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CELLULAR RADIO CHANNEL CARRIER AGGREGATION MOTIVATION AND BENEFITS OVERVIEW

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Abstract: The main challenge in the evolution of cellular networks is providing increased channel capacity and data rates. Mobile operators are obligatory to boost the researching of methods for enhancing the spectral efficiency in response to the growing needs for better connectivity and signal coverage. The engineering of transmitters and receivers should be processed in a very precise manner as a matter of frequency effectiveness. An essential competitiveness is achieved having the combination of carrier frequencies as elements of one whole traffic trunk. Multicarrier techniques provide fulfilment of user requirements in the face of continuous on-line actions, fast file sharing and permanent Internet connectivity. Carrier aggregation in radio channels is seen as sophisticated technique for improving frequency usage assuring higher throughput and capacity.

Keywords: HIGH-SPEED PACKET ACCESS+ (HSPA+), 3.5G, LTE, 4G, CARRIER AGGREGATION, SPECTRAL EFFICIENCY, PEAK DATA RATE.

1. INTRODUCTION.

The reasons for the colossal increasing in the needs of higher data rates within mobile network communications are many and have their strong philosophy – evolution in mobile applications; need for constant broadband Internet connectivity; faster video and multimedia streaming, and the presence of low-cost smart phones as well. Cellular mobile operators must invest sufficient resources in response to the customer's whimsical requirements. Frequency limitations are on the front line and therefore sophisticated solutions are the object of research. The challenge is to optimize the available crowded bandwidth with methods of increasing peak data rates. Optimizing unused channels with carrier frequencies in a given particular moment of time are one direction for further development. Finding a way to use the unused is no other than a perfect solution for communication network engineers and designers. The dynamic traffic splitting among multiple carriers seems to be very efficient way for improving the overall performance of the cellular network.

Mobile operators' data traffic analysis show the flow of packets is seen difficult for prediction [1]. The packet switching technique in digital cellular networks appears to be extremely complex while having abstract modulation and signaling. Higher data rates require better error performance and optimized signal detection. As a matter of improving the signal detection, non-correlating signals should be in mind. Signal distribution play main role in extreme data loads. As an example it can be pointed that if transmission of large file is requested in a particular moment, the corresponding radio channel will get overloaded. While adjacent channels stay unused, inefficient carrier frequency distribution is present. Adjacent channels can also be in neighboring cells as well.

Avoiding such spectral inefficiencies, radio designers are to develop enhanced methods for migration toward future generation networks – 3.5G, 4G and even 5G. High-Speed Downlink Packet Access (HSDPA) and Long Term Evolution (LTE) are the available cellular networks on the market. Improving the concept of channel usage these systems migrate toward 3.5G and 4G. One main benefit chased is better spectrum usage while decreasing unused frequencies. The multi carrier systems present Carrier Aggregation and/or OFDM. Carrier Aggregation (CA) is a technique that distributes one data flow over multiple cellular radio channels achieving larger throughput and therefore faster data rates. The other technique - OFDM - is the already studied and tested way of modulation with multiple sub-carriers comprising one data stream.

2. THE CONCEPT OF CARRIER AGGREGATION.

The optimization of the available frequency bandwidth in cellular radio systems is achieved by means of a channel rescheduling technique. This channel reschedule is essential having unused channels free of charge and other channels being overloaded. To improve the existing HSDPA (3G) technology, HSPA+ and LTE-Advanced are using radio channel carrier aggregation [6]. Carrier aggregation allows expansion of effective bandwidth delivered to a user terminal through simultaneous utilization of radio resources across multiple carriers.

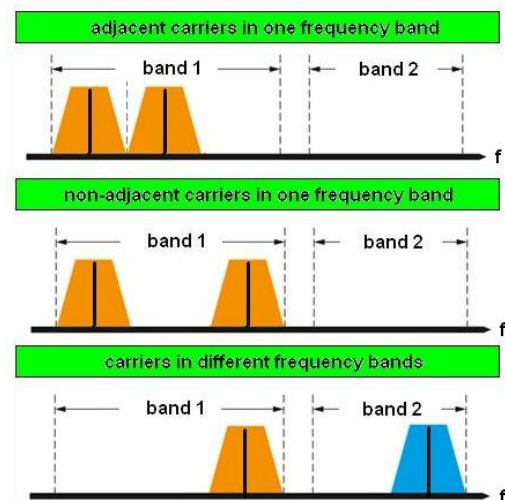


Fig. 1 – Types of carrier aggregation for downlink channel.

The multiple carriers are aggregated to form an overall larger bandwidth. Carrier aggregation permits the LTE radio interface to be configured with up to five “component carriers” of any bandwidth. We can assume that three types of carrier aggregation are defined: contiguous aggregation in one band, non-contiguous aggregation in one band and different band aggregation (fig. 1). In LTE-Advanced, carrier aggregation provides wider frequency bands in comparison with the previously supported in 3GPP Release 8 or Release 9 ratifications.

Enhancing consistent user experience across the network cell appears to be the main purpose of Carrier Aggregation. The multi carrier traffic splitting idea is to achieve better resource utilization and spectrum efficiency. On one hand, aggregation is achieved by:

- combination of peak channel capacities and available throughput performance in adjacent and non-adjacent carrier frequencies;
- avoiding the relative spectral inefficiencies that may be inherent in wireless deployments in non-contiguous carriers, often spread across different frequency bands;
- performing consistent QoS and highly efficient load balancing across frequencies and systems (cells);
- immediate rescheduling over unused channels at another carrier or system while data congestion occurs;
- smart interference management system with dynamic resource allocation.

On the other hand, mobile operators are saving financial resources with the increase of network capacity provided by cost effective solution in the face of already deployed equipment and just a few software upgrades.

2.1. 3GPP RELEASE 8.

The first concept of carrier aggregation was introduced in 3GPP Release 8 in 2009 announcing that two adjacent carriers can operate together to serve one user [3]. That is two adjacent channels, serving one user in one frequency band, can operate simultaneously while one of them is not busy. This version of carrier aggregation is called “Dual-Cell HSDPA Operation on Adjacent Carriers”. Two carriers of 5MHz bandwidth are combined and with the use of 64QAM the peak data rate is doubled to 42Mbps. MIMO antennas here are still not included. Resources can be assigned at the same time on both carriers with the Dual-Cell capable HSPA user equipments.

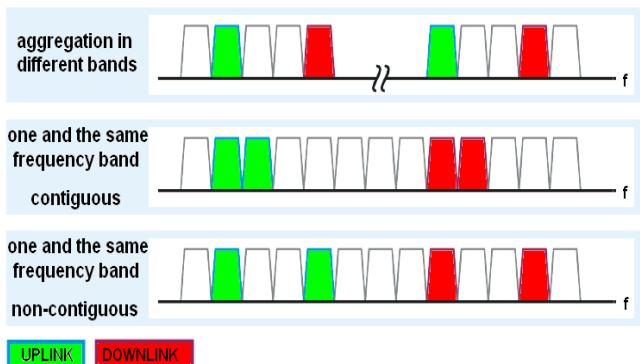


Fig. 2 – Uplink and downlink channel carrier aggregation

The channel non-related to HSDPA technology stays in so called “primary serving cell”, the physical layer procedures rely also on this primary serving cell. The transport channel chains are independent and perform coding, modulation and Hybrid Automatic Repeat request (HARQ) retransmissions separately in a similar fashion as MIMO.

The dual carrier is a natural evolution of HSDPA allowing theoretically doubling the 15 user peak data rate. The Dual Carrier DC-HSDPA is already a reality in numerous commercial deployments in the world. The DC-HSDPA is limited to 2 adjacent carriers of 5 MHz.

2.2. 3GPP RELEASE 9.

The adjacent carrier limitation is overcome in 3GPP Release-9. It provides a Dual Band HSDPA operation with separate frequency bands using Multiple input - multiple output (MIMO) antennas. The uplink is also considered and the Dual Band Dual Carrier HSPA is introduced. The same principles as DC-HSDPA are standing at the foundation: to double the uplink data rate up to 23 Mbps using 16QAM. Moreover, it is well known that UE in uplink condition is often more limited by the bandwidth rather than by the actual

transmit uplink power. Here the advantages of DC-HSDPA in terms of data rate and availability are well expressed.

A DC-HSDPA user can transmit over two E-DCH 2 ms TTI transport channels, one on each uplink carrier [10]. The user is served by the same eNodeB over two different cells on the same sector [1]. The secondary carrier can be activated or deactivated through special HS-SCCH protocol orders. In Release-9, dual-band HSDPA operation is specified for three different band combinations, one for each ITU region:

- Band I (2100 MHz) and Band V (850 MHz);
- Band I (2100 MHz) and Band VIII (900 MHz);
- Band II (1900 MHz) and Band IV (2100/1700 MHz).

2.3. 3GPP RELEASE 10.

In Release 10 the number of carriers is proposed to four. Uplink and downlink may be independently configured, but the number of uplink carriers must be less than or equal to the number of downlink carriers. Each component carrier is equivalent to a Release 8 or Release 9 carrier.

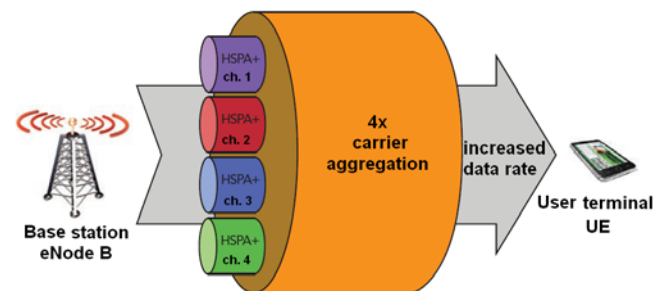


Fig. 3 – 3GPP Release 10 - 4x carrier (channel) aggregation

The standardization of the framework developed during the previous rounds of multi-carrier standardization in 3GPP is reused to provide a 4-Carrier HSDPA on two separate frequency bands.

2.4. 3GPP RELEASE 11.

A natural step in Release-11 is to provide a support up to 8-Carriers HSDPA aggregating up to 40 MHz of spectrum meeting the requirement of ITU for a real 4G system [12]. Release-11 also brings support aggregation of non-adjacent carriers on the same frequency band.

