecycle stages in Table 1.

Table 1. Analysis of key indicators defining lifecycle stages of a motor vehicle

Indicator defining lifecycle stages	Previously researched in
Emergence of new engine technology	[7]
Innovation of vehicle manufacturing	[8]
Market trends regarding demand and supply	[9]
Eco friendly technologies connected with vehicle manufacturing and recycling	[10], [11]

In [12] there is analyzed transport sector incentives for purchase of electric vehicles, through the decarbonization initiative, so it can be concluded that external incentives can also influence the retirement of existing vehicles.

Depending on passenger car size and emissions connected with fuel engines, major EU markets, China, USA and Japan recorded a significant shift in the last decade, switching from petrol to electric vehicles in the segment of larger cars (SUVs etc).

In the case of medium and heavy-duty trucks, entering the last stage of the lifecycle occurs when total cost of ownership increases drastically (as previously investigated also in [13] because the likelihood of sudden end of life a motor vehicle increases drastically.

Apart from environmental (emissions) and economic dimensions, such as the research conducted in [14], there it was analyzed interdependency of fuel technology and maintenance costs of engines, as the main distinguishing factor.

CONCLUSION

This research enabled introduction to different factors influencing maturity and decline phase of motor vehicles's lifecycle. Since the characteristics of both lifecycle phases were developed through theoretical analysis, it is important to discuss the results with potential previous papers by other authors.

Apart from taking into consideration the most obvious indicator (age of motor vehicle), it is possible to conclude the following:

- regarding maturity phase of lifecycle – since maintenance costs are optimal with number of kilometers travelled is as high as 200.000 kilometers, this phase is also characterized with low to

medium external costs,

- GHG emissions, market appeal is still more important than technology, and the potential for recycling is medi-um to very high- during this phase majority of resources can be reused;
- regarding decline phase of lifecycle – in this phase, maintenance costs are no longer sustainable after passing the 200.000km mark, external costs are higher than ever, GHG emissions are higher than ever and influence of brand loyalty is dropping significantly. Lastly, potential for reuse of resources is minimal and end of life is approaching where the vehicle shall be put out of order through waste management.

In [15] it is analyzed the life cycle sustainability by taking into account corporate, social and eco-friendly parameters/indicators. This paper expands on it by introducing market trends and some environmental indicators. Also, this study presents a preliminary effort to distinguish between key lifecycle stages of a motor vehicle.

This study can be a useful addition to previous studies which analyzed life cycle of motor vehicles through input-output analysis, where appropriate analysis enabled initial definition of boundaries between the key lifecycle phases.

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PRELIMINARY REPORT

Key Impacts on Environmental Improvements in Case of Road Transport Companies

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Abstract: This research includes the analysis of key impacts on environmental improvements, which are engaged in road transport of cargo or passengers. The basic assumption of this paper is that the level of fulfilment of environmental standards (measured by decreasing emissions of harmful gasses) is largely conditioned by the external influences, such as business strategy, performance or logistics management activities. The main goal of this paper is to theoretically identify key impact in the case of transport companies when it comes to potential for improvements of environmental indicators. Improvements for the living environment can be caused by fleet renewal, tighter vehicle lifecycle management and via different government regulations. Key findings suggest that the fact whether a road transport company does business internationally. Future research involves extending this sample of road transport companies to all Balkan countries, who are members of the EU or are candidate countries. Additionally, future research should be including additional environmental indicators that are not conventionally measured during vehicle inspections.

Keywords: logistics, road transport company, sustainability.

INTRODUCTION

In the case of road transport companies, small profit margins and large competition cause a drastic increase (larger than ever before) in the number of routes driven and ship-ments being delivered. More often than not it occurs that efficient fuel savings, emissions decrease, are not prioritized at all in road transport companies [1], followed by the fact that there are no incentives helping haulers to become more efficient.

The largest share of freight transport in Europe is recorded in the case of road transport companies (among rail, air, water and other types), with companies from Germany and Italy who are recording the biggest turnovers [2].

Several EU targets have been set to reduce the environmental impacts of transport in Europe, including its greenhouse gas emissions. The transport sector's targets are part of the EU's overall goal to reduce greenhouse gas emission by 80-95% by 2050.

Finally, studies show that top tier transport companies position their peak performance goals according to successful management of these indicators of business performance [3], but also in combination with all other important indicators.

MATERIAL RESULTS FROM LITERATURE REVIEW

In [4] was defined several most important indicators of operational performance, dividing them by process - procurement, manufacturing, warehouse, delivery and transport, delivery and post-sales service. Previous research papers considered various indicators of operational performance, which can distinguish and measure success between transport and logistics operations.

During the last 20 years, several authors analysed the majority of important indicators of operational performance of cargo carriers, such as capacity and on time delivery [5], covered distance measured in kilometers and finally productivity measured through the amount of transported cargo or number of passengers over time, lead time for domestic market [6]. On the other hand, in [7] found, in the case of large trucks operating in Spain,

that maximizing gross load of vehicles (up to 44 tonnes per truck) causes a decrease in number of deliveries, and indirectly influence lowering emissions into the air.

Inter-city bus operators can add or remove routes between cities relatively easy, al-lowing them to enter different European markets on a short-term test basis, or to modify type of passenger transfer service rapidly as markets change and emerge. In [8] supports this correlation between attracting new passengers and increasing number of totally new buses in fleet.

In [9], there was conducted an efficiency evaluation of bus transport companies with and without taking into account environmental emissions, concluding that most research assumed that profit maximization strategy was limited by neither environmental emissions nor government regulations, and that efficiency meas-urement and productivity analysis have been rarely analyzed before. Consequently it is not clear whether larger fleets (companies with more than 250 employees) are modernized quicker and more often (innovation cycle is shorter), and are indirectly causing decreased emissions towards the environment.

In a study [10], it is suggested that heavy-duty vehicles (cargo transport trucks) are one of the most significant contributors to emissions and air polution in transport of goods outside cities (in contrast to light duty vehicles being the most common type). Additionally, heavy-duty vehicles are interesting for environmental topics also because of the type of cargo they are carrying, since dangerous cargo is entirely related with large trucks.

Fuel consumption per km presents on its own a very important indicator of influence towards the environment, and various efforts are made to improve that parameter, as previously analysed in [11].

Another very important indicator (often avoided by business decision makers) includes emissions of CO2 (measured in total number of kilograms per km). According to [12], emissions of harmful gas such as CO2 grew by 27% over the last 30 years, and account for majority of all transport-caused emissions in the last few years.

Figure 1. displays key targets for reduction of harmful gas emissions until 2050.

Taking into account a wider time horizon, the situation regarding emissions of road transport carriers is even worse, since it has drawn attention to a record growth of emissions caused by road transport, from majority of total emissions in the 20th century, to almost three quarters in the first decade of 21st century. Figure 2. indicates that most significant reduction of emissions is due to happen in the case of vans and cars.

Marginal cost analysis handled in [14] initiated a concern whether smaller road transport companies are even able to consider fleet modernization and investment in ecology projects. Overall (CO2, NOx) emissions from worldwide road transport activities are projected to increase by double until 2050 [15], opposed to the fact that CO2 emissions in Europe are predicted to drop almost by a half in the next 10 years [16]. Also, near zero reduction in emissions is desired until 2050, and around 80% reduction from overall transport (commercial and private) [17].

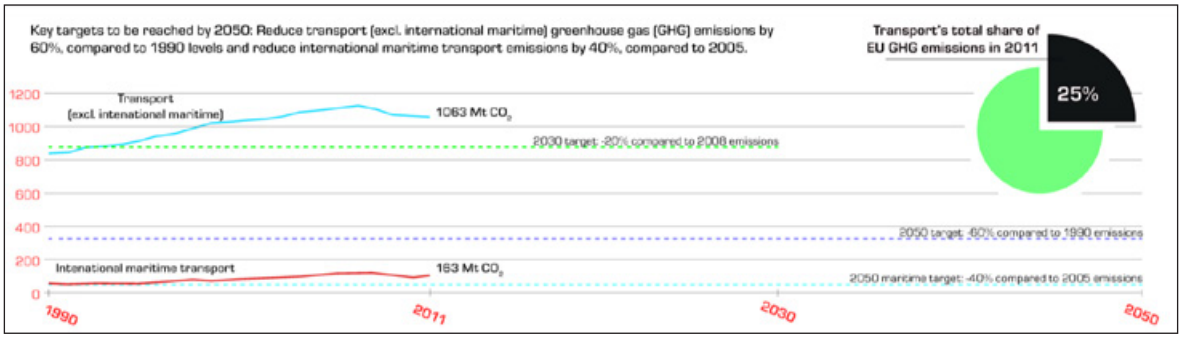

Figure 1. Share of total emissions due to transport activities [13]

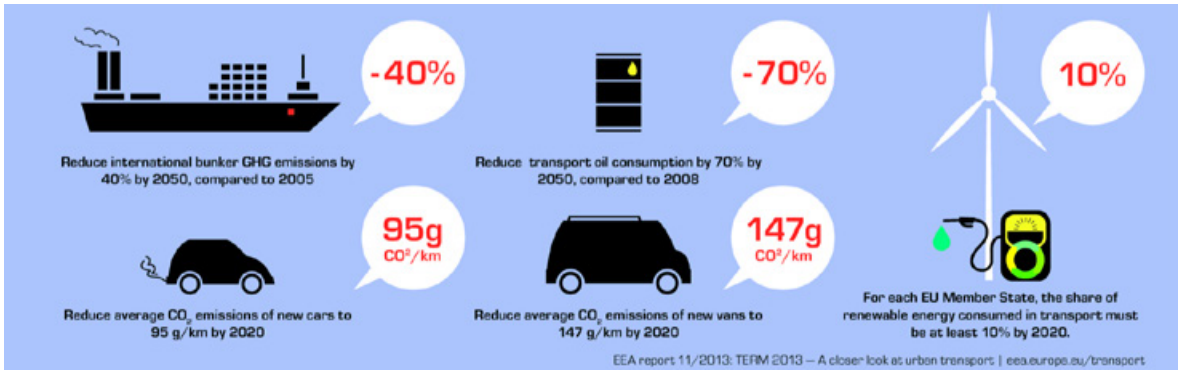

Figure 2. average reduction of emissions as the main effect of environmental impact [13]

Therefore, it is very clear from a strategic point of view that transport businesses need to align their investment plans with EU trends and predictions. For the purpose of this re-search, it is not clear whether it is easier to commit to environment protection goals when doing business at large, and hard to think about it when counting every penny spent and every mile crossed.