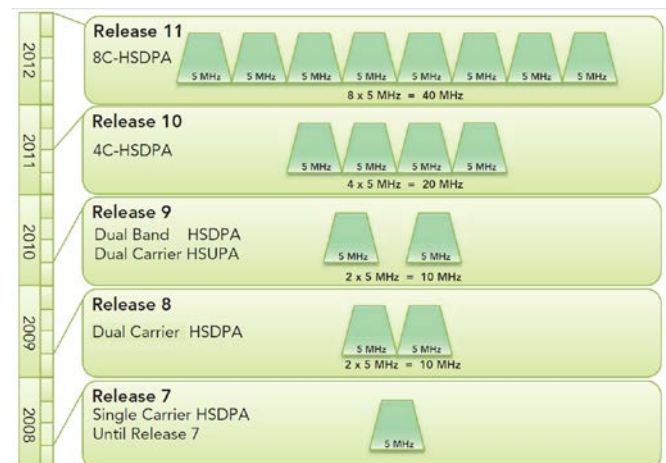


Fig. 4 - Evolution of HSPA Carrier Aggregation.

Higher utilization efficiency is provided with the use of dual carriers. Dynamic user multiplexing and improvement of the load sharing allows theoretically doubling the instantaneous data rates by assigning all the code and power resource to a single user in a network cell. By increasing transmission speeds, the round trip delay time is reduced. The 10 MHz bandwidth is also used to schedule user terminals (UEs) more efficiently around fading

conditions bringing frequency selectivity gain and improved QoS gain from joint scheduling.

The peak rate capabilities provided by each evolution is improved significantly. Carrier aggregation is one of only a few features to provide such a clear capacity improvement on the network. From a downlink theoretical peak data rate in Release-7 of 28 Mbps, each release doubles this peak, to reach in Release-11 a throughput of 336 Mbps with 2x2 MIMO and a throughput of 672 Mbps when combined with 4x4 MIMO antenna. It is possible to reach a theoretical peak data rate of 168 Mbps using the highest modulation scheme (64QAM) and the downlink MIMO 2X2 configured on each downlink carriers. It doubles the performance achievable with (DB)-DC-HSDPA [12]. The study Item called "LTE and HSDPA Carrier Aggregation" is currently under investigation as part of 3GPP release 12 [14].

3. CERTAIN BENEFITS AND CHALLENGES.

Carrier aggregation enables high data rates by aggregating multiple Release 8 carriers to support transmission bandwidths of up to 100 MHz [14]. This approach provides the following advantages:

- backward compatibility with release 8 and 9 capabilities;
- dynamic scheduling over different carriers to mitigate varying channel conditions;
- higher throughput rates;
- a practical solution for the LTE spectrum fragmentation issue.

Data rate improvement of LTE networks through aggregated spectrum is just one of the many advantages of CA. Network coverage and network access performance enhancement through better capacity and coverage management are also affected. CA could also help to avoid interferences induced by heterogeneous networks where small cells and macro cells operate in the same carrier frequency. If interference exceeding certain threshold is detected, the cell can reschedule a mobile terminal to a different carrier.

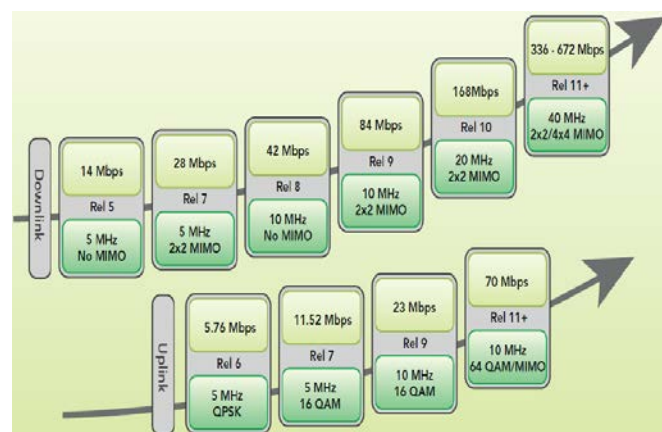


Fig. 5 – Increased data rates.

Having the flexibility to schedule data across multiple carriers to the same device provides spatial and frequency diversity, allowing for more reliable communication to the terminal. All carriers with cross carrier scheduling can be managed by one cell. This option introduces Inter Cell Interference Coordination (ICIC).

While the concept of carrier aggregation is simple, the feature has significant impact on transceivers. Mobile device developers implementing carrier aggregation need to consider impacts on the Radio Resource Control (RRC), Medium Access Control (MAC) and PHY layers as well as receiver design. From the device point of view, the user plane and layers above RRC are not impacted. UEs are classified according to their carrier aggregation aggregate bandwidths.

The LTE CA-ready devices have to support data downloading at rates up to 150Mbps and should also be packed with advanced features such as Full-HD video and audio, sophisticated computational imaging all without compromising the terminal battery life [9]. Therefore terminal powering schemes should be a very careful choice having components like 8C-HSDPA/LTE modems and multimedia processors. Real-time media streaming like Ultra-HD content and quality videoconferencing will be available when the modem and the multimedia processor are closely integrated.

Another challenge facing the implementation of CA is the use of two transceivers and related upfront components to detect the two/four/eight aggregated carriers. Receiving information from two and more (up to 8) cellular radio channels and converting them into a single stream should be designed in baseband frequencies.

These considerations complicate the overall design of the smartphone and compromise its power consumption, its form factor and its overall cost. In addition Carrier Aggregation could add more burdens to the already-fragmented environment of HSPA+/LTE spectrum as vendors will have to anticipate multiple CA combinations across various bands. This could have a dramatic impact on economies of scale, which in turn could have a significant impact on the overall device market price.

4. CONCLUSION.

After deploying the carrier aggregation technology, good amount of benefits are provided. Such are maximization of the peak rate and throughput performance; higher and consistent QoS; seamless access to unused channel capacity and also mitigation of relative inefficiencies in non-contiguous and narrow channel bandwidths. Of course the evolution to multicarrier also comes at the expense of UE and eNode B complexity, for which hardware implementation is challenging.

Carrier aggregation seems to be cost effective solution since expensive investments are avoided. Finding a way to utilize the frequency spectrum more efficiently, channel aggregation provides prolonged functional services from the deployed equipment and infrastructure.

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VERTICAL INNOVATIONS NECESSARY FOR INCREASING THE ACCESSIBILITY OF ICT ACADEMIC PROGRAMMES

ВЕРТИКАЛНА ИНОВАЦИЯ ЗА ОТВАРЯНЕ НА УНИВЕРСИТЕТСКИТЕ ПРОГРАМИ ПО ИКТ

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Abstract: *The specifics of the ICT labour market require continuous and rapid qualification and retraining of staff. At the same time, the existing conventional educational structure does not allow the rapid adaptive retraining of specialists as the majority of university programmes are based on a fixed set of foundation courses and a modular education system. This paper describes a new concept for academic curriculum structure that aims at providing open access to the curriculum excluding the historical relationships in forming the foundation of knowledge, and opens the market of educational services to other providers, such as colleges, private academies and practical hands on experience. The presented model encourages competition and does not allow dividing the operators of educational services into new entrants or players in a dominant position, thus the concepts found in real terms realisation of new undergraduate program in Network Engineering at New Bulgarian University.*

Keywords: INNOVATION IN ICT EDUCATION

Introduction

The introduction of online technology in university training has created new opportunities for teaching innovation. Online technologies have already changed the educational services market worldwide. The disruptive effect of online innovation has made way for suppliers of new educational services on the market and has changed the dominance of state and private schools and universities [1]. This tendency has been observed worldwide (USA, Europe, India, etc.). The largest universities are actively developing online training platforms, but most of them are using very simple models, such as YouTube and Moodle. Recently, the ICT education market has introduced some new platforms specially created for entry operators in online training. These new platforms introduce full automation in the learning process and support of individual users (students), allowing significant reduction in the price of the end product.

Why VERTICAL?

2.1. Problems inherited from the classical academic curriculum

The classical model of academic education implies the realization of a unified multi-level concept in teaching, learning and use of knowledge. This model seems logical with regard to the course of development of the industry over the past 200 years, where engineers as well medical or law students can be effectively trained. However, this is not an adequate model for emerging technologies and services. The inability of this unified model to adapt new courses makes it incompatible with the current trends in the labour market. The concept of the unified approach is that the foundation of all engineering training must be obtained through compulsory subjects like mathematics, physics, chemistry, biology, electrical engineering, electronics and more. The problem does not lie in the relevance of such knowledge for engineers, but in the teaching these outside the context of their application. The classical structure of academic education programmes dictates that in order to produce an engineering professional, a 2- to 3-year study plan of fundamental education must be undergone. This classical academic approach leads to engineering and technology majors being considered extremely hard and boring by students. Moreover, the classical model of compulsory fundamental subjects leaves no room for the development of new and modern courses. Thus often the percentage of current courses does not exceed 30% of the total course count. During their studies most of the students in various engineering programmes continue to get the same basic format of fundamental courses, which form about 50% to 65 % of the studied material.

2.2. Modular – major and minor approach

The modernization of the classical university engineering programme is an extremely complex process. The difficulties come from the historical interdependencies created between disciplines such as physics and mathematics, electronics, electrical engineering and mathematics, biology and chemistry, etc. These relationships are "hollow" and, in fact, modern lecturers in mathematics rarely have a real understanding of what the application of the material they teach is. For many years university programmes have been devised by isolated specialists teaching highly diversified knowledge and who have no idea about the underlying physical processes of the technological courses they teach. This has created additional complex dependencies between completely "hollow" specialized theoretical courses and as a result the students of our day are not prepared for their future line of work. These dependencies on a fundamental level get less and less clear in the subsequent relationships of courses such as digital systems, strength of materials, microprocessors, etc. Over the years, curricula have been built by a horizontal structure method, each successive level presuming that students have successfully acquired the previous level of knowledge.

This multi-level structure concept is similar to classical engineering approaches used to building large buildings in the near past. The advent of technology has lead to the need for modern engineers to be trained in a large number of applied skills. However, these skills cannot find an adequate place in a curriculum that adapts very slowly to the changing needs of engineering training due to the pressure of the inherited relationships between courses. The current situation has resulted in large fragmentation of knowledge. The legacy of the unified academic approach, however, prevents the rapid adaptation of university programmes precisely because of the huge amount of horizontal and vertical interrelated subjects that the change cannot be done separately. For example the introduction of new technology courses implies that the whole technological background is covered. This of course is absolutely impossible and uneconomical. Consequently, the inclusion of a new technology in university programmes takes far more time than the one needed for its development, and after becoming obsolete even more time to be removed from that same curriculum.

To solve this problem, the modular training system can be introduced. The segmentation of the engineering disciplines today leads to a huge amount of nomenclature names for the same curriculum. In these programmes, foundation courses still account for 40% to 50% of the basic knowledge taught in all engineering specialties, some major differences lie mainly in the degree of use of disciplines associated with mechanics, electrical engineering or

other technical disciplines (physics, chemistry, biotechnology, etc.) Due to the desire of universities in the past 40-50 years to engage the attention of as many students as possible, a huge amount of similar curricula that overlaps by 65%-70% were created. This diversification of education combined with the loss of a clear connection and analogy between seemingly different curricula today is causing the collapse of engineering education. At the same time, the last two years of study evolve into the modular model. However, university programmes fail to change the general structure of foundation courses. As a result, a number of university lecturers today, such as mathematicians, physicists and chemists, function in isolation, without a clear idea of their role in the creation of the final product. Today these academics appear to be a parasitic body of the same old structural concept. For example, few mathematicians have a clear idea and a desire to understand the exact application in engineering practice of the concepts they teach. The problem is similar with lecturers in chemistry, engineering physics, mechanics, etc. The highly theoretical courses in the first two years of study are the stumbling block of engineering disciplines. This fragmented type of teaching gives students an unrealistic idea about their future jobs. This leads to the destruction of the natural human concept for the implementation of education, namely, being of use to society, advancing in one's career and earning the respective remuneration in the latter part of an engineer's life. The situation is aggravated even further by the fact that using the Internet the modern student can easily navigate in the world of technology, while the university curricula gets more abstract and their usefulness is becoming less and less clear.

Another major problem of this modular approach built on common foundation courses is the lack of flexibility in order to build an open educational model that ensures the mobility of students and professionals in need of retraining. This historically obsolete approach cannot meet the current requirements of the labour market. It is useless precisely because it is clumsy and lacks interdisciplinary qualities. Moreover, it is closed and cannot be adapted to the needs of either the labour market or to the specific needs of the individual student. Using this foundation approach in education an engineer cannot re-qualified for a period shorter than two years, thus serious questions can be raised about the usefulness of such a qualification in the context of the ongoing development of technology. The separation of the various engineering disciplines in different nomenclatures without any real justification works only for public universities, whose funding is not based on market principles. These are state subsidized and aimed at preserving the jobs of a large number of senior scientists in dozens of different nomenclatures.

At the same time, universities are trying to become more attractive to their students by generating a huge number of minor programmes. This stems from the idea of reusing of existing product and selling it at lower prices, as low quality products, to customers who would not have bought it at the original price, but would prefer to get it within the total educational package. This model, however, makes the job of the university administration much harder worldwide, as every university within the last few years has started offering dozens or even hundreds of minor programmes in almost all professional fields. The seemingly cheaper for the end customer programme has become more expensive for the provider of educational services. Objectively speaking, this marketing gimmick to artificially maintain unprofitable programmes is as useless as a fifth wheel. The main idea of the possibility of continuous training and mobility is the ability to react to the requirements of the dynamics of the labour market, not to bundle educational packages for the sake of making them more attractive.

The buy-one-get-one-free model actually wastes resources by making the customer get something that she does not want or need.

2.3. Vertical versus horizontal

The ICT sector is the fastest growing sector of the economy. Innovations made in it, such as computer, software and electronic

technology, have led to innovations in several classical areas such as mechanics, medicine, chemistry, physics, etc. The leading ICT companies were quickly to discover the inability of the classic academic model of education to prepare and re-train professionals in new and emerging industry areas. Due to these facts, a number of companies such as Cisco, Microsoft, VMWARE, HP, Siemens, IBM, etc., have created a network of internal corporate academies [3]. Moreover, by developing the role of their academies on a worldwide scale, they have managed to seize large market segments in their main activity: computers, networks, software etc. Typical benefits of the model these corporations use is its high efficiency, clear hierarchical structure and a clear picture of the necessary steps that a professional should take in order to be able to acquire a certain position and consequently to reach a level of remuneration. This model is completely different from the academic educational approach. It implements the vertical structure of the curriculum. This means that a network engineer does not need to know all the maths and electronics, but only the part of the technology with which she will work directly. However, when the level of his knowledge becomes insufficient, she can easily add to her arsenal of knowledge and skills acquired by doing other certification courses at the same or at a different company. It is because of its flexibility that this vertical model is particularly effective in conditions of high competition in technology. It is also modular because it implies a gradual stepwise accumulation of knowledge by students. Naturally, this model is open, as a professional can learn a technology from different educational providers, or to learn it by himself if he so desires. This makes learning open and accessible to a much wider audience, even to those with extremely low incomes, who generally have absolutely no chance to get quality education and training to ensure their professional growth and a better life. An increased quality of life should be a key element in leading the implementation of strategies for the development of higher education. That university, academy-style and individual educational service provider should provide such conditions as well as a set of technological tools by which the customer will be able to improve her social status and consequently her quality of life. This will make a number of curricula currently considered unattractive, anew interesting and preferred by students.

2.3. The verticalisation process is costly

At present we do not have objective information about how successfully the structural conversion in higher education can be accomplished. All we know is that this model works well in corporate academies and specialized training programmes on the market of educational services from third party suppliers. Historically shaped interconnections between basic disciplines in engineering programmes make them extremely difficult to reform. The main problem is not to convince teachers of the usefulness of this process, but how to make it as open as possible and providing the best mobility options for students.

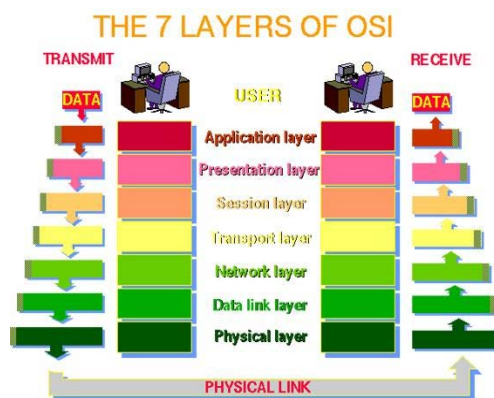
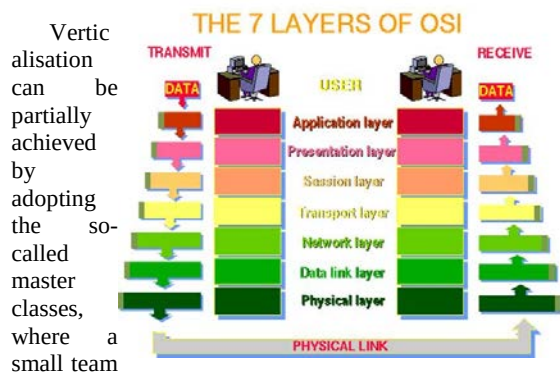


Fig. 1 Studying technology must be very similar to a technology's internal architecture.



We suggest the implementation of hybrid structural model curricula. In this process, some subjects may converge with other disciplines and also create a highly intertwined composite structure of knowledge and skills. However, for this to happen, we need vertical structural knowledge "pillars" and horizontal connecting elements, forming different levels of knowledge about the technology we teach. This approach allows us to create programmes in ICT that are open for teaching of technological subjects in the way that the technologies themselves are built Fig. 1. (ISO/OSI model on open interconnection between networks is a typical example of the realization of vertical modular architecture that can be seen as a whole and in the context of individual technologies.)

Why OPEN?

The vertical model combined with modular upgrades of the basic training programmes can provide the hybrid technology of teaching that is needed to open the market of educational services [2]. In this context, the presence of as many providers of specialized educational content as possible not only increases competition and affects directly the quality of training but also allows the construction of a specific ecosystem to better meet the demands of the labour market. So for example the implementation of the hybrid vertical - horizontal modular model will instantly set us free from the legacy of the classic fundamental model and Major - Minor modular approach. The vertical model of education will strengthen the role of universities and research institutions in teaching foundation subjects, but in a way that opens up these courses to the general public, making them more accessible, useful and effective for all users of the educational services market. For example, the teaching of mathematics, a subject highly specialized in vertical direction, will contribute to its proper use by students in their future work. In that way mathematics becomes a part of the growth of the professional, and an engineer will acquire new and relevant knowledge of mathematics where and when the need for this knowledge emerges. So when an engineer climbs the ladder of knowledge year after year he can be continuously supplied with specific knowledge directly influencing the quality of implementation of specific learning material in the relevant technological disciplines. This will get rid of the aggravating influence of fundamental disciplines and will make the engineering profession more attractive, useful and creative.

The NBU case?

In the context of the need to create attractive and truly effective curricula, the NBU was able to build a vertical modular curriculum model in several Network Engineering and ICT based programmes [4]. Within these programmes, we first created three vertical pillars on which we base our entire program structure. These are: mathematics, electronics, computer and software technology. These pillars start from the beginning of the study instead of concentrating on teaching of engineering fundamentals during the first two years; we develop and upgrade these disciplines vertically in the teaching process. This allows us to create a flexible programme that can easily adapt course modules acquired outside the university, as it does not interfere with the core support structure of the engineering education. Moreover the teaching of mathematics, electronics, and software in the context of specific technologies and their applications gives a very accessible form for students. In that way mathematics and electronics do not become obstacles in acquiring specialized knowledge, but rather they are a natural extension of the courses in specific technological fields. As a result, students learn more mathematics, electronics, computer technology and software than classical fundamental model. Moreover, this vertical approach can optimally be adapted to a variety of business-oriented courses such as the courses of Cisco, Microsoft, HP etc. Reforming the curriculum took about 3 consecutive iterations. The first pillar we erected was the one that is most closely technologically related to communications – the electronics pillar. In this process in several consecutive school years the electronics courses were reformed so that today they are taught during the whole study of undergraduate students, up to the last year of study. The next iteration required the insertion of a separate pylon next by previous. It consists of courses in computer technology and software. By introducing applied courses as early as the first semester, the students get confident about what expectations and benefits they will have as a result of choosing this specific programme. Moreover, the introduction of this vertical professional model gives students the outline of concrete knowledge and skills they need to start work immediately. The most complicated step in reforming the curricula was the verticalisation of the foundation of mathematics. Being the most important subject, mathematics requires the longest time for reform. As a result, however, we have created a very applied curriculum and from the beginning of their studies, students get a clear picture of the application of mathematics for solving specific technological problems that they will encounter in their future practice.

Conclusions

At present there is no universal model of the successful accomplishment of the structural conversion in higher education. All we know is that this model works well in corporations and that apparently it can be applied in higher education. However, the advent of this innovation will lead to a number of difficulties related to regulation. It is possible that regulation regarding programme accreditation at present will be reoriented towards accreditation of specific courses: pillar, modular, horizontal and caulking. It is also difficult to imagine without appropriate computer models how these will work in a hybrid model. At present, the authors hope to achieve a wider popularity of the proposed vertical model of innovation in higher education. We think this will strengthen the role of higher education in the process of training and retraining of labour resources. The main driving factor here is the focus on technology, the variety of technologies used in higher education, creating consumer-oriented education through the introduction of online innovation in higher education.

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ABOUT THE RESEARCHING TRAFFIC INTENSITY OF CROSSROAD KOSTA AVRAMIKOV STREET AND RODOPI STREET IN THE TOWN OF SMOLIAN

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Abstract: This article renders the results from researching the traffic intensity of the vehicles and the pedestrians through the crossroad in the town of Smolian, direction Kosta Avramikov str – Rodopi str and vice versa.