CONCLUSION

Taking into account everything analysed throughout this paper, in order to comprehen-sively understand the problem, the existing rationale about impact on the environment can be adequately expanded with the following, that key impacts are oriented around profitability and expansion of fleet (trucks). Mixed with key indicators of operational performance (fleet size and internationalization), findings show that companies doing business locally tend to be oriented towards profitability (with less investments in new fleet), while larger are focused on fleet modernization and achieving greater success on international markets (all of this leads to incumbent environmental improvements). But, further analysis is certainly necessary, to be able to fully understand the perspective for the whole region (majority of neighbour countries are in the EU).

There is a clear gap left for further research since there is a clear preference of the EU for further expansion and integration, at least in terms of business relationships with West Balkans countries. Another iminent contribution of future research is to establish more knowledge about road transporters who operate outside large supply chains, their approach to logistics management, as well as to describe additional examples from Serbia as one of countries outside EU with the prospect of becoming moderately developed with regard to sustainability.

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REVIEW

2014 Doboj Floods – Consequences and Hazard Elimination Activities

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Abstract: The Republic of Srpska is susceptible to natural disasters, with particular regard to floods. Floods had caused human losses and property damage to both civilian and commercial facilities, road infrastructure and other infrastructure, on several occasions, including the 2014 floods. It is not always possible to predict natural disasters but human and material losses may be reduced if institutions undertake planned prevention activities and educate the population in terms of flood protection and risk reduction. The paper addresses floods as the natural disaster to which the Republic of Srpska is susceptible due to a long network of non-regulated water streams and frequent heavy rains. A special attention is paid to the floods which heavily affected the city of Doboj in 2014 as we analyze the activities on hazard elimination and consequence mitigation. The analysis is based on the study, assessment and plans designed in order to protect the city from floods in near future. Along with that we analyzed the impact of floods on the changes in the size of traffic flow requirements on the part of the M-17 road damaged in floods.

Key words: natural disaster, floods, hazard, consequence, defense.

INTRODUCTION

Natural disasters[1] consequentially occur due to activities of forces of nature and severely affect humans, other living beings, and property. Most common natural disasters are drought, earthquakes, fires, landslides, drifts, stormy winds and frost. Climate change has had an increasing impact on the frequency of natural disaster occurrence with floods being the most common natural disaster in the Balkans [2]. Hence, scientists and general public have been paying a growing attention to the flood risk mitigation and protection [11]. Flood is an overflow of water from both natural and artificial recipients, i.e. riverbeds and water accumulations. Being a natural process and an atmospheric and hydrological phenomenon, floods may last long and disturb large areas with massive consequences for humans, environment, property, agricultural soil and road infrastructure [3].

According to the origin, there are several categories of floods – floods caused by rain and snow melting, ice jams, floods caused by high water levels, torrential floods, floods caused by landslides, and floods caused by dams or levees cracks. Other than water amount and hydrological regime, the following parameters are crucial for flood occurrence – size and shape of the watershed, river network density, terrain slope, meander features of the riverbed, the ratio of surface water and groundwater outflow, woodiness of the terrain, and the deposit ratio [4]. Given the timeline of the flood wave formation, floods may be slow-rising floods (typical of large rivers), torrential floods (hilly areas) and sudden floods (large flood waves are formed due to crashing of hydropower or water management facilities). According to the size, floods may be minor, moderate, major and catastrophic [3].

From the hydrological point of view, the Republic of Srpska is relatively rich in surface and groundwater hydrological networks. All the major river streams are parts of the Black Sea drainage basin. The backbone of the Black Sea drainage basin is the low-lying Sava River water stream fed by the rivers of Una and Sana, Vrbas, Ukrina, Bosna and Drina. All these river streams are characterized by composite river valleys with large river slopes and distinguished hydro-energetic potentials. In addition, the Republic of Srpska has suffered climate change effects resulting from natural element activities and laws of wide air mass circulation. Summers are warm and winters are moderately cold, the mean annual air temperature being above 10°C. The distribution of precipitation has been rather uniformed and largest amounts are poured down in May and June. As a rule,

1 "Natural disasters are hydrometeorological, geological and biological phenomena caused by forces of nature: earthquakes, floods, torrentuous floods, heavy rains, atmospheric outbursts, hail, drought, drifts, landslides, avalanches, extreme air temperature, waterstream freezing, infectious disease epidemic, vermin, and other large natural phenomena which may threat the well-being of humans and cause large damage" (*Zakona o zaštiti i spasavanju, 2012*).

the amount of precipitation declines from west (1500 mm) to east (700 mm) due to air flow from the west [1].

Given the abovementioned facts, we may say that floods, including torrential floods, are the most common natural disaster in the Republic of Srpska in terms of human and material losses and that they occur in both rural and urban areas. Most rivers in the country are likely to occasionally overflow and floods are even more likely to take place in plain areas [11]. The regions most susceptible to floods are the middle and upper streams of the Sava River tributaries: Novi Grad, Prijedor (the Sana River), Banja Luka (the Vrbas and Vrbanja rivers), Čelinac (the Vrbanja River), Doboj, Šamac and Modriča (the Bosna River), Foča, Novo Goražde, Zvornik, Bijeljina (the Drina River), as well as the following settlements along the Sava River valley: Kozarska Dubica, Gradiška, Srbac, Brod, Derventa (the Ukrina River), Šamac, Brčko and Bijeljina. Speaking of karst fields, the most threatened ones are Gatačko polje, Nevesinjsko polje, Dabarsko polje, Fatničko polje, Bilećko polje, Trebinjsko (Mokro) polje, Ljubomirsko polje, Ljubinjsko polje and Popovo polje [9].

Erosion and torrential floods are another threat for the watersheds in the Republic of Srpska. Torrential floods have a large impact on roads, settlements, and agricultural soil in river valleys. The estimations indicate that around 85% of the Republic of Srpska's territory is affected by erosion, which is most pronounced in the Drina River watershed (around 94% of the watershed suffers some type of erosion) and the Adriatic Sea drainage basin (around 93% is affected by erosion). The Sava River watershed is where the erosion occurs the least frequently (around 49% of the watershed). High intensity erosion (category I – excessive, II− intense, and III – moderate erosion) affects only 15% of the overall territory suffering from erosive processes, whereas most territory registers weak erosion processes which can be addressed through biological protection measures. The following river streams are well-known for erosion processes: the lower Una River, parts of the Sava River watershed (the Gomjenice River), the narrow Sava River watershed (the Vrbaška and Jablanica rivers, parts of Tinja Brka and Lukavac river stream), the lower Vrbas River (rivers of Vrbanja and Turjanica, the narrow Vrbas River watershed, the Povelič River), The Ukrina River watershed (rivers of Vijak, Mala Ukrina and Velika Ukrina, the narrow Ukrina River watershed down to the town of Derventa), The Bosna River watershed (The Usora, Glogovica, Lovnica and Zarječje river streams), the Drina River watershed (the Janja and Tavna river streams, parts of the Drinjača river stream, the Lim and Rzav, and Križevica river streams), the Sušica river stream within the Trebišnjica River watershed [6].

The Republic of Srpska witnessed major floods in 2014. It was the intensive precipitation from March to May that caused overflows in the rivers of Bosna, Sava, Drina, Vrbas, Una, Sana and their tributaries, resulting in sudden and extreme floods in many cities and municipalities [10]. In the year of 2014, the Bosna River and its tributaries flooded the city of Doboj and the municipalities of Šamac and Modriča, causing human losses and massive property and infrastructural damages. Given the fact that the Bosna River overflow resulted in a large number of human victims and major infrastructural destruction in the city of Doboj, this paper accounts for the consequences the flood left in both city center and suburban areas. The paper also provides an analysis of activities conducted in order to eliminate the hazard and mitigate consequences as well as the city's flood defense plan. Finally, we provide certain recommendations in regard to protection improvement and rescue plan for the near future.

CONSEQUENCES OF NATURAL DISASTER – FLOODS IN THE CITY OF DOBOJ

Massive precipitation occurred in the territory of the city of Doboj in March, April and May 2014 causing catastrophic flood and landslide as the Bosna River[2] and its tributaries Usora and Spreča overflew the riverbed. The immeasurable consequences were manifested in the destruction of housing, commercial and public facilities, interruption of public and telecommunication traffic, water and electricity supplies, and finally, severe devastation of agricultural soil, buildings and forests.

Doboj has witnessed three major flood threats in its recent history: on May 13, 1965 the maximum water level was registered at the Doboj gauge station at 142.79 m altitude; on June 21, 2001 the maximum water level was registered at 142.47 m altitude; and on May 15, 2014 the maximum water level was registered at 144.41 m altitude. The latest flooding water level was 1.5 meters higher than those ever registered before. The first two water levels were approximate to the so-called centennial statistical probability of high water level, and the third maximum was around 1 meter higher than so-called millennial statistical probability of high water level [5].

Causes and types of damage initiated by flood

From March to May 2014, the city of Doboj was exposed to a series of cyclones resulting in constant rainfall and occasional heavy rainfall. Massive precipitation was particularly pronounced from 14th to 18th of May (150 liters per square meter), which later led to a sudden increase of water level in riverbeds. Another crucial factor, which led to impaired hydrological circumstances at the Modrac dam and the Spreča River, was the sudden water inflow to the lake and the consequential increase of the Bosna River water level. The water inflow to the lake was 1.600 m^3/s at 03:00 pm on May 16, 2014, and the water

2 The Bosna River is 275 kilometers long, 35-150 meter wide, 1-7 meters deep.

outflow from the lake was 1.137 m^3/s at 01:00 p.m. on May 16, 2014. Two factors acted simultaneously. Massive precipitation and abundant discharge from the Modrac Lake resulted in an alarming situation at the hydrological systems of the Bosna, Spreča and Usora rivers, finally causing major floods in the city of Doboj. The hydrological station on the Bosna River located near the pumping station in the city of Doboj registered the highest ever water level (730 cm) on May 15, 2014 [8].

Given that the soil was sodden by large amounts of water, many landslides accompanied the flood and caused damages to both private facilities and public infrastructure.

5.168 hectares of land were affected by the flood on the city of Doboj's territory. The flooding area of the Bosna and Usora rivers and inland river streams covered the surface of 4.676 hectares, and the flooding area of the Spreča River covered the surface of 492 hectares. Therefore, the flood covered the center of the city of Doboj, suburban areas and 33 other settlements. Along with the settlements located in the valleys of Bosna and Spreča rivers, the flood also affected parts of Stanari and Raškovci settlements. The total estimated losses were 172.688.971,95 BAM. 45.845.714,33 BAM was the damage on private buildings and private property, and 123.059.227,62 BAM was the damage of legal entities in terms of buildings, equipment, and indirect losses. There were 2.850 flooded housing facilities registered in the city center, suburban areas and other settlements.

The data outlined in Table 1 suggest that most of the damage was registered on private buildings and private housing facilities, which was 98.5% of total losses on private property.