KEYWORDS: TRAFFIC, INTENSITY, AUTOMOBILES, PEDESTRIANS, RESEARCH, RESULTS

1. Introduction

This article renders the results from researching the traffic intensity of the vehicles and the pedestrians through the crossroad in the town of Smolian, direction Kosta Avramikov str – Rodopi str and vice versa.

The increasing numbers of the automobiles and the traffic jams put the question about the traffic safety. There are objective factors for the traffic safety as well the automobile technical condition, road condition, road organisation and there are the subjective factors too – the drivers condition and behaviour [2]. Moreover one of the requirements for the correct automobile driving is ensuring the possibilities for minimal fuel consumption [3].

The methods of traffic researching may be classified to three main groups: documental, natural and model [1].

The natural researching is performed in separate conditions during the determined period of time. They are the only activities, by whose help may be obtained real information for the real traffic condition. By them may be contained whole characteristic of the current transport and pedestrians' flows.

2. Research methodology

The choosing of the particular crossroad is performed by paying the attention to the specific features of its crossing roads and the indicators of the transport and pedestrians flows, such as content and intensity.

In this meaning there are crossroad with special characteristics which is made from the crossing of the Peter Beron str. – Rodopi str. + Rodopi str. – Kosta Avramikov str., whose maps is represented at fig.1 [4].

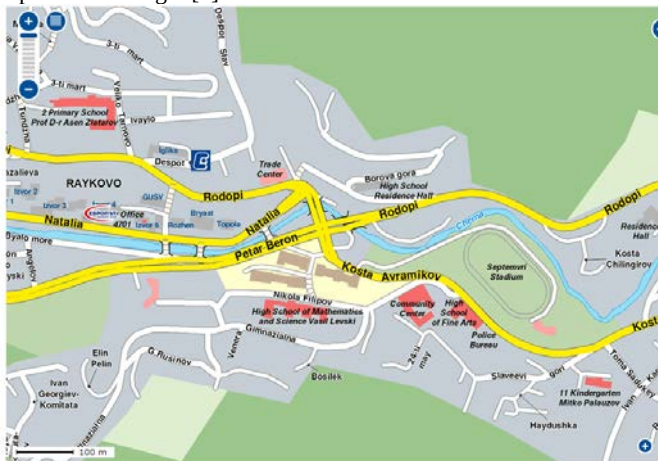


Fig.1. The maps of researched crossroad

The crossroad is built from the most loaded transport directions of the town of Smolian, along which is moving a transport flow, consisted from passenger cars, light trucks, heavy trucks, busses and long vehicles.

Together with these transport vehicles, the crossroad is crossed also by the pedestrians, who are moving towards the direction of adjacent buildings and neighbourhoods.

The entrance branches (approaches) of the crossroad are built from eight roadways, any of them with three sectors for the shifting of the direction.

The permitted movements for each one of the sectors are presented at the crossroad scheme on fig.2.

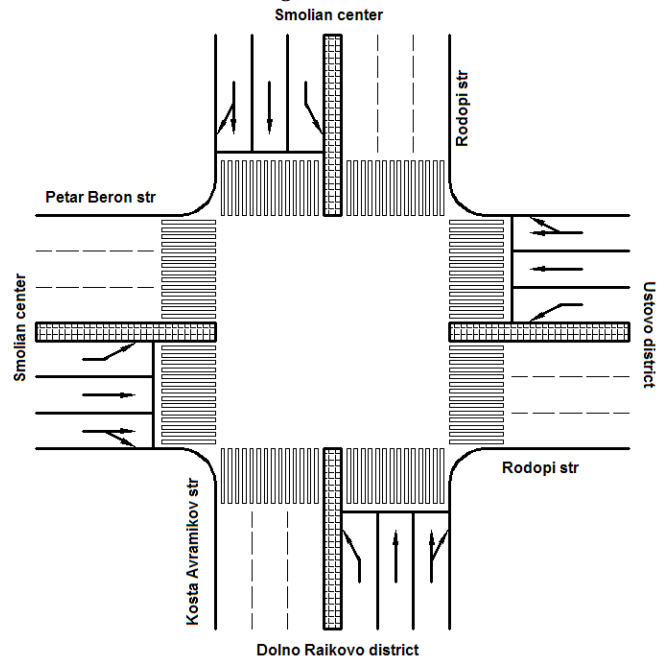


Fig.2. The scheme of researched crossroad

The researching of the traffic intensity of the transport and pedestrians flows, which crossing the crossroad is carried out at the natural conditions with applying the visual method. The researching is realized during the autumn-winter period of the 2012-year.

The directions of the researched crossroad, which is considered in the present article, are (fig.2):

-Kosta Avramikov street– Rodopi street (below is called Smolian center – Dolno Raikovo district);

-Rodopi street – Kosta Avramikov street (below is called Dolno Raikovo district – Smolian center).

The hour intervals of researching the traffic intensity of the separate directions of the crossroad are assumed according to the natural dynamics of the traffic in this crossroad and are found in the limits, accordingly 06.00-09.00 h, 11.00-13.00 h and 16.00-19.00 h.

The counting of the passing automobiles by type and by direction, as well as the counting of the pedestrians, who are crossing the crossroad is performed for the same two researching crossroad directions, which is mentioned above.

The traffic intensity P_a is determined by the equation [1]:

$$(1) \quad P_a = \frac{Q}{T}, \text{ automobiles/h (pedestrians/h),}$$

whereas Q are the automobiles (pedestrians) passing for the determined period of time, items;

T – determined period of time, h.

3. Researching results

During the researching is obtained the following results, which are shown at the tabl.1 and tabl.2, according with the traffic direction and hour interval.

The data from tabl.1 and tabl.2 are graphically represented at fig.3 to fig.10 and rendering the traffic and pedestrians flow dynamics for the examined directions of the researched crossroad.

Table 1

Distribution of the transport flow by content and intensity for the direction Kosta Avramikov str. – Rodopi str. (Dolno Raikovo district – Smolian center)

Interval	Passenger cars	Light trucks	Heavy trucks	Busses
Turning on the left				
06:00-09:00	111	17	6	1
11:00-13:00	58	10	6	0
16:00-19:00	75	19	10	6
Moving to the straight				
06:00-09:00	246	28	5	18
11:00-13:00	156	12	3	10
16:00-19:00	102	8	3	8
Turning on the right				
06:00-09:00	55	9	6	0
11:00-13:00	53	6	1	1
16:00-19:00	40	3	3	0
Pedestrians				
06:00-09:00	46			
11:00-13:00	30			
16:00-19:00	49			

Table 2

Distribution of the transport flow by content and intensity for the direction Rodopi str. – Kosta Avramikov str. (Smolian center – Dolno Raikovo district)

Interval	Passenger cars	Light trucks	Heavy trucks	Busses
Turning on the left				
06:00-09:00	553	35	9	14
11:00-13:00	395	35	12	7
16:00-19:00	687	43	5	11
Moving to the straight				
06:00-09:00	235	23	2	18
11:00-13:00	172	27	7	10
16:00-19:00	237	20	8	17
Turning on the right				
06:00-09:00	53	14	3	0
11:00-13:00	61	10	5	0
16:00-19:00	69	12	4	0
Pedestrians				
06:00-09:00	242			
11:00-13:00	28			
16:00-19:00	47			

As shown on the fig.3 and fig.4 the intensity of the left turning transport flows is the biggest for the passenger cars and reaches at the rate of $Pa \approx 136$ automobiles/h about the direction Smolian center – Dolno Raikovo district (fig.4). For the reverse direction is observed bigger intensity for the rest of the automobiles, which is respectively $Pa \approx 9,4$ automobiles/h for the light trucks, $Pa \approx 2,2$ automobiles/h – heavy trucks and $Pa \approx 2,7$ automobiles/h – busses.

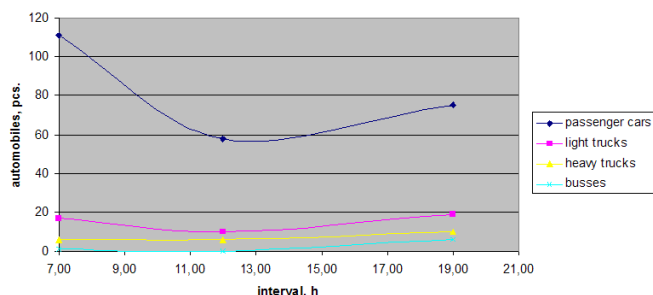


fig.3. Dynamics of the traffic intensity about the direction Dolno Raikovo district – Smolian center for left turning flows

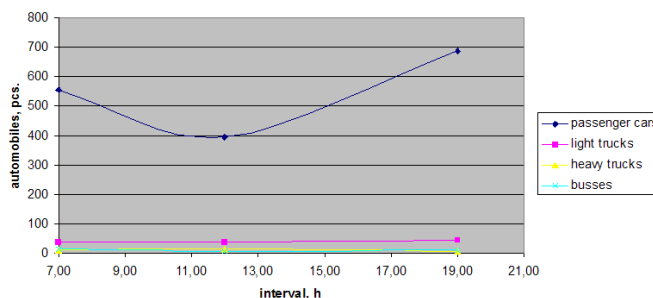


fig.4. Dynamics of the traffic intensity about the direction Smolian center – Dolno Raikovo district for left turning flows

The traffic intensity of the transport flows moving to the straight (fig.5 and fig.6) is less for the passenger cars (compared to the previous direction), but is bigger for the rest of the transport vehicles.

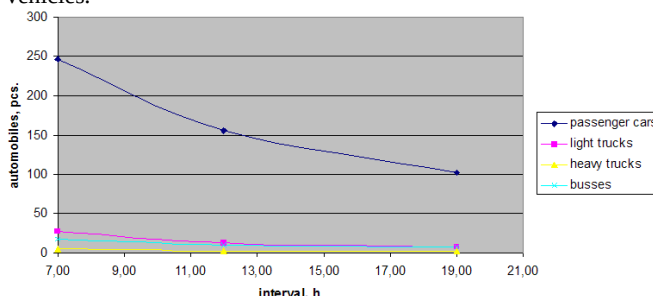


fig.5. Dynamics of the traffic intensity about the direction Dolno Raikovo district – Smolian center for moving to the straight flows

On the direction Smolian center – Dolno Raikovo district the traffic intensity of the passenger cars reaches $Pa \approx 54$ automobiles/h, and for the light trucks – $Pa \approx 6$ automobiles/h. In the same time the traffic intensity of the heavy trucks reaches $Pa \approx 1,4$ automobiles/h, and for the busses – $Pa \approx 4$ automobiles/h.