Table 1. Estimated damages on buildings and citizens' property in BAM

Summary of damages on facilities and assets owned by private citizens								
Soil	Buildings	Equipment	Longterm plots of land	Livestock, fowl, fish, current assets	Household assets	Working capital	Other assets	Total
477.707,30	25.061.269,63	31.307,00	12.153,90	107.940,00	20.079.379,50	61.159,40	14.797,60	45.845.714,33

Taken from*: (Study on estimated damages, 2014)*

Consequences of the Doboj city floods did not only entail material damage but also human losses. Once the water withdrew from specific parts of the city, bodies of 11 victims were recovered from housing facilities and the cause of deaths was either drowning or connected with the flood. According to the information provided by the Ministry of Internal Affairs of the Republic of Srpska, there were four male and seven female victims aged 41 to 91. Speaking of body injuries, the "Sveti Apostol Luka" public hospital in Doboj registered 73 patients with minor and major body injuries.

It was the public road infrastructure that also suffered damages. According to the estimations of supervising authorities, the losses suffered by road infrastructure mounted up to 3.784.030,00 BAM (categorized roads – 433.350,00 BAM; uncategorized roads – 2.250.680,00 BAM; city roads and utility infrastructure – 850.000,00 BAM; infrastructure facilities – 250.000,00 BAM).[3]

In addition, the flood also resulted in interruption of regular social and commercial activities in the city of Doboj. Those activities mostly referred to postponed classes in primary and secondary schools and colleges, closed kindergartens, interruption of road and telecommunication traffic, urban and suburban transport, shutdown of businesses and social activities, stoppage of electricity and water supplies, etc [5].

Table 2 provides information on damages in terms of sectors of activity, i.e. commercial and non-commercial sectors. Commercial sectors which suffered most damage were trade (67.7% of total commercial damage), hospitality industry and tourism (11.3%), and handicrafts (7.5%). Taking into account the non-commercial sectors, it was the health and social care, education, science and culture that were most affected respectively.

Table 2. Overview of damages per sectors of activity

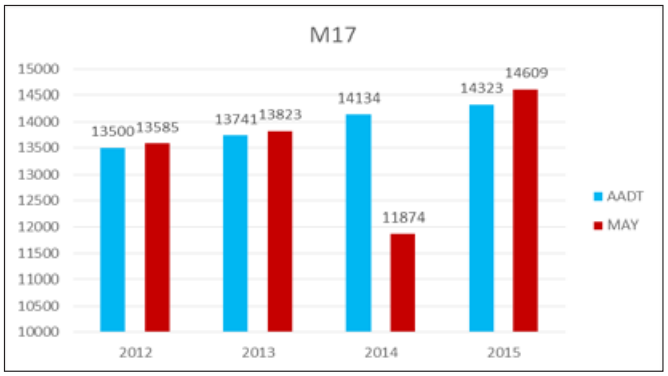
Description	No. of units	Total damage BAM
Commercial sectors	690	82.780.105,615
Industry and mining	4	910.601,91
Agriculture and fishery	6	1.734.769,72
Forestry	2	15.287,77
Water management	1	286.730,36
Civil engineering	18	4.217.708,62
Traffic and communications	7	1.799.448,14
Trade	325	56.074.710,58
Hospitality industry and tourism	130	9.361.475,72
Handicrafts	154	6.201.573,63
Utility services	27	1.092.584,96
Finances and other services	16	1.085.214,2
Non-commercial sectors	150	18.649.161,6
Education, science and culture	19	1.985.468,32
Social and health care	28	4.885.289,32
Other non-commercial activities	103	11.778.403,98

Taken from: (*Study on estimated damages, 2014*)

3 The amount does not include damages on regional and main roads, railways and agriculture.

The impact of floods on the size of traffic flow requirements on the part of the Doboj – Republic of Srpska border main road at location Karuše

On the part of the M17 main road, section 220 Doboj – Republic of Srpska border in the village of Karauše, an automatic traffic counter, number 000015, of the Republic of Srpska public company was placed. This part of the main road is one of the most traffic heavy parts of state roads in the Republic of Srpska and Bosnia and Herzegovina. The next graph shows the size of the traffic flow requirements from 2012 to 2015 as average daily traffic. In order to assess the impact of floods for the same analysed time period we also show the level of average daily traffic in the month of May.



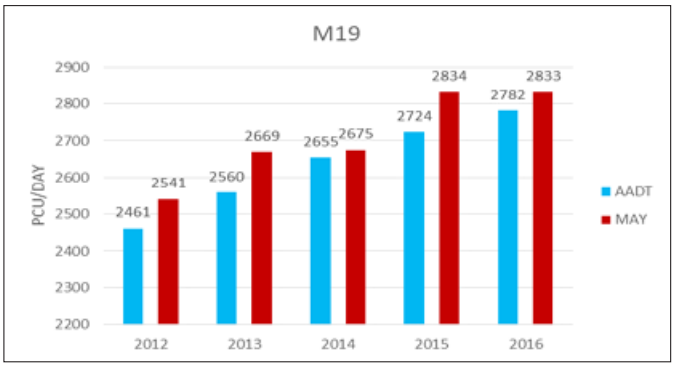
Picture 1. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000015 in the village of Karuše

As we can see in the previous graph, characteristics of the month of May are increased requirements for traffic flow copared to AADT. However, due to damages to this part of the road, 2014 shows drastic drop in traffic flow requirements to average of 2,260 vehicles per day. That means that in May, this road was travelled by 70,060 less vehicles compared to the monthly annual average. We can objectively presume that due floods the number of travel and transport of goods was partially decreased. However, until the section 220 of the M17 main road was repaired, a large number of vehicles was redirected to alternative roads, which increased transport labour, i.e. expenses of travel and transport of goods.

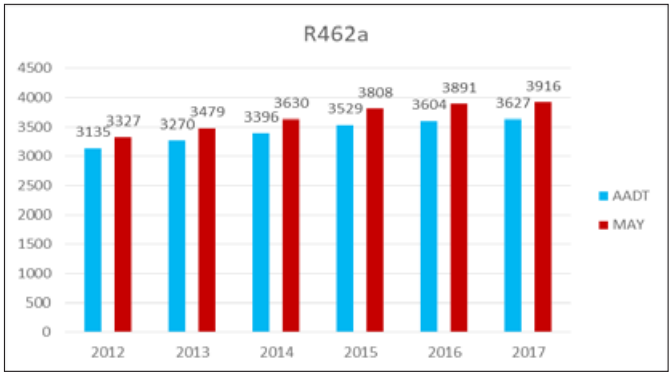
Similar characteristics of changes in traffic flow requirements were also identified at other sections of M17 main road near Doboj.

Comparative analysis of traffic flow requirements at other sections had also been damaged in the floods, a conclusion was drawn that the most damages caused by transport labour occurred at sections of the main road around Doboj.

The following graphs show changes in traffic flow requirements at Section 288 Konjević Polje Milići, M19 main road, i.e. at the automatic traffic counter 000033 at Dušavno residential area, as well as the section Grebnice - Obudovac 1 of the R462a regional road at the automatic counter 000052 in the village of Batkuša.



Picture 2. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000033 in the village of Dušanovo



Picture 3. Average daily values of traffic flow at annual level and for the month of May at the automatic counter 000052 in the village of Batkuša

As we can see at previous graphs, average daily load at analysed sections of the main and the regional road in the month of May is higher compared to AADT, i.e. does not deviate from usual trends.

Based on the conducted analysis we can conclude that the highest damages was caused by increased transport labour due to floods in the Republic of Srpska occurred on sections of M17 main road near Doboj.

ANALYSIS OF ACTIVITIES UNDERTAKEN TO ELIMINATE HAZARD AND MITIGATE CONSEQUENCES CAUSED BY FLOOD

The Republic Emergency Headquarters for the territory of the Republic of Srpska and the Doboj city emergency headquarters were formed as operational and expertize bodies to address the natural disaster caused by floods in the Republic of Srpska in April and May 2014. Also, the

Republic Emergency Headquarters appointed an expert team in order to facilitate the communication. On May 17, 2014, the Government of the Republic of Srpska adopted a Decision on emergency declaration in the Republic of Srpska due to regional flood threats. Nine days later, on May 26, 2014, the Government adopted a Decision on cessation of the Decision on emergency, with an exception of the cities of Bijeljina and Doboj and municipalities of Vukosavlje, Modriča, Šamac, Srebrenica, Donji Žabar and Šekovići. The Decision on emergency in the cities of Bijeljina and Doboj and municipalities of Vukosavlje, Modriča, Šamac, Srebrenica, Donji Žabar and Šekovići was set aside by the Decision adopted by the Government of the Republic of Srpska on June 20, 2014 [15].

Activities undertaken during and after the flood

All the activities undertaken on the city of Doboj's territory were instructed by the Republic Emergency Headquarters for the territory of the Republic of Srpska and the Doboj city emergency headquarters.

The activities undertaken during and after the floods were as follows:

- Engagement of all Civil protection resources,
- Engagement of commercial entities with resources to act during flood,
- Engagement of the Ministry of Internal Affairs of the Republic of Srpska,
- Engagement of specific resources of the B&H Armed Forces,
- Sharing information with the citizens through the media,
- Population evacuation,
- Pumping of the water from the flooded facilities,
- Conducting hygienic, epidemiological and health protection measures,
- Supplying the citizens with food, water, toiletries and other supplies,
- Reparation of infrastructure in terms of maintenance of regular water and electricity supplies.

One of top priorities was to evacuate people from the flooded housing facilities and provide them with temporary accommodation. The city Assembly allocated facilities for the temporary accommodation of people whose houses were flooded. The total of 108 people was accommodated in the facilities of "Retirement home", PE "Directorate for Construction and Development of the City" and PE "Doboj Senior Nursing Home", whereas patients were also evacuated from the "Dialysis Center". We should point out that the majority of citizens whose homes were located at lower floors were moved to higher floors in both private and joint buildings. Once the water withdrew, citizens whose houses were flooded voluntarily moved to their family, neighbors or weekend houses [5].

The Republic Emergency Headquarters for the territory of the Republic of Srpska adopted a decision to assign a telephone number through which the citizens could report missing persons in Doboj or other threatened areas. The call center was open 24 hours a day [14].

The rescue activities were supported by the members of the Helicopter Service of the Republic of Srpska and the B&H Armed Forces who offered the Miljkovac barracks to accommodate evacuated citizens and water and food supplies. The Ministry of Internal Affairs of the Republic of Srpska and the B&H Armed Forces continuously coordinated the activities to distribute food and water through all boats and vehicles available. The available vehicles allocated to the Republic Emergency Headquarters were then at the disposal of the Doboj PSAP, who coordinated the evacuation. Food and water were transferred via boats, but once the water withdrew the water and food supplies continued via military trucks. During the first seven days, food was distributed through the heads of condominium communities for all the citizens (around 30.000 users). Afterwards, the Republic Emergency Headquarters reached a decision to distribute water, food and baby products only for those directly affected by the flood (around 10.000 users). Starting from May 25, 2014, distribution points were used to allocate humanitarian aid more easily. Hot meals were served for 1.300 public center users on a daily basis with 152 volunteers engaged in aid distribution.

Once the rainfall ceased and the water withdrew, The Republic Emergency Headquarters engaged all available resources, equipment, people and companies in order to restore the catastrophic flood damage in the city of Doboj, particularly in terms of cleaning the city and removing the bulky garbage. Many fire squads were employed in order to drain water from flooded underground facilities and provide tanks with drinking water. The assistance was offered by the cities and municipalities of Banja Luka, Trebinje, Prnjavor, Bileća, Teslić, Celje, Srbac, Rogatica, East Sarajevo, Foča, Gacko, Mrkonjić Grad, Ugljevik, Višegrad and Petrovo.

The city health centers managed to adequately distribute medicines and hygienic products to all citizens regardless of extremely difficult circumstances. Following the flood, disinfection, disinsection and deratization of the flooded areas and facilities were conducted in order to prevent possible epidemic and infection among the population [5].

The floods were followed by many activities undertaken by both the Government of the Republic of Srpska and the city of Doboj focusing on incentives for private citizens and legal entities. The Government of the Republic of Srpska initiated a Solidarity Fund as a measure to mitigate the consequences of the floods. Also, as a priority, each flooded household was allocated the single payment in the amount of 5.000 BAM as an aid to restore the flooded facilities.

FLOOD DEFENSE PLAN IN THE CITY OF DOBOJ FOR THE UPCOMING YEARS

Most floods in the city of Doboj's territory are initiated by the overflow of the Bosna River, and partly the rivers of Spreča and Usora. The most pertinent torrential points in this catchment area are located along the riverbank from Ševarlija to Kožuhe settlements on the right Bosna River bank and from the city of Doboj to the Podnovlje settlement on the left riverbank. The water levels in the riverbeds vary and are largely dependent on the season and precipitation. The water levels reach their maximum in autumn and spring, and the minimum water levels are registered in late summer and early autumn.

It is the heavy rainfall and sudden snow melting, or both, that directly trigger the floods. The height of the flood wave is mostly dependent on the amount of precipitation and large concentration of long-term rainfall. Short downpours cause local floods but long rainfall affects the entire watershed of the rivers resulting in sodden soil and increased water level along the watershed. The Doboj floods were mostly a consequence of long rainfall within the Bosna River catchment area. The city flood defense was difficult due to the large zone of the Bosna River overflow over the main road. The zone was around 850 meters long, from the Usora River mouth to the Doboj electricity substation. The Liješanj brook is the next critical point which additionally complicates the flood defense [8].

Bearing in mind all the aforementioned facts, we may infer that there are four critical points in terms of flood in the city of Doboj. The following critical points at which the city's population is most threatened are as follows:

The first critical point – location

In cases of high water levels of the Bosna River, once the water level reaches 4.80 m at the measuring bar, the backwater at the Liješanj brook may cause the flooding of the Usora local community and the entire urban area up to the "Luka" pumping station. Nevertheless, a partial regulation of the Liješanj brook stream entailed the construction of a 2.5 meter high defensive wall. Along with the regular cleaning of the Liješanj canal, the chances of flooding were significantly reduced.

The second critical point - location

The overflow over the defensive embankment takes place once the Bosna River water level reaches + 6.00 meters and the inflow surpasses the riverbed capacities. The flood wave pours over the M-17 main road covering 4.150 meter distance, from the pumping station to the Usora's mouth into the Bosna River. There is a 3.200 meter long overflow over the embankment, ranging from the point where the local road intersects the M-17 main road, over the Makljenovac local community, Elektro Doboj substation, the turn to the "'Džungla" swimming pool from the M-17 main road, all to the pumping station located at the city entrance leading to Bare local community. Then, the water spreads quickly and devastates and floods the settlements of Usora, Centar and Donji grad. Both the population and property are threatened by the flood wave.

Encouraged by the May 2014 floods, the city of Doboj constructed a protection network against water overflow from the Bosna River. The 2.400 meter long defensive embankment is set along the M-17 main road, starting from the point where the local road intersects the main road to the Makljenovac local community and Elektro Doboj substation. The embankment includes mobile concrete blocks, which greatly decrease the chances of flooding the Usora settlement and the urban area. It was in 2020 that the entire riverbed of the Liješanj brook, the left Bosna tributary, was cleaned. There was also a partial cleaning of the Lukavica riverbed which covered 1.500 meters (from the stationary to the Bešići - Ostojići bridge), which solved the issue of the Lukavica overflow in the settlement of Bušletić [7].

The third critical point - location

There is a flood threat and potential breakdown of the city sewage pumping station due to intensive rainfall and downpours. The water which pours from the local hills down to the urban area triggers the flooding of lower floors in all facilities and 180 hectares of land. We should point out that there are no backup electricity supplies at the pumping station, which is yet another threat in cases of floods.

The fourth critical point - location

The Bosna River water level above +5.30 meters would trigger the flooding of facilities located along the „Šećerane" canal on the Usora River, and the „Luke" and „Bosanka" water supply lines' pumping stations because of the water retreating to the Bosna River and the lack of a pumping station at the canal. The same water level would also flood the City's thermal power plant in Pridjel Donji (ground floors at point 0) and the facilities located in low Poljica area along the Spreča's mouth into the Bosna River.

Apart from these four critical points which threaten the urban areas, we should also mention the rural areas. Namely, once the Bosna River water level reaches +5.50 meters, the entire Doboj region is under the flood threat due to the lack of defensive embankment which might offer protection in cases of Bosna, Usora and Spreča high water levels. If the Bosna River water level reaches +6.00 meters, the following areas would certainly be flooded: the left river bank and the Maglaj - Doboj - Modriča main road, as well as the railway roads on the right river bank including the agricultural soil and infrastructure facilities in the local communities of Rječica, Paklenica Don-

ja, Trbuk, Jabučić Polje, Ševarlije, Pridjel Gornji, Pridjel Donji, Doboj Novi, Poljice, Kostajnica, Grapska, Bušletić, Osječani, Kožuhe, Bare, Bukovica Velika, Bukovica Mala, Čivčije Bukovačke, Kladari, Johovac, Kotorsko, Bukovac, Vranduk, Ritešić, Majevac and Podnovlje, covering the surface of around 3.000 hectares. Furthermore, there is a flood threat to the settlements of Poljice, Lipac, Suvo Polje, Tekućica and Boljanić covering the area of around 300 hectares along the main road to Tuzla due to potential backwater of Spreča and Bosna rivers, with minor deviations between the railway to Tuzla and the right Bosna riverbank. The lack of defensive embankment and poorly maintained water facilities could also threaten the following areas: Bukovica Velika (the area is often flooded by the Rudanka River and the water further overflows to Čivčije Bukovičke settlement due to insufficient water drainage at the M-17 main road and the dam constructed to provide water supplies to the local fish pond); settlements of Stanovi and Ljeskove Vode (poor management of the Rudanka riverbed and inadequate water drainage on the local roads, especially in the area of the Stanovi train station). Also, there is a 300-400 meter long cluttered canal on the right side of the Doboj - Banja Luka regional road and a narrow water flow section at the exit of the railway road where a car road was constructed.

Bearing in mind the fact that the large water inflow into the Modrac Lake and the water overflow caused an unfavorable hydrological situation at the Bosna, Spreča and Usora rivers back in 2014, a special attention should be paid to the hydrological system of the lake in order to conduct timely activities and mitigate all possible consequences.[4] If the dam on the Modrac Lake collapsed, the flood wave would reach the city of Doboj (the settlement of Suvo Polje) in 230 to 240 minutes, Stanić Rijeka gorge in 260 minutes (4 hours and 20 minutes), and the mouth to the Bosna River in 4 hours and 33 minutes. The speed of the front wave is around 4.7 m/s. The Spreča River water depth in Doboj is around 5 meters in terms of the maximum average water level and it would flood 300 meters of the area outside the riverbed at the Suvo Polje point. The water level right before the Stanić Rijeka gorge would be 9.8 meters and around 8 meters in the gorge where backwater is usually formed, so it would flood the roads and the railway to Tuzla and the Doboj -Tuzla railway tunnel. The direction of the flood wave would threaten all the facilities and land within its reach. There is no threat for the city itself due to the embankment on the left Bosna riverbank ranging from the Usora river mouth to the Bare settlement. Still, the belt ranging from the main road to the Poljice settlement, including the settlements of Poljice, Svjetlič, Srpskih ozrenskih brigada, and Robna pijaca would be under a threat from the flood wave originating from the Bosna and Spreča rivers. It is the protection measures as integral parts of urban plans and the construction of defensive embankment that play a pertinent role in flood protection. Nevertheless, the construction of settlements failed to obey the construction terms and conditions [8].

Conducting the flood protection and rescue measures

In line with the Water Law of the Republic of Srpska, mandatory flood defense measures are applied within the regular and emergency flood defense plans.[5]

The criteria for the flood emergency announcement depend on the Bosna River water level at the water meter bar near the Bare vet station. Regular flood emergency is announced once the water level is above 3.00 meters, and the extreme flood emergency is announced once the water level reaches 4.5 meters with a tendency to grow (another reason might be the long-term high water level). The regular flood defense plan refers to the organization of the pumping station's full capacity functioning. If the water levels suggest tendency to grow, the city of Doboj's Emergency Headquarters are on standby. The emergency flood defense plan entails the activation of the Doboj's Emergency Headquarters and the following activities are conducted: all companies which own technical, material and human resources and equipment necessary for the flood defense are on alert, the public is informed about the flood threats and measures in cases of flood protection and rescue, and finally, the defense dykes and facilities are constantly monitored.

The following activities are conducted in cases when the Bosna River water level reaches 4.80 meters crucial for the emergency plan: flood defense at specific locations (the Liješanj brook and Bare settlement) and mobilization of all companies which signed the contract to engage in the activities of civil protection for the purpose of temporary defensive embankment construction. There is an emergent closure of six outlets/openings as the nine existing mobile concrete blocks are fit in in order to strengthen the defensive wall along the M-17 main road. Once the Bosna River water level reaches 5.30 meters, the flood protection measures and activities are conducted and the citizens, civil protection workers and other organizations are on alert. The water level of 5.50 meters suggests that the Doboj city emergency headquarters instruct the hydraulic structure and the canal to close (Šećerana) at the former "Bosanka" site. If there is an overflow or an uncontrolled water discharge at the M-17 main road and the water level is above 6.00 meters,

4 The Modrac damn is located in the municipality of Lukavac. The Modrac Lake accumulation is formed by the Spreča and Turija rivers and their tributaries. The accumulation surface is 16.69 km2. The total capacity of the accumulation is 66.5 milion m3. The overflow point is 200 meters. Water discharges from the accumulation through three outlets. In cases of high water inflow when the water cannot be discharged through the outlets, the water is further raised to the damn and the three damn spillways after which it outflows into the Spreča River.