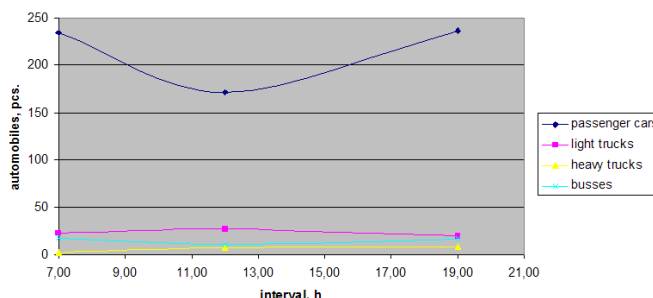


fig.6. Dynamics of the traffic intensity about the direction Smolian center – Dolno Raikovo district for moving to the straight flows

For the direction Dolno Raikovo district – Smolian center (fig.7) about the right turning flows is observed the least values of the traffic intensity by the whole examined interval of time: $Pa \approx 12,3$ automobiles/h (passenger cars), $Pa \approx 1,5$ automobiles/h (light trucks), $Pa \approx 0,8$ automobiles/h (heavy trucks) and $Pa \approx 0,08$ automobiles/h (busses).

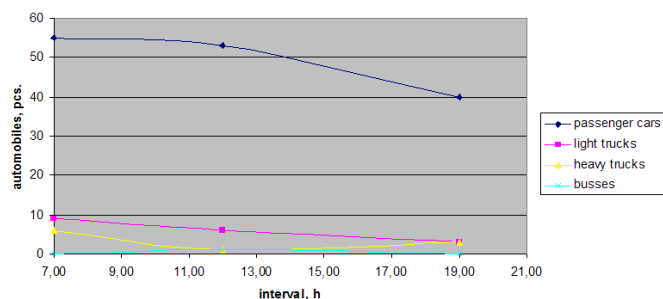


fig.7. Dynamics of the traffic intensity about the direction Dolno Raikovo district – Smolian center for the turning on the right flows

The dynamics of the turning on the right flows by the direction Smolian center – Dolno Raikovo district (fig.7) is distinguished with more quantity passing automobiles according to the previous direction. The traffic intensity in this case for the passenger cars is $P_a \approx 15$ automobiles/h, $P_a \approx 3$ – light trucks automobiles/h, $P_a \approx 1$ automobiles/h – heavy trucks and $P_a \approx 0$ automobiles/h – busses.

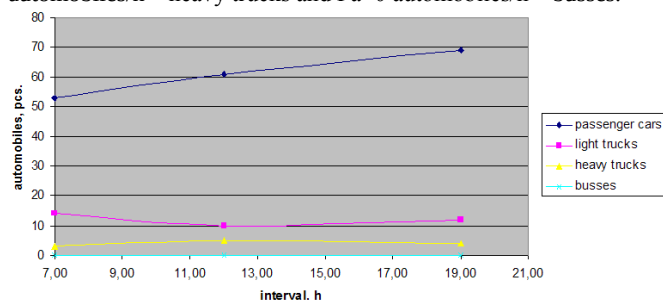


fig.8. Dynamics of the traffic intensity about the direction Smolian center – Dolno Raikovo district for the turning on the right flows

The dynamics of the pedestrians flow crossing the direction Dolno Raikovo district – Smolian center is shown on the fig.9. The quantity of pedestrians is biggest at the beginning of the examined interval (at 7.00 h), the least at 13.00 h and smoothly increasing at 19.00 h. The average pedestrian flow intensity for the examined direction is $P_p \approx 10,4$ pedestrians/h.

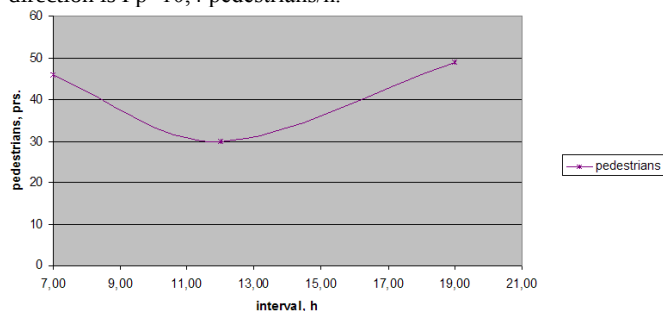


fig.9. Dynamics of the pedestrians' intensity for the direction Dolno Raikovo district – Smolian center

The pedestrians' flow crossing the reverse direction (fig.10) is distinguished with opposite dynamics, and here is the biggest quantity of pedestrians which passing on the morning (at 7.00 h) and decreasing significantly during the next hours. The average intensity of the pedestrians flow for this direction is bigger: $P_p \approx 26,4$ pedestrians/h.

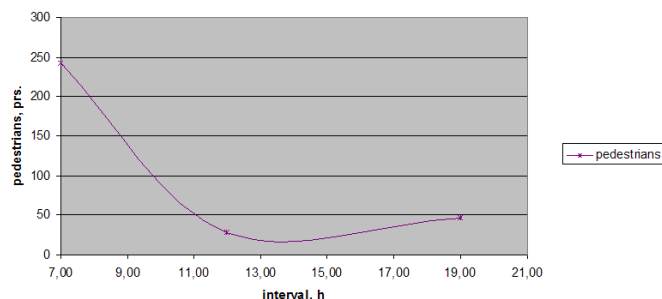


fig.10. Dynamics of the pedestrians' intensity for the direction Smolian center – Dolno Raikovo district

After the analyzing of the above pointed dependences and researching data is rendered that the traffic intensity is the biggest for the transport flows, which are turning on the left to the direction Smolian center – Dolno Raikovo district, and this means for the pedestrians flow crossing the same direction. The average traffic intensity is observed for the traffic flows moving to the straight and the little intensity – for the flows turning on the right, which is at fact for both directions. The least traffic intensity is observed for the traffic flows turning on the right to the direction Dolno Raikovo district – Smolian center.

4. Conclusion:

1. Researched is the traffic intensity of the transport and pedestrians flows for the direction Dolno Raikovo district – Smolian center and vice versa as part of the crossroad in the town of Smolian.
2. Determined is the average values and dynamics of the traffic intensity of the transport and pedestrians flows by the researched crossroad directions.

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A METHOD OF VEHICLE-PEDESTRIAN ACCIDENT RECONSTRUCTION

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Abstract: This paper presents a method of vehicle-pedestrian accident reconstruction in case of vehicle low beam illumination and transverse movement of the pedestrian. This method allows to determine the pedestrian visibility time and pedestrian visibility distance in the case of nighttime accidents. The analysis of this type of accident is only possible if a certain shape and size of the illuminated area. This method can be very useful in the pedestrian accident reconstruction expert practice.

Keywords: ACCIDENT RECONSTRUCTION, VEHICLE-PEDESTRIAN ACCIDENT

1. INTRODUCTION

In the Bulgaria alone approximately 130 pedestrians are killed as a result of motor vehicle crashes every year, and approximately 2000 are injured. In urban areas about half of vehicle accidents with killed people are pedestrian accidents. Pedestrian injuries from vehicle collisions arise from both the vehicle and the ground contact. Above 7 m/s collision speed, the vehicle impact is responsible for higher severity injuries [5]. The injury outcome in elderly pedestrians was more severe and the head severe injury proportion in children was more than that of an adult. Multiple injuries were common in pedestrians. The pedestrian injury outcome was relative to the impact speed [7].

Assessing the ability of a driver to see objects, pedestrians, or other vehicles at night is a necessary precursor to determining if that driver could have avoided a nighttime crash. The visibility of an object at night is largely due to the luminance contrast between the object and its background [6]. This difference depends on many factors, one of which is the amount of illumination produced by a vehicle's headlamps.

Vehicle-pedestrian accidents reconstruction is becoming critical in the field of traffic accident reconstruction [4]. Pedestrian accident reconstruction at nighttime differs from typical pedestrian accident reconstruction. Little attention has been paid to the investigation of such accidents in Bulgaria. The aim of this work is to be present a method of vehicle-pedestrian accident reconstruction in case of low beam illumination and transverse movement of the pedestrian.

2. METHOD AND DISCUSSION

Pedestrian visibility distance at night is limited in space, which is illuminated by the vehicle headlight beams (high or low). When the driver uses the vehicle's high beams, they illuminate the road over a distance of 100 meters and the driver can see and identify objects in this area. In this case the driver have enough time to react in case of hazard, provided that moves permitted by law speed. Furthermore, the pedestrian visible at a distance greater than the stopping distance for a car [3].

When the driver uses the vehicle's low beams the form of illuminated space in front of the car is asymmetric. In this case at transverse movement of the pedestrian the driver has a different time to see pedestrian and react. This time depends on the location at which the pedestrian crossing and enters the illuminated area in front of the car.

The main difficulty in this type of accident reconstruction is to determine the moment at which the pedestrian enters in the illuminated area where it is possible to be seen by the driver and pedestrian visibility time. Theoretically, this is the moment when the pedestrian crosses the 2,0 lx border luminance by a vehicle's low headlamps. The determination of this moment allows to determine the time at which the driver of the car has to perform action to prevent an accident.

The analysis of this type of accident is only possible if a certain shape and size of the illuminated area. Another prerequisite is known character of the movement of the car since the illumination of the pedestrian until the moment of impact - constant speed or deceleration.

Fig. 1 shows the low beams illuminated area in front of the car. The same figure shows and pedestrian that enters in the illuminated space.

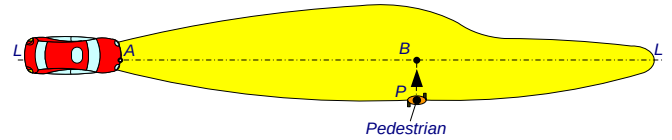


Fig. 1. Low beams illuminated area and pedestrian

With point A indicated the place of the vehicle, which hit the pedestrian. This point moves on the line LL, provided that the vehicle moves rectilinearly.

From the moment of illumination of the pedestrian until the collision, vehicle travels a distance $D_v = AB$. For the same time the pedestrian travels a distance $D_p = PB$. Consequently, the time for movement of pedestrians from point P, which is on the border of the illuminated area to point B, located on the line LL, can be calculated by the equation 1:

$$t_p = PB / V_p, s \quad (1)$$

where PB is the pedestrian distance D_p , travelled from the moment of illumination of the pedestrian until the collision, m;

V_p - pedestrian speed, m/s;

Once known shape and size of the illuminated area can be calculated pedestrian movement time t_{pi} for each point P_i from the border of the illuminated area to the line LL and draw appropriate graphics. Practical for this purpose are required at least 8-10 points.

Fig. 2 shows a graph that displayed the pedestrian movement time t_{pi} from point P_i to point B_i in a certain interval ΔL along the illuminated area.

Along the X axis is applied the illuminated area, and on the Y axis – the pedestrian movement time.