5 The Water Law of the Republic of Srpska aranges the integral water management in the RS territory, which entails water protection, water usage, protection from water damages, arrangement of waterstreams, institutional framework and activity funding.

the city mayor declares the state of emergency for the Doboj region. The state of emergency suggests the construction of local embankments, the evacuation of citizens and other activities in line with the planning documents and the current state of affairs.

The flood protection and rescue plan of the city of Doboj clearly defined the management and conducting of measures for protection and rescue in cases of floods. The plan defined the following sections:

- location of the emergency headquarters depending on the situation on the ground;
- roads for the evacuation of citizens;
- the city emergency headquarters' activities when on alert;
- the city emergency headquarters' activities when there is a direct threat and flood risk;
- the city emergency headquarters' activities during the floods;
- the city emergency headquarters' activities during the flood consequence removal;
- the city emergency headquarters' activities in terms of communication during the floods.

We should also mention that the plan entails prevention activities, response measures, recovery measures and reports on conducted activities [7].

CONCLUSION

Natural disasters occur more and more frequently due to climate change. Flood is the most common one in the Balkans. Over the past 60 years, Bosnia and Herzegovina has witnessed several major floods as follows: in May 1965, three floods in 1976, in June 2001, in April 2004, in December 2010, and in May 2014. Devastating floods took place in the Republic of Srpska in May 2014. Sudden heavy rainfalls caused major floods in many cities and municipalities and those most affected were Doboj, Šamac, Modriča, Čelinac, Banja Luka, Bijeljina and Prijedor.

The massive water overflow from the riverbeds of Bosna, Usora and Spreča and the Modrac Lake resulted in an alarming hydrological situation in the city of Doboj in May 2014. The floods covered 5.168 hectares and the total estimated damage was around 1.72 million BAM. According to the official information from emergency headquarters, there were 18 human victims most of which (11) were registered in the city of Doboj.

Along with damages to infrastructure, there was also significant damage due to increased transport labour. In the month of May, over 70,000 vehicles were redirected from sections of the main road around Doboj to alternative roads, which caused increased time of travel and transport of goods, as well as all other operational expenses.

Decisions adopted by emergency headquarters resulted in a whole range of measures and activities focusing on providing help and assistance to the citizens – evacuation and accommodation, water pumping, health and hygiene measures, food and water supplies, and electricity supplies. Measures and activities following the floods included city cleaning, bulky garbage disposal, medicines and utility products distribution, financial assistance for the affected households and businesses, and the disinfection, disinsection and deratization in order to prevent epidemic and infections. Both during and after the floods, all available resources were engaged: civil protection services, companies, the Ministry of Internal Affairs of the Republic of Srpska, B&H Armed Forces, the Helicopter Service of the Republic of Srpska, health centers, fire squads, diving clubs, and other communities, including a large number of volunteers.

There were four critical points (locations in the city particularly threatened by flooding) identified in the city of Doboj based on the estimations and the rescue and flood prevention plans following the floods. There was a construction of a 2.5 meter high defense wall regulating a part of the Liješanj stream. Also, the riverbeds of Liješanj and Lukavica were cleaned and mobile defensive concrete blocks 2.400 m long were set in order to prevent the Bosna River overflow on the left river bank across the dyke. The authorities identified the following risks in case the city is hit by the flood again: the lack of a drain station on the water canal, the lack of a backup electricity supply source at the pumping station, the lack of defensive infrastructure along the Bosna, Usora and Spreča rivers, the lack of dykes and poorly maintained existing water stations, blocked canals along the roads, the construction of buildings and settlements without complying with the regulatory and urban spatial plans. All the identified risks suggest an urgent need for adequate measures and activities for the hazard elimination.

In order to protect the city of Doboj from future floods, we propose the following activities: the construction of upper stream accumulations and retention basins, the cleaning of all canals and riverbeds, management of watersheds, the prevention of uncontrolled waste disposal at riverbeds and canals, the prevention of unplanned gravel exploitation, the prohibition of construction in flooding zones, occasional population education via practical seminars on "Tactics of flood protection and rescue" which should include mandatory training.

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REVIEW

Application of Aluminum and ITS Alloys in the Automotive Industry With Special Emphasis PN Wheel Rims

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Abstract: The use of aluminum in modern cars began in the early 1970s, when under the pressure of the oil crisis, car manufacturers around the world began to reduce the weight of cars in order to achieve the lowest possible fuel consumption. The first applications of larger volumes were radiators, engine blocks and wheels. Meanwhile, in Europe, the average amount of consumed aluminum has continued to increase, reaching an average of 180 kg per car. Aluminum castings, forgings, sheets and extruded parts are used for a large number of car parts, including car bodies, chassis, suspensions, wheels and many others. The use of aluminum is also important for hybrid and battery electric cars. Due to the threat of global warming due to the greenhouse effect, it is very important to reduce the weight of the car by using aluminum, and thus fuel consumption.This paper explains why, now more than ever, vehicle weight reduction is necessary and how aluminum can be used to further improve the sustainability and safety of future generations of cars. Special attention is given to the use of aluminum for car wheels, which represent almost 15% of the average aluminum content in passenger cars.

Key words: Aluminum alloys, light metals, steels, automotive industry, wheel rims..

INTRODUCTION

Metals are still the most commonly used materials in the automotive industry. In addition to steel, one of the most important light metals on cars is certainly aluminum, the use of which is becoming more frequent, but still relatively rare.

Probably the most famous aluminum car will forever remain the "Audi A2" (Figure 1), which was expensive and whose poor sales stopped production somewhere in the middle of the planned production cycle. But this car was not expensive in itself, but the high price was primarily due to the technology of making cars from aluminum, which is still more expensive than the one in which we use steel. [1, 2]

Figure 1. Aluminum in the automotive industry, model Audi A2

Lightweight materials such as aluminum and its alloys do not only bring weight savings to the vehicle. The savings in terms of production costs are also signifi-

cant because this material enables the application of new processing technologies, and thus, in some cases, lower energy consumption. Also, the advantage of materials such as aluminum is the possibility of making car parts with better properties. In addition to new ways of joining aluminum surfaces, one interesting advantage of this metal is the development of special ways of pressing aluminum sheet used to make the hoods, trunk hatches, as well as front and rear bumpers (high speed blow forming). In this process, the aluminum sheet is heated to a temperature of 500 ° C in a heated mold. After the sheet is heated, a medium under high pressure acts on it and shapes the part according to the die. [3]

Application of aluminum and its alloys in the automotive industry

Aluminum provides savings of up to 50% compared to competing materials in many applications. The typical relative and absolute mass of the average savings of the main assemblies of aluminum applications in serial production of cars are given in Fig.2. [4]

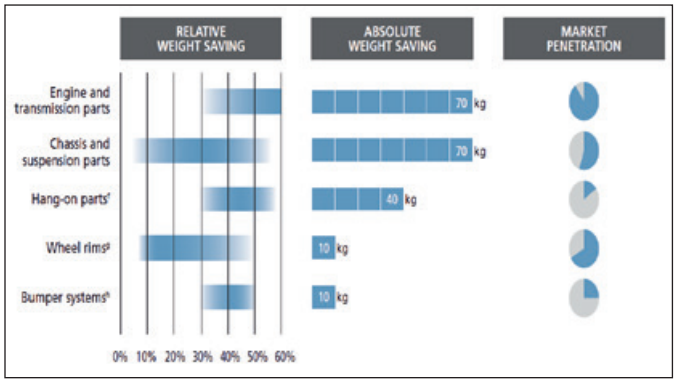


Figure 2. Aluminium's direct weight savings [4]

The Jaguar and Land Rover brands have the highest aluminum content of around 500 kg, and other premium brands are also above market average (149 kg net weight), but many low-budget cars actually contain significant amounts of aluminum as well (Figure 3). [5]

Analyzing European car production (2019) by segment, C-compact class cars (e.g. VW Golf, Ford Focus, BMW i3, etc.) make up the majority of car production (43%) (Figure 4). The segment distribution is projected to remain similar until 2025, but with stronger growth in the B-sub-compact segment (e.g. Audi Q2, etc.) and a reduction in the A-basic segment (e.g. Opel Adam, etc.). [5]

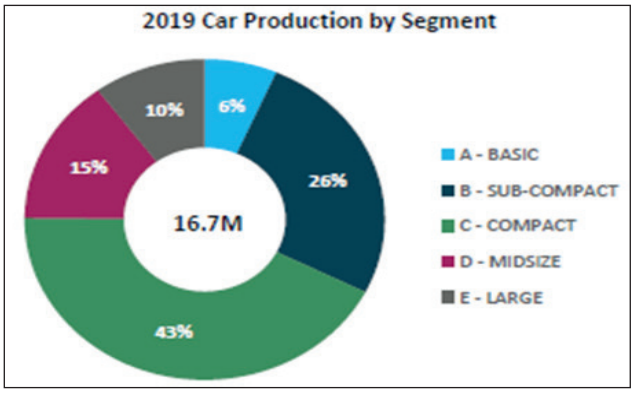


Figure 4. Car production by segment (2019) [5]

Although E-large segment vehicles (e.g. Audi e-tron) have the highest average Al content per vehicle (442 kg) (Figure 5b), C-compact segment vehicles account for the largest share (36%) (Figure 5a) of total Al consumption due to the total production volume of C-compact segment vehicles. [5]

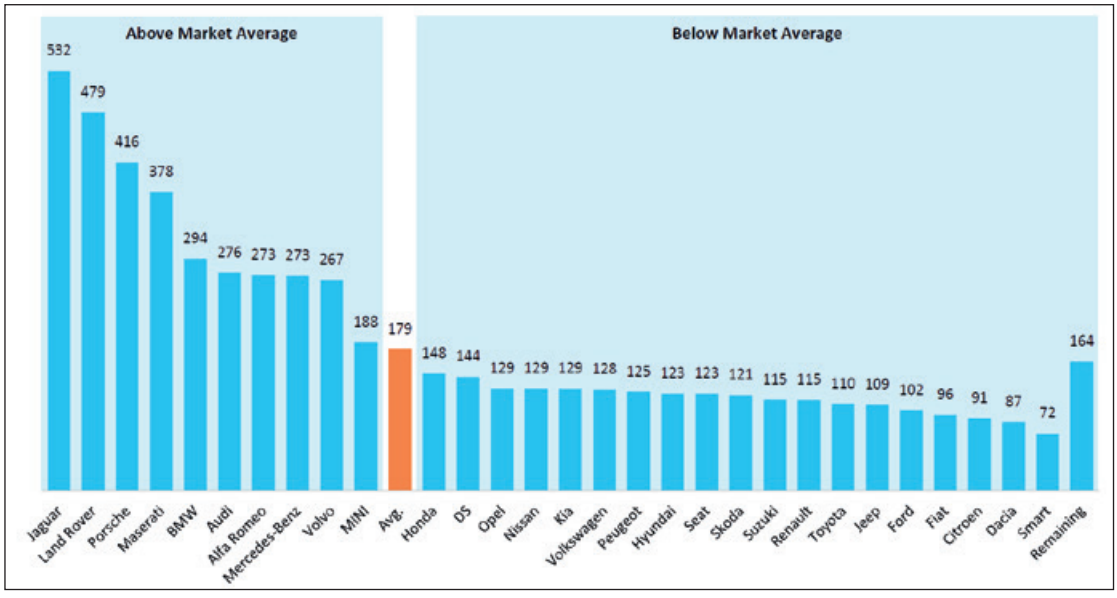


Figure 3. Average Al Content per Vehicle by Brand 2019, (Net Weight in Kg) [5]

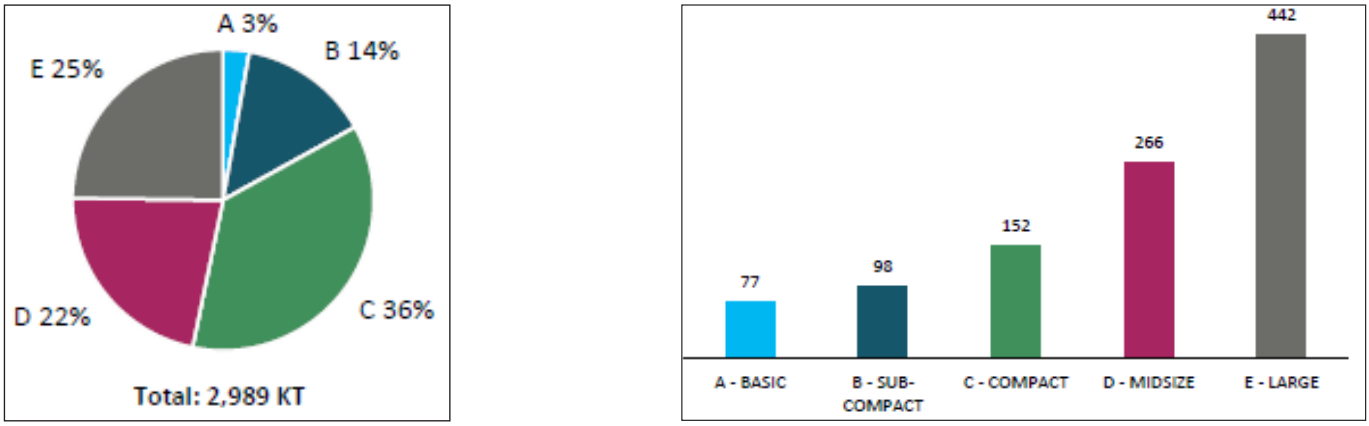
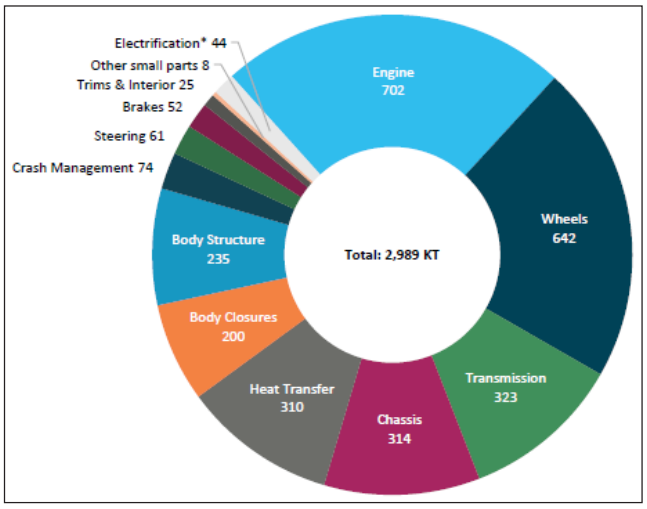


Figure 5. a) Total AL Content by Vehicle Segment (2019, Net Weight in %), b) Average AL Content by Vehicle Segment (2019, Net Weight in kg) [5]

The average aluminum content per vehicle in 2019 for European car manufacturers was 179.2 kg. This amount is projected to increase to 198.8 kg by 2025, if small and medium-sized vehicles follow the evolution prediction of the automotive industry. [5]

Analyzing the use of aluminum by component groups in cars, we come to the conclusion that the engine and the wheels represent almost half of the total share of aluminum in the vehicle (~45%) (Figure 6). [5]

Electric vehicles are quite expensive today, mainly due to the cost of batteries. Therefore, it is important to make electric cars as energy efficient as possible. Lightweight aluminum is one way to improve energy efficiency for any vehicle, including ones with the electric propulsion.



Electrification components include Battery Box, Battery Cooling and Electric Motor Housing

Figure 6. Total Aluminum Content by Component Group 2019, Net Weight in KT [5]

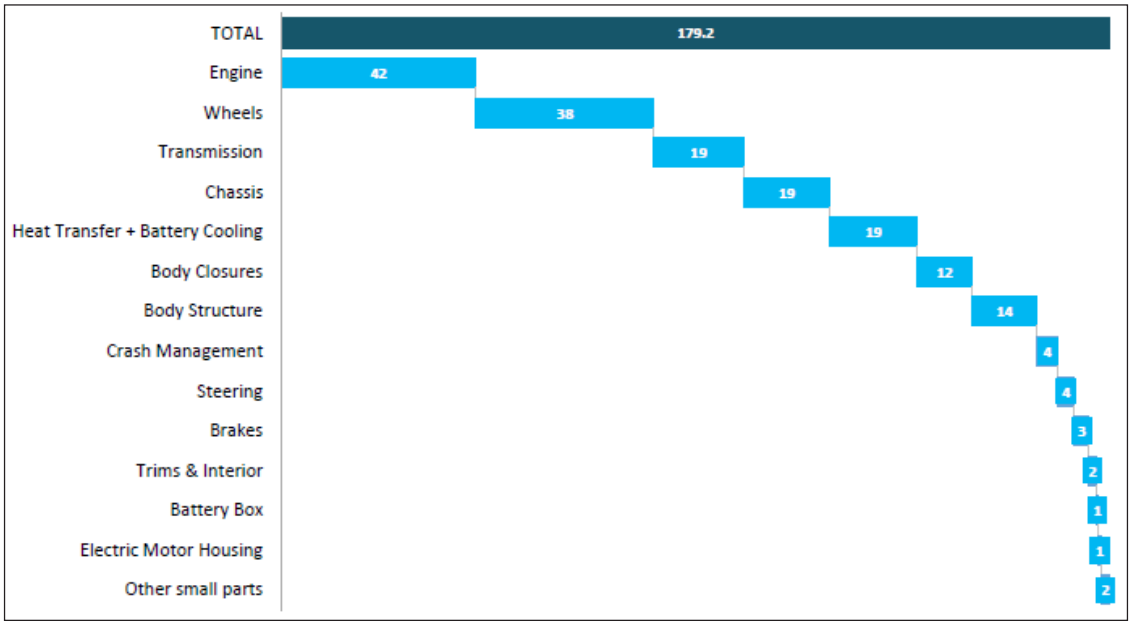


Figure 7. Average Aluminum Content per Vehicle by Component Group Incl. all powertrain types, (Net Weight in kg) (2019 year) [5]

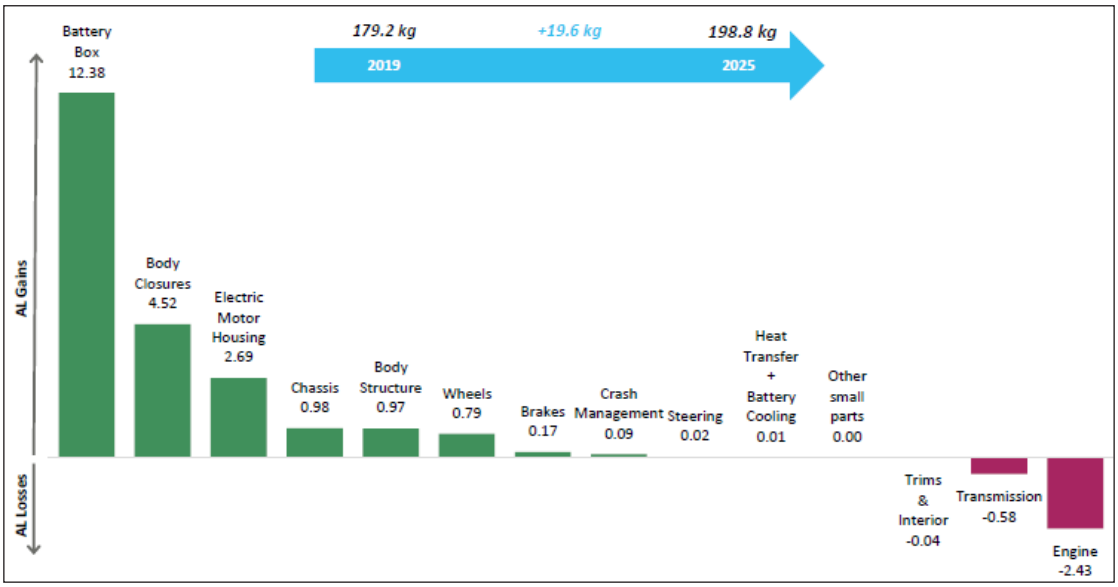


Figure 8. Expected AL Gains & Losses within Average AL Content per Vehicle *For the time period 2019 to 2025 (Net Weight in kg)* [5]

In addition, life cycle analysis of electric vehicles made of steel and aluminum shows that an aluminum electric vehicle during its entire exploitation emits 1.5 tons of carbon dioxide less than steel electric vehicles. [6]

The average aluminum content per vehicle, related to battery boxes and electric motor housings in battery electric vehicles (BEVs) is currently small (Figure 7) but will grow rapidly with the expected growth of electric vehicle production. [5]

According to projections, by 2025, battery boxes and electric motor housings will have the largest contribution within the increase in the average share of aluminum per vehicle (Figure 8). On the other hand, the use of aluminum for traditional engine and transmission components will be reduced. [5]

Nowadays innovative, safe and economical car parts can be found on all car models, regardless of brand and luxury class. For these parts, the transition from steel to aluminum is relatively easy and does not require a complete reengineering of the car. In the car manufacturing practice, material replacement is usually performed during a redesign, which happens seldom for already existing models. The design of parts comprised of mixed materials is generally not a major issue, but it is necessary to solve some problems related to the stiffness of the entire structure, the joining of diverse materials, with different thermal expansion coefficient and the occurrence of electrochemical corrosion. By solving these problems, the potential for weight reduction could be very significant. [1]

Today, high-strength steels (HSS) and advanced-high-strength steels (AHSS) are the dominant materials in the automotive industry. The newly developed AHSS steels of the second generation enable a further increase in the combination of tensile strength and deformation (Figure 9), which makes them suitable for meeting even greater requirements [7]. However, strength is not the only material parameter that should be taken into account when designing a car body. The density and stiffness of aluminum are about one third of the value that steels have, which is very important. By comparing the specific strength (ratio between the strength of the material and its density) between AHSS steel and Al alloys, it shows that aluminum alloys can be competitors to AHSS steels of the first generation6 (Figure 9).