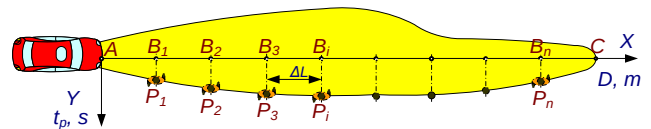


Fig. 2. Pedestrian movement time in illuminated area

The width of the vehicle B_v is given by the time for which pedestrians can travel that distance. It can be calculated by the equation 2:

$$t_{pv} = B_v / V_p, s \quad (2)$$

where B_v is the width of the vehicle, m .

If the vehicle is moving at a constant speed, it will go the distance $S_{vi} = AB_i$ (Fig. 2) for the time t_{vi} :

$$t_{vi} = S_{vi} / V_v, s \quad (3)$$

where V_v is the vehicle speed, m/s .

The time t_{vi} is equals to the time t_{pi} . These two times are equal to the pedestrian visibility time - t_{pvt} from the moment of illumination of the pedestrian until the collision.

Vehicle movements in the coordinate system “distance – time” at a constant vehicle speed is shown a straight diagonal line that passes through the coordinate system start.

2.1. Determination of the shape and size of the illuminated area on the road from vehicle's low beams.

The shape and size of the illuminated area on the road from vehicle's low beams is determined by measuring in 2,0 lx border luminance. Measurement data are filled in table 1.

Table 1. Vehicle illuminated area

$N\hat{g}$	1	2	3	...
D, m	5	10	15	...
$B_{r(l)}, m$				...

The symbols in the table 1 have the following meaning: D is the distance ahead of the vehicle; $B_{r(l)}$ - width of the right (left) half of the illuminated area in front of the vehicle.

2.2. Determination of the distance that the pedestrian travels in the illuminated area.

The distance D_p , which the pedestrian travels in the illuminated area is determined by considering the position of the impact point on the width of the vehicle relative to its longitudinal axis by the equation 4:

$$D_p = B_v \pm \Delta, m \quad (4)$$

where Δ is the distance between the longitudinal axis of the vehicle and the impact point on the width of the vehicle B_v, m .

Calculation data are filled in table 2.

Table 2. Distance and time for the movement of pedestrians in the illuminated area

$N\hat{g}$	1	2	3	...
D, m	5	10	15	...
D_p, m				...
t_p, s				...

2.3. Determination of the time that the pedestrian travels in the illuminated area.

The time t_p that the pedestrian travels in the illuminated area can be calculated by the equation 5:

$$t_p = \frac{D_p}{V_p}, s \quad (5)$$

Pedestrian speed V_p is determined by the rate of movement, age and sex of the pedestrian. The results of the calculations for the time t_p , that the pedestrian travels in the illuminated area are filled in the last row in table 2.

2.4. Drawing of chart for the pedestrian movement.

Based on data from table 2 drawing of chart for the movement of the pedestrian according to the distance ahead of the vehicle (Fig. 3). X-axis is applied to the distance ahead of the vehicle D , and on the Y-axis - pedestrian movement time t_p in the illuminated area.

2.5. Drawing of chart for the vehicle movement.

By different vehicle accident reconstruction methods known in expert practice is determined the vehicle speed V_v [1]. Set value of time (for example, $t = 2,0 s$ – Fig. 3) and calculate the distance that the vehicle traveled for this time at constant speed by the equation 6:

$$D_v = tV_v \quad (6)$$

Using the coordinates of the value of the time (used for the above example $t = 2,0 s$) and the calculated distance D_v determined point in the coordinate system (point A). Drawing a straight line through the coordinate system start and the point A (Figure 3). This straight line represents vehicle movement.

2.6. Determination of the pedestrian visibility time and distance.

The place, where are crossed the line 1 constructed in the order specified in paragraph 2.4 and the straight line 2 that describes the vehicle movement (paragraph 2.5), determine the pedestrian visibility time (Y axis) and the pedestrian visibility distance (X axis) – Fig. 3.

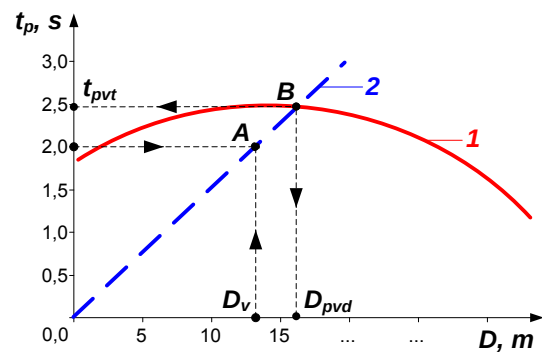


Fig. 3. Determination of the pedestrian visibility time (t_{pvt}) and distance (D_{pvd}): 1- Pedestrian movement; 2 – Vehicle movement

After determining the pedestrian visibility time and pedestrian visibility distance, analysis continues on known vehicle-pedestrian accident reconstruction methods [2].

2.7. Analytical determination of the pedestrian visibility time.

Based on data from table 2 to the time that the pedestrian travels in the illuminated area and the distance ahead of the vehicle can be obtained an equation by which discloses the graph that depicts the function of the time for the movement of the pedestrian according to the distance in front of the vehicle.

When a pedestrian has entered from the right side of the vehicle, equation which describes the movement of the pedestrian is equal to:

$$y = -ax^2 + bx + c \quad (7)$$

When the pedestrian has entered from the left side of the vehicle, for obtaining of the equation which describes the movement of the pedestrian are required from more points. It is a polynomial of the sixth degree:

$$y = -ax^6 + bx^5 - cx^4 + dx^3 - ex^2 + fx + g \quad (8)$$

Vehicle movement graphics is described by the equation of the first degree. This equation has the following form:

$$y = ax \quad (9)$$

By solving the equations 7 and 9 or 8 and 9 (depending on the direction of the pedestrian) was obtained value of the pedestrian visibility time.

Determination of the pedestrian visibility time by analytical method can be applied when is necessary determining at the visibility time for different variants of pedestrians movement.

3. CONCLUSION

In this paper, a new method for vehicle-pedestrian accident reconstruction in the case of nighttime accident was constructed.

The most important part of the paper is the possibility of determining the pedestrian visibility time and pedestrian visibility distance in case of vehicle low beam illumination and transverse movement of the pedestrian.

This method provides investigators a new possibility to reconstruct pedestrian-vehicle accident.

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THE EFFECT OF THE ACCELERATOR POSITION ON THE FUEL CONSUMPTION OF ROAD VEHICLES

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Abstract: The fuel consumption of road vehicles is influenced by many factors. One of them is the accelerator position. Measurement of the fuel consumption on a rollingstand was done for the quantification of this effect. The tested vehicle was Kia Cee'd with a petrol engine. The measurements were done in laboratory conditions to give higher accuracy. The results describe the degree of the effect of the accelerator position. They can be used for the determination of the position considering the actual output power of the engine and for the determination of the correct driver behaviour. The correct usage of the accelerator contributes to the reduction of environmental burden of transport.

Keywords: ACCELERATOR POSITION, OUTPUT POWER, FUEL CONSUMPTION

1. Introduction

One of the most common bad behaviors of drivers is incorrect usage of the accelerator. Its actual position is influencing the fuel consumption. With the decreasing of the distance between the accelerator and the floor, the fuel consumption is increasing very fast and the vehicle's acceleration is increasing slower. This effect is higher with increasing ratio of the acceleration position.

2. Measurement

The measurement was done on the rollingstand. This equipment allowed to simulate different driving modes with high accuracy. So it is able to simulate vehicle's drive at a constant speed, uphill driving, acceleration or the mixture of them. The rollingstand MAHA LPS 2000 with external equipment – engine speed sensor. Except of the driving modes simulations, the rolling stand can measure the maximal wheel power, engine effective (output) power, velocity and torque.

For the measurement of the fuel consumption was used Flowtronic. This equipment measures the volume of the flowing liquid fuel (petrol) on the principle of the rotating pistons with rated volume.

For the monitoring of the throttle position was used diagnostic unit Kia HiScan. This unit can be connected to the OBD port. It is measuring and visualising all operational data of the engine. It can be used only in the vehicles of the mark Kia.

The tested vehicle was Kia Cee'd with petrol engine of the volume 1,6 l, the output power 90 kW.

The rollingstand, other equipment, the vehicle and laboratory are the property of the Department of the Road and Urban Transport at the University of Zilina.



Fig. 1 Rollingstand in the laboratory.

3. Vehicle dynamic specifications

As the basic point of the output power which is needed to reach standard driving dynamic, it is necessary to determine what is „the standard“. This standard driving and dynamic situations are:

1. Driving at a constant speed (according to the conditions – urban area, extra-urban area, motorway)
2. Acceleration needed to reach a constant speed (according to the regulation ECE 101).

3.1. Driving power equations:

Rolling resistance:

$$(1) \quad P_f = G_T \cdot \cos \alpha \cdot f \cdot v = m \cdot g \cdot \cos \alpha \cdot f \cdot v [W]$$

m – vehicle weight [kg], g – gravity acceleration [$m \cdot s^{-2}$], α – elevation angle [°], f – rolling coef. [-], v – velocity [$m \cdot s^{-1}$]

Aerodynamic drag:

$$(2) \quad P_v = \frac{1}{2} \cdot \rho_v \cdot c_d \cdot S \cdot v^3 [W]$$

ρ_v – air density [$kg \cdot m^{-3}$], c_d – drag coef. [-], S – frontal area [m^2]

Elevation:

$$(3) \quad P_s = G_T \cdot \sin \alpha \cdot v = m \cdot g \cdot \sin \alpha \cdot v [W]$$

Acceleration:

$$(4) \quad P_a = m \cdot a \cdot \delta \cdot v \quad [W]$$

a – driving acceleration [$m \cdot s^{-2}$], δ – rotating masses coef [-]

Summary of wheel power:

$$(5) \quad P_k = P_e \cdot \eta_p = \Sigma P = P_f + P_v + P_s + P_a \quad [W]$$

P_k – wheel power [W], P_e – engine output power [W], η_p – gear efficiency [-]

The summary are considered for individual driving modes:

1. Constant speed, no elevation

$$P_1 = P_e \cdot \eta_p = \Sigma P = P_f + P_v \quad [W]$$

2. Constant speed with elevation

$$P_2 = P_e \cdot \eta_p = \Sigma P = P_f + P_v + P_a \quad [W]$$

3. Acceleration (only without elevation)

$$P_3 = P_e \cdot \eta_p = \Sigma P = P_f + P_v + P_a \quad [W]$$

3.2. Input vehicle values

$m = 1518$ kg (1263 kg empty vehicle + 3 persons á 75 kg and 30 kg luggage)

$f = 0,01$

$c_d = 0,32$

$S = 2,05$ m²

$\delta = 1,05 - 1,11$ (according to the actual gear)

$\eta_p = 0,93$

- Other factors are considered with values in reference physical conditions

For the calculation of „normal driving power values“ was necessary to set casual acceleration and velocity values. Velocity at constant speed was chosen as border or round values used in cities, local roads or highways. For the set of acceleration was chosen as basic the values used in the ECE Vehicle Regulation n. 101.