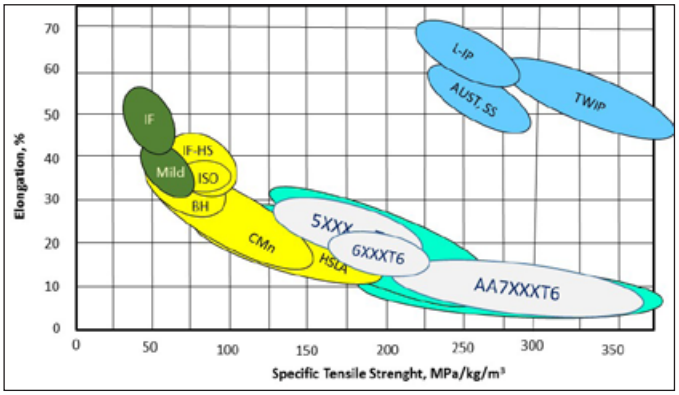


Figure 9. Weight specific comparison of the mechanical properties of aluminium and steels [8]

Aluminum also has a special advantage over steel, it protects the body structure in the case of a collision. Its lower modulus of elasticity allows for greater energy absorption with a weight savings of up to 64%. Even when the beam is designed to match the strength of the steel, energy absorption is higher and 40-50% of weight is saved. [4]

Aluminum alloy parts in the automotive industry can be machined in a variety of ways thanks to the

	Average Al Content Per Vehicle	
	Aluminum Content in Cars (2019)	Aluminum Content in Cars (2025)
	179.2 kg	**198.8 kg**
 **Cast**	116.0kg	118.1kg
 **Sheet**	34.0 kg	43.2 kg
 **Extrusions**	19.0 kg	26.7 kg
 **Forged**	10.2 kg	10.7 kg

Figure 10. The average presence of aluminum in cars according to the processing method [5]

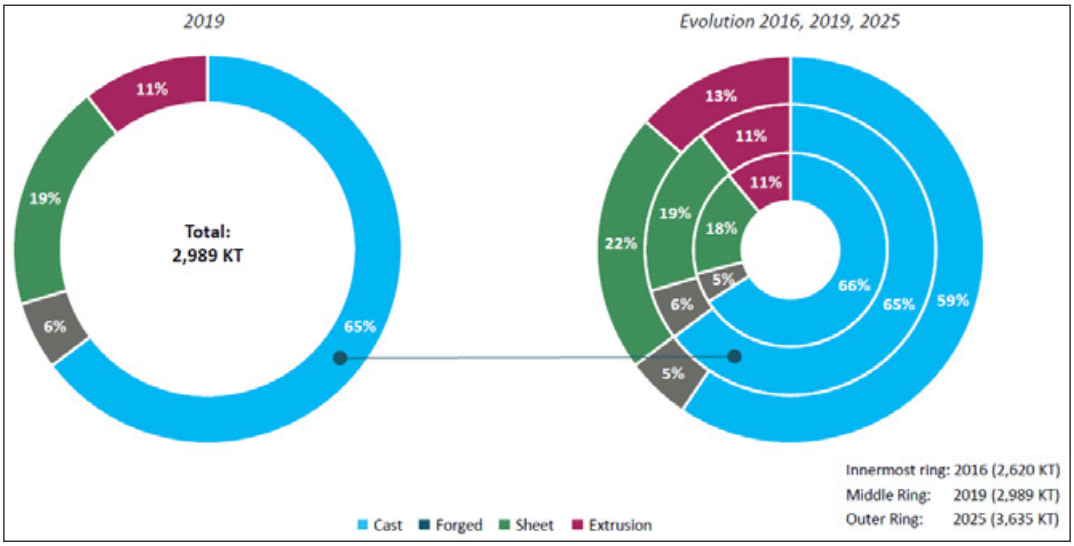


Figure 11. Forming Process Split of Total AL Content (Net Weight in KT) [5]

good machinability of these alloys. The casting process is most often used, followed by pressing sheet metal parts, then shaping parts obtained from extruded profiles, and finally forging, which is the least represented (Figure 10). Thanks to the growing number of electric cars, the trend in the coming period is that the amount of parts obtained by sheet metal processing will increase and that the quantities of parts obtained by casting will decrease (Figure 11).

Today's vehicles must meet an increasing number of strict safety regulations, both in terms of vehicle control and in terms of pedestrian protection. To meet different safety requirements, modern vehicles include a strong and stable passenger space that provides the necessary space to survive in the event of an accident, which is surrounded by a deformation zone in which the impact energy is efficiently absorbed. In the development of car construction, the most important thing is to find an appropriate compromise between construction stiffness, energy absorption capacity in the event of a collision and other requirements. Aluminum is an ideal material of extreme structural stiffness, which is the result of the high thickness of the material (aluminum components are 50% thicker than steel components). [9]

Table 1. Comparison of different types of wheels

Production technology	Steel wheel (sheet, welded)	Cast aluminium (classical)	Cast aluminium (w. hollow spokes)	Aluminium (sheet welded)	Forged aluminium (classical)	Forged aluminium light wheel	Cast magnesium
Weight (relative)	1,0	0,75-0,85	0,7	0,65-0,75	0,60-0,80	0,60-0,75	0,60-0,75
Cost (relative)	1,0	4,5	13,0	3,3	10,0	4,0	16,0

Application of aluminum for car wheel rims

Car wheels consist of tires and wheel rims, however, in the rest of the paper, in order to have concise text, we will use term "wheel" instead of "wheel rim". High quality wheels need to meet all the requirements of standard driving conditions. The most important features expected from the wheels are flexibility and aesthetic appearance, even after long-term use. Another important factor is reduced weight and low moment of inertia. Reducing the total weight of the vehicle also affects the reduction of fuel consumption. In addition, better thermal conductivity of the wheel rim material leads to faster heat dissipation from the brakes, which improves braking in very demanding driving conditions and reduces the chance of brake failure due to overheating. [10]

Various materials can be used to make car wheels: soft low-carbon steels, high-strength steels, aluminum alloys, magnesium alloys, titanium alloys and carbon fiber-reinforced epoxy matrix composite materials. [11]

Steel wheels are often comprised of multiple pieces of pressed sheet metal welded together. They are less likely to consist of single piece due to complicated production. They are still found on many cars today because they are cheap, durable and flexible, but on a down side, they are also heavy. Instead of low-carbon steels for wheels, it is possible to use high-strength steels (HSS) which, with the same strength as low-carbon steels, have a lower weight. [12]

Magnesium alloy wheels are much lighter compared to other materials and have very good mechanical properties, both static and dynamic. Poor resistance to atmospheric influences is overcome by alloying and appropriate coatings. Mg alloy wheels are expensive so they are mainly used for race cars and luxury class cars. [13]

Titanium is a material that is very resistant to corrosion and has a strength that is 2.5 times greater than the strength of aluminum. However, the cost of production is very high, moreover, it is not available for commercial car classes. Titanium wheels are still in the early stages of development for road cars, but are sporadically used for racing and luxury cars. Poor wear resistance is eliminated by nitriding the surface layer or applying other hard coatings. [14]

Composite materials with polymer matrix and carbon fiber as reinforcement represent the latest group of materials that is trying to find its application for car wheels. This group of materials is much lighter than other materials used for vehicle wheels and the first tests showed very good dynamic resistance. [15]

The appearance of the wheels made of different materials is shown in the Figure 12.

A comparison of different types of wheels, made of different types of materials and different technologies, both in terms of relative weight and relative price in relation to the steel wheel is given in the table 1. [16]

Aluminum alloys used for the production of wheels have a significant role in the automotive industry, initially found in the luxury and sports models, today they are an option in the middle and lower class cars as well. On the market, wheels made by casting from Al-Si type alloys are the most common. In an effort to achieve the lowest possible wheel mass, molding technology has been developed, as well as wheel fabrication by sheet metal extrusion and spinning forming.

The successful start of aluminum wheel production in Europe began with the development of the 1962 Porsche 911. Porsche was looking for a special wheel that should have outstanding quality, as well as a new and attractive look. In addition, its light weight and the resulting vehicle mass reduction ensure a very good ride quality. Then in 1970, cast aluminum wheels began to be used in mass production of cars, and a little later (1984) forged aluminum wheels as well. [16]

Steel Al alloy Mg alloy Ti alloy Composite

Figure 12. Car wheels made of different materials

The representation of aluminum wheels in 2000 was between 30 and 35% for European vehicles, and in the USA and Japan with more than 50%. Today, over 50% of worldwide vehicles use aluminum wheels, i.e. wheels represent almost 15% of the average aluminum content in passenger cars and pick-up trucks. Today, in North America, aluminum wheels are represented with approximately 70%, and in Japan with about 60%, while in Europe the representation is about 50% [16]. In recent years, the growth rate of the aluminum wheel market has slowed, but the market share is still growing. The development of new high-strength steels (HSS and AHSS) and sophisticated production methods have enabled a significant reduction in the weight of steel wheels.

Aluminum alloys must meet a number of conflicting requirements:

- to have good mold casting properties,
- to withstand the physical impact (deformation and impact strength),
- have corrosion resistance (normal and salty atmosphere) and
- have fatigue resistance.

These requirements have led to the use of subeutectic Al-Si alloys with 7 to 12% silicon content, different magnesium content (compromise between strength and elongation), low iron content and lower impurity concentration.

In the USA and Japan, only heat-treated alloy (T6) AlSi7Mg0.3 is used. In Europe, the share of heat-treated wheels is increasing, but it is still far from 100%; an AlSi7Mg0.3 alloy is also preferred. [16]

Non-heat-treated cast wheels are made either from AlSi7Mg0.3, mainly in France, or from AlSi11Mg, which contains less magnesium, mainly in Germany and Italy; this alloy is less favorable in terms of fatigue strength, but has a better casting ability and different shrinking characteristics. However, it is not suitable for heat-treated wheels. [16]

The experimental test results of Al-Si-Mg type alloys, with different Si and Mg contents, on static and dynamic loads showed that the heat-treated (T6) AlSi7Mg0.3 alloy offers the best compromise between fatigue strength and elongation. The same studies were conducted with different silicon contents. They have clearly shown that increasing the Si content also has a negative effect on ductility, especially at low degrees of hardening (thick hubs). However, alloys with 9-11% Si are still acceptable if better casting ability is required. Increasing the magnesium content does not clearly improve fatigue resistance, but significantly reduces ductility. [17]

Table 2 shows an overview of the most common alloys for the production of automobile wheels.

The wheels must provide critical safety functions and must meet high standards of design, engineering and construction. Almost all modern aluminum wheels are obtained by one or two processes: casting and forging. While the look of the wheels was the main motive for cast wheels, forged wheels are usually lighter and stronger, but also more expensive than cast wheels. However, with the right choice of materials and control of the casting process, cast aluminum wheels can have a high quality level and provide long-term reliable usage.

Today, cast aluminum wheels are most common with a market share of over 80% in North America, more than 90% in Europe and close to 100% in Japan. In North America, the share of forged wheels is about 15%, in Europe only 5% [17]. Increasing requirements for weight reduction represent a good opportunity for further growth of forged aluminum wheels, despite the higher price. Many studies are being conducted to further reduce the weight of the aluminum wheels without compromising the benefits of styling (e.g. aluminum foam wheel; Figure

Table 2. Basic alloys for the production of automobile wheels [16]

Percentage of the main alloying elements %		Commercial designation	Standards of appropriate or similar composition
Si Mg Mn	7 0,3 0,5	G-AlSi7MgMn	356.1 /USA/
Si Mn Mg	9 0,5 0,3	G-AlSi9MnMg	A 360.2 /USA/
Si	13	G-AlSi 13	A 413.2 /USA/ AlSi12 /Fe/ /JUS/
Mg Mn	3,5 0,3	P-AlMg3,5	5154 A.A /USA/ AlMg3.00 /JUS/
Si Mg	0,5 0,5	P-AlMgSi	6060 A.A /USA/ AlMgSi0,5.00 /JUS/
Mg Si Cu	1 0,6 0,25+Cr	AlMg1SiCu	6061 A.A /USA/ AlMgSiCu.00 /JUS/
Si Mg Mn	1 0,6 0,4+Cr	P-AlSi1MgMn	6080 A.A /USA/ AlSi1Mg.00 /JUS/

13) [18, 19]. Figure 14 shows wheels made by different technologies (casting and forging).

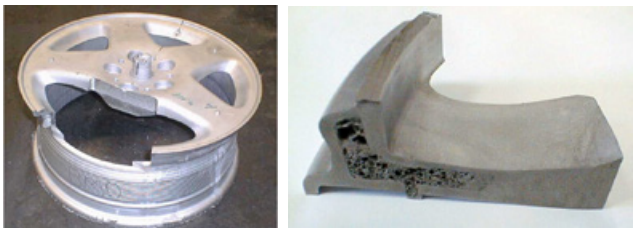


Figure 13. Aluminium foam wheel

a) b)

Figure 14. Wheels made by the process of a) casting and b) forging

Cast wheels provide high dimensional accuracy and corresponding static, dynamic and mechanical characteristics. An important reason for choosing cast aluminum wheels is their attractive visual appearance.

Different technologies are used for the production of cast wheels. The main casting processes used to produce aluminum wheels are:

- low pressure casting (mainly used),
- gravity casting in the mold (less used),
- extrusion process (used marginally).

Most cast aluminum wheels are manufactured under low pressure. During casting, a relatively low pressure (about 2 bars) is used to achieve a very fast filling of the mold and to obtain a uniform microstructure, which improves the mechanical properties compared to the gravity casting. [20]

Forged aluminum wheels are usually one-piece wheels formed from one block of metal by hot forging, followed by hot or cold spinning forming and other necessary processing operations (drilling, milling, scraping, polishing, etching, painting, etc.). The forging process allows flexibility in the design of the stylized disc, almost similar to a cast one. One-piece forging is considered superior to other forms of wheel production in providing ultimate strength while reducing weight compared to cast and multi-piece aluminum wheels (and of course steel wheels). Forged wheels are usually about 25% lighter than cast wheels (and potentially even more). Although casting can be a cheaper process, cast wheels show significantly lower mechanical properties than forged wheels. Forged wheels outperform cast aluminum wheels, especially in terms of impact and fatigue performance. The alloys most commonly used for forged aluminum wheels are: EN AV-AlSi1MgMn (6082) in Europe and AA-6061 (AlSiMgCu) in the USA. [17]

One-piece cast wheels are the most common type of aluminum wheels. In addition, there are multi-part wheels that consist of two or three components assembled together to produce a finished wheel. Multi-part wheels can use different production methods (e.g. a combination of casting and forging). Generally speaking, wheel parts offer the ability to customize wheels for special applications that would not otherwise be available. The parts are connected to each other with screws, and less often by welding and gluing. The multi-piece wheels were originally developed for racing in the early 1970s and have been used on cars ever since. There are many multi-part wheels options on the market now. The 2-piece wheel design does not offer as wide a range of applications as the 3-piece wheel; however, they are more common in the market, and their prices start well below the average 3-piece rims. Multi-piece wheels are produced in small quantities and due to high development and production costs they tend to be at the high end of the price scale. Figure 15 shows the appearance of a one-piece (monoblock), two-piece and three-piece car wheels.

a) b) c)

Figure 15. Aluminum wheels made as a) one-piece (monoblock), b) two-piece and c) three-piece

CONCLUSION

As the average weight of passenger cars has increased significantly since the 1970s, and as vehicle weight directly affects fuel consumption, less weight is now needed more than ever to reduce CO_2 emissions. Reducing the car's weight by 100 kg, lowers CO_2 from the exhaust by 8 grams per one km travelled.

Today, it is simply impossible to imagine the automotive industry without aluminum and its alloys. Aluminum is used to manufacture a number of car compo-

nents, including the engine parts, bodywork and even interiors. Aluminum is an ideal lightweight material, as it allows weight savings of up to 50% compared to competing materials in most applications without compromising safety. Modern European cars contain an average of 180 kg of aluminum components with a trend of increasing to 200 kg by 2025. In the short term, it will be possible to realize many additional applications of aluminum without significant reengineering or a major impact on car price. This could easily reduce the average weight of cars produced in Europe by 40 kg. The industry is working to reduce the costs of other applications of aluminum, especially in the construction of bodywork, chassis and suspension parts, which are currently used in sports and luxury cars, so that they can find their place in smaller cheaper cars as well.

Nowadays, cast and forged one-piece and multi-piece aluminum wheels have reached a high level of technical development. However, there is still some potential for further improvement. This has been demonstrated, for example, by the recent introduction of aluminum foam wheels.

The problem with the use of aluminum is the price of this metal, since it is higher than the price of steel and plastic. By reducing the cost of aluminum, production and the use of modern processing technologies, it is certain that its application in the automotive industry will be more frequent.

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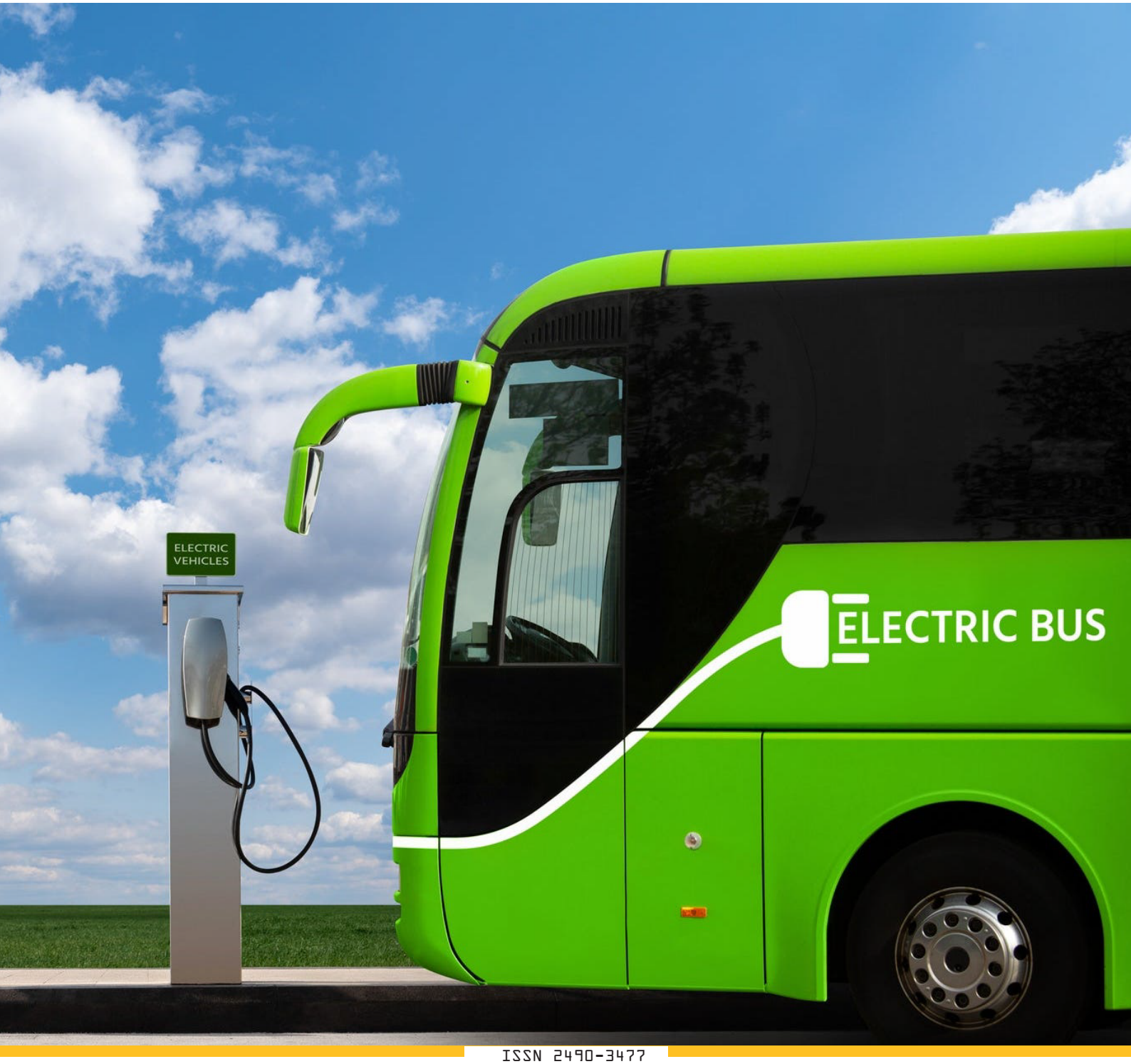

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