Table 1: Acceleration values

Our values		Reg. No. 101		
Velocity (km.h ⁻¹)	Acceleration (m.s ⁻²)	Acceleration (m.s ⁻²)	Velocity (km.h ⁻¹)	Cycle
15-30	0,8	0,79	(15-32)	urban cycle
30-50	0,5	0,45	(35-50)	urban cycle
50-70	0,45	0,4 - 0,43	(50-70)	urban cycle
70-90	0,25	0,24	(70-100)	extra-urban
90-110	0,25	0,24	(70-100)	extra-urban
110-130	0,3	0,28	(100-120)	extra-urban

Table 2: Engine output power

Engine output power (kW)							
Mode	Elevation (%)	Velocity (km.h ⁻¹)					
		30	50	70	90	110	130
Constant speed	0	1,6	3,4	7,1	12,4	20,2	31,1
	3	5,6	10,1	16,4	24,4	34,9	48,5
	6	9,6	16,7	25,7	36,3	49,5	-
	9	13,6	23,4	35,0	48,3	-	-
	12	17,5	29,9	44,2	60,1	-	-
	15	21,4	36,4	53,2	71,8	-	-
Acceleration	Acceleration (from - to, velocity)						
	15 - 30	30 - 50	50 - 70	70 - 90	90 - 110	110 - 130	
	13,6	16,0	22,4	23,2	33,4	46,6	

Table 2 describes the engine output power calculated according to the equations of the driving power (Eq.1 - 5). The red numbers are the border values, which occur infrequently during normal operation. The elevation values and the velocity were set according to the border or round values. E.g. the elevation 6% is usually at local roads where is the speed limit 90 km/h, but it is rather an exception on highways. So it is not necessary to consider with output power in these columns (-). The power values during accelerations were set as the largest value of the output power in the corresponding interval.

4. Accelerator position and fuel consumption

Table 3: Accelerator position and output power

Throttle position (%)	Accelerator position (%)	Engine output power (kW) at rpm					
		2100	2500	2700	3300	3500	3900
78,8	100	29,7	35,6	40,1	48,7	51,9	59,6
32,2	41	26,7	32,1	36,0	43,8	46,7	53,7
20	25	24,0	28,9	32,4	39,4	42,0	48,3
16,1	20	21,4	25,7	28,9	35,2	37,5	43,1
13,7	17	17,9	21,5	24,2	29,4	31,3	36,0
11,4	14	14,6	17,5	19,6	23,9	25,5	29,2
10,2	13	12,4	14,9	16,8	20,4	21,8	25,0
9	11	9,9	11,8	13,3	16,2	17,2	19,8
7,8	10	7,7	9,2	10,3	12,6	13,4	15,4
6,7	9	5,5	6,6	7,4	8,9	9,5	11,0

This table describes the most often used output power and operational engine rotation. These values were calculated according to the previous table. The colour of each column represents driving mode and corresponding elevation from the previous table. This calculated power occurs during the vehicle operation described in the previous tables.

Throttle position was identified through HiScan diagnostic. It is necessary to note, that the accelerator position and the throttle position are not the same values.

The table shows the area of the accelerator position used during the „normal“ operation. The operational range of the accelerator is in the interval of 0 – 40 % of its whole range. It seems that every position out of this interval is unnecessary, because the output power increases very slowly (see fig. 1), but the fuel consumption considerably (see fig. 2).

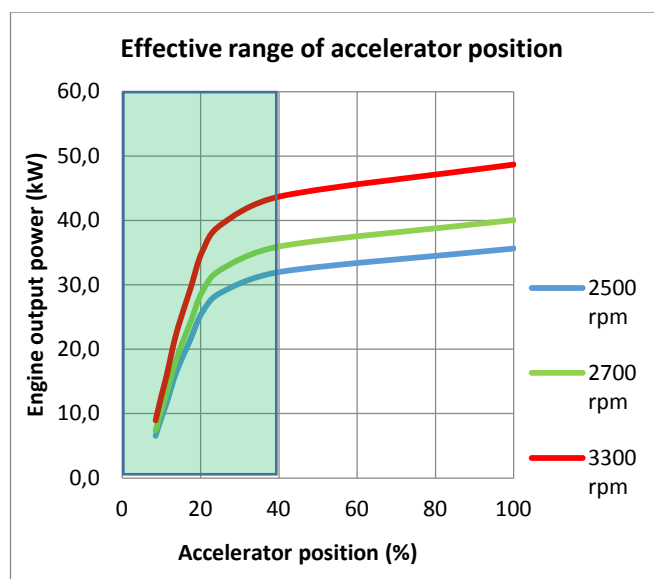


Fig. 2 Effective range of the accelerator position

Figure 2 shows the increasing output power according to the accelerator position (0% is idle, 100% is kick down). The output power values and increasing characteristics in the interval up to 40 % is optimal for the vehicle operation.

Table 4: Accelerator position and fuel consumption

Accelerator position (%)	Fuel consumption (l/100km)	Output power (kW)
100	25,76	35,6
41	21,09	32,1
25	19,96	28,9
20	15,29	25,7
17	13,84	21,5
14	11,43	17,5
13	9,98	14,9
11	8,37	11,8
10	7,08	9,2
9	7,89	6,6

Table 4 shows the characteristic the fuel consumption according to the accelerator position. The right column represents the output power needed to drive the vehicle at the velocity 50 km.h⁻¹ (colouration to the elevation and acceleration). The blue square borders the output power needed to the acceleration to the velocity 50 km.h⁻¹. The fuel consumption values are results of the fuel consumption measurement done at engine speed of 2500 rpm using the 3rd gear which corresponds the velocity 50 km.h⁻¹.

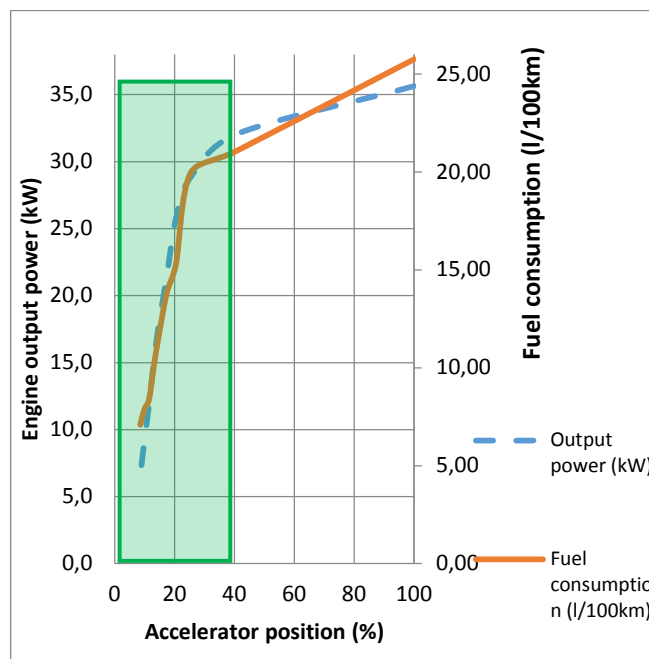


Fig.3 Course of the fuel consumption and the output power

5. Conclusion

The results point to the fact to mind during driving. It is the reality that accelerator position does not correspond with the engine output power, vehicle dynamics and fuel consumption. During the accelerator pushing down (from the idle to the kick down), the output power is increasing less and the fuel consumption is increasing more. The optimal operational range of the accelerator is up to 40% of the total range. Over this interval is the vehicle operation less effective from the economic and environmental point.

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POSSIBILITIES OF MEASURING THE BRAKE SPECIFIC FUEL CONSUMPTION IN ROAD VEHICLE OPERATION

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Abstract: Fuel consumption is one of the most important operating characteristics of road vehicles. In operation of road vehicles there we usually express fuel consumption in l/100 km for driving performance, or l/h when the car engine is idling. The fuel consumption can be quantified by several methods, and it affects a number of factors (driver, vehicle, and environment). It can be considered as a posteriori consumption, i.e. operational consumption. The priori fuel consumption (inserted, pre-defined) based on the construction properties of respective engine. Most often it is the priori fuel consumption expressed by measuring the effective consumption, which defines the amount of fuel consumed per unit of effort and time. It is usually quantified at a time when the engine is mounted to the vehicle itself. The contribution presents a practical example of measuring the effective fuel consumption in operation of road vehicles.

Keywords: FUEL CONSUMPTION, FUEL FLOW METER, ROLLER TESTER

1. Introduction

Specific fuel consumption and other technical parameters of the internal combustion engine are determined in the laboratory with using a dynamometer. Here we can be testing engine for under various operating conditions which are occurring in practice. The results of individual measurements are processed and they putting in diagrams – engine characteristics. [1].

We recognize the following type of fuel consumption formulation.

Fuel consumption per hour – M_p - is mass rate of flow fuel in the combustion engine [kg.h⁻¹].

Brake specific fuel consumption – BSFC is the quantity, which expressing how much fuel uses the engine on perform useful work 1 Joule. This is calculated from the relation:

$$BSFC = \frac{M_p \cdot 1000}{P_E}$$

BSFC [g.kW⁻¹.h⁻¹]

P_E - Effective engine power (kW)

Engine speed characteristic is the best known and the most widely used from characteristics. The course of BSFC is part of this characteristic. It is detected by help constantly open throttle valve (usually 100%).

2. Methodology of measuring BSFC in operation of road vehicle

1 Measurement technology

For measuring fuel consumption is needed in the laboratory conditions ensure that is using following measuring technique:

- roller tester with accessories - this type of diagnostic equipment is used in the measurement of fuel consumption as a driving simulator. It allows movement of the vehicle in laboratory conditions with simulating load (air resistance, rolling resistance, resistance gradients) at different speeds.
- device for determining the fuel consumption - measuring technology, whose role is to quantifying the amount of fuel consumed by the engine road vehicle during the implementation kind of measurement.
- additional measuring equipment - in this group may to include, for example. diagnostic equipment to enable communication with the engine control unit to obtain

additional data (temperature, vehicle speed, etc.), or densimeter when using the volumetric method.

Tests of the measuring fuel consumption are performs out in laboratory conditions, the Department of Road and Urban Transport on the measuring devices:

- Maha LPS 2000 - representative of roller tester
- Flowtronic 205 - volumetric flow meter for measuring fuel consumption of vehicles with diesel or petrol engine
- Datron DFL-3 - volumetric flowmeter for measuring the fuel consumption of trucks.
- Laboratory balances Kern KB 10000 - laboratory balances that are used at gravimetric method.
- Densimeters

2 Calculating BSFC

Measurement requires the recording of the following parameters on the roller tester:

- Effective engine power - P_E [kW] - Performance is quantified from the measured power to the wheels - P_w by adding the power loss - P_L (transmission...)
 $P_E = P_w + P_L$ [kW]
- Engine speed - n [min⁻¹]
- Torque - M [Nm]. Torque is quantified by calculation according to the formula:

$$M_t = \frac{P_E \cdot 1000 \cdot 60}{2 \cdot \pi \cdot n}$$

P_E [kW]

n [rpm]

- Fuel consumed - FC [cm³]. It registers the volumetric flowmeter at a specified unit of time (eg, 30 sec, 1 min.)
- Fuel consumption per hour - M_p [kg.h⁻¹]. We calculated according to:

$$M_p = \frac{3600 \cdot FC \cdot \rho_F}{t_M \cdot 1000}$$

FC – fuel consumption [cm³]

ρ_F - fuel density [eg. gasoline 0.75 g.cm⁻³]

t_M – interval measurement of one point of the curve (eg, 30 sec, 60 sec) Accurate measurement ensures a longer measuring period but at higher loads, the engine is occurring of the overheating roller tester. 30 second measuring period is used in practice.

- BSFC can be calculated according to the equation:

$$BSFC = \frac{M_p \cdot 1000}{P_E}$$

3. Practical example of BSFC measurement

Results were measured in the laboratory of Department of Road and Urban Transport on vehicle Kia Ceed 1.6 CVVT with the following parameters:

Table 1: Vehicle data

Car brand	Kia Ceed	Engine code	G4FC
Engine Capacity	1591 cm ³	Length	4265 cm
Fuel	Petrol	Width	1790 cm
Cylinders	4	Height	1480 cm
Max. power	90 kW, 6200 rpm	Empty mass	1163 kg
Max. torque	154 Nm, 4200 rpm	Max. permissible mass	1710 kg
Top speed	192 km.h ⁻¹		

According the above procedure shall be calculated the individual engine parameters needed for assessment measuring the BSFC. However, it is useful to know duration the special fuel consumption throughout the engine speed range and load. Engine speed characteristics recorded only progressions at full open of the throttle valve (ie when is fully pressed the accelerator). In tab. 2 are recorded the results of the required parameters for setting of specific fuel consumption for constant engine speed 2510 rpm. The first column shows the value of full the throttle valve opening statement of actual values obtained through internal diagnostics HiScan.

Table 2: Measurement results at 2510 rpm

Opening throttle valve (%)	P _w [kW]	Velocity [km.h ⁻¹]	n [rpm]	FC [cm ³]	P _L [kW]
7,1	5	49,7	2510	27,89	0,65
15,7	21,5	49,7	2510	67,06	2,80
25,1	27,1	49,2	2510	82,34	3,52
35,7	28,6	49,7	2510	88,98	3,72
45,1	29,1	49,7	2510	90,30	3,78
55,3	29,5	49,7	2510	90,30	3,84
65,5	29,7	49,7	2510	92,30	3,86
72,5	31,2	49,7	2510	105,58	4,06
78,8	31,3	49,7	2510	107,57	4,07
Opening throttle valve (%)	P _E [kW]	M _t [Nm]	M _p [kg.h ⁻¹]	BSFC [g.kW ⁻¹ .h ⁻¹]	
7,1	5,75	21,87	2,51	436,73	
15,7	24,71	94,02	6,04	244,24	
25,1	31,15	118,51	7,41	237,89	
35,7	32,87	125,07	8,01	243,60	
45,1	33,45	127,26	8,13	242,98	
55,3	33,91	129,01	8,13	239,69	
65,5	34,14	129,88	8,31	243,33	
72,5	35,86	136,44	9,50	264,96	
78,8	35,98	136,88	9,68	269,09	

From results it can be constructed so called Workload characteristics of the engine (Fig. 1). Measurement the load characteristics allows to construct the multiple modes engine complete engine characteristics, from which it is possible count almost all important engine parameters throughout the load range.

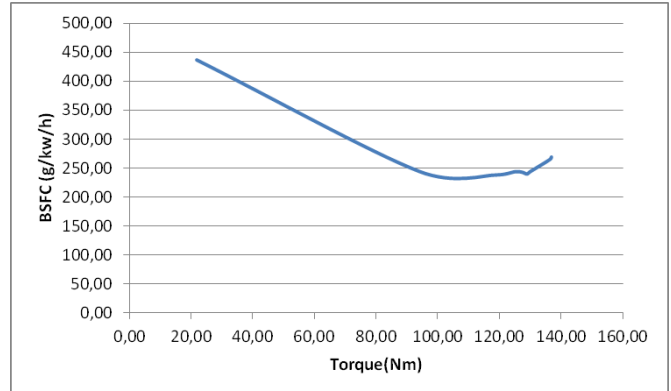


Fig. 1 Load characteristic

The engine parameters shall be recorded at full throttle valve opening for compiling the external characteristics of the engine. In the particular example is the final row the measured values in table 2. A value thus obtained defines the external characteristics of the engine for the entire speed range. In Table 3 are the values measured for the Kia Ceed at engine speed 1700-6300 rpm.

Table 3: Values of engine external characteristic

n [rpm]	BSFC [g.kW ⁻¹ .h ⁻¹]	P _E [kW]	M _t [Nm]
1700	289,48	21,47	119,90
1900	286,26	24,63	123,81
2100	273,76	28,82	130,41
2300	278,39	32,09	133,25
2500	269,09	34,58	131,56
2700	272,11	38,87	136,98
2900	270,17	41,58	136,46
3100	265,78	44,07	135,76
3300	269,49	47,23	136,27
3500	284,58	50,40	137,12
3700	277,48	54,92	141,36
3900	287,15	57,86	141,30
4100	297,60	63,05	146,51
4300	306,32	66,33	146,97
4500	293,41	68,03	144,04
4700	313,74	70,29	142,81
4900	343,88	71,08	138,24
5100	340,52	76,95	143,81
5300	352,10	75,60	135,95
5500	355,60	77,18	133,52
5700	357,84	76,95	128,70
5900	362,20	80,68	130,15
6100	361,92	80,91	126,25
6300	369,31	80,91	122,45

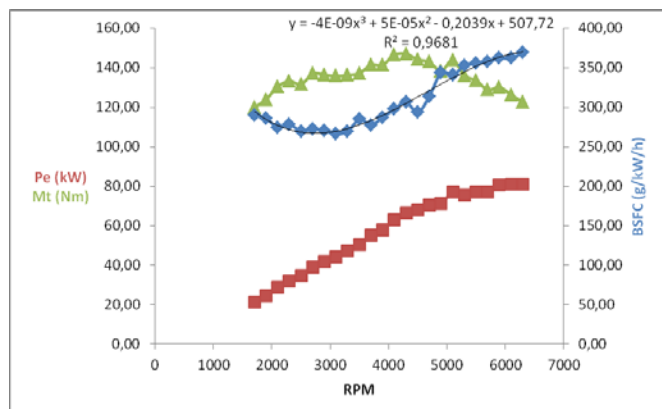


Fig. 3 Engine characteristic

4. Conclusion

Measuring the specific fuel consumption is difficult in operation road vehicles. This type of measurement requires a rolling tester and flowmeter. This type of measurement requires a test cylinder and flow meter to record the amount of fuel consumed. This characteristic defines in which areas (speed range) engine operates the most economical, respectively, the most effective in terms of performance parameters. It is area around speed of 3000 min^{-1} in the example of figure 2. It is surprising that when the vehicle is driven in said areas does not reach the lowest operating vehicle fuel consumption (l/100 km), because the engine works enough big output, and vehicle goes either relatively quickly or uphill.

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THE ROLE OF TRAFFIC SIGNALIZATION ON REDUCTION OF ACCIDENTS ON THE CROATIAN ROADS

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Abstract: Safety of all road users on the roads is one of the fundamental social objectives. Measures for improvement or remediation of dangerous sites (black spots) in Croatia are carried out in several phases, from planning the envisaged measures, valuation measures, the implementation of measures to observation and assessment derived measures. Certain dangerous places are repaired only by changing traffic signalization and those sites and measures are described in this paper. In last eight years on the roads in Croatia, 215 dangerous places were repaired and partial restoration was carried on the 46 dangerous places. The success of provided measures, expressed through an analysis of the number and consequences of accidents on dangerous places for three years before and three years after restoration, shows the drastic reduction in traffic accidents on this places. The conclusions and solutions of these measures are presented in this paper.

KEYWORDS: BLACK SPOTS, TRAFFIC SIGNALIZATION, RETROREFLECTION, MEASUREMENTS

1. Introduction

The National Program of road safety in Croatia was first planned and implemented in 1994. Since then, it has been conducted the four National Programs, and the latest, fifth, is in force since April 2011. (Period 2011-2020). Considering the positive experience in the implementation of these programs, which have resulted decreasing fatal casualties and decreasing injuries in traffic accidents, it has continued with the adoption of the program, with addition to tracking the latest trends in increasing road safety and compliance with best practice in European countries, which recorded the best results. In determining the cause of the accident or wrong behavior of participants that started the accident event is of crucial importance. Is it for wrong behavior that caused the accident responsible only the subjective factor, i.e. direct participant in traffic, or the incorrect behavior that caused the accident occurred in some form of interaction between subjective and objective factors.

2. Defining black spots in Croatia

There are several definitions of "black spots" and two of them are most commonly used: 1. „Black spot is a place, location in the road network (point or road section), or the streets network where is more likely than an accident will happen, depends on the other network elements.

2. In accordance with the methodology of traffic safety, the "black spot" can be called an intersection or road segment lengths up to 300 m, or "dangerous section" can be called a part of the road length of 300 m to 1000 m, with conditions that they have to comply in following criteria:

- If at the critical location in the last three years occurred 12 or more accidents with injuries,
- If at the monitoring location in the previous three years recorded 15 or more accidents, no matter the consequences,
- If at the critical location in the previous three years happened three or more identical traffic accidents, with the same group of participants, same direction of movement, on the same conflict areas etc.

In Croatia, since 2001 was detected 220 black spots (on 95 remediation is completed or is in progress). In 2012 was detected 45 new black spots, mostly in the Splitsko-dalmatinska (16) and Krapinsko-zagorska (7) county. Figure 1 shows the network of national roads and highways on the Croatian territory with the risk assessment of the causing accidents. The risk assessment is carried out in accordance with the rules of EuroRAP (European Road Assessment Programme), and it can be seen that on the majority of the network of national roads there is a very high risk of causing accidents, and the majority of black spots are just on the network of national roads.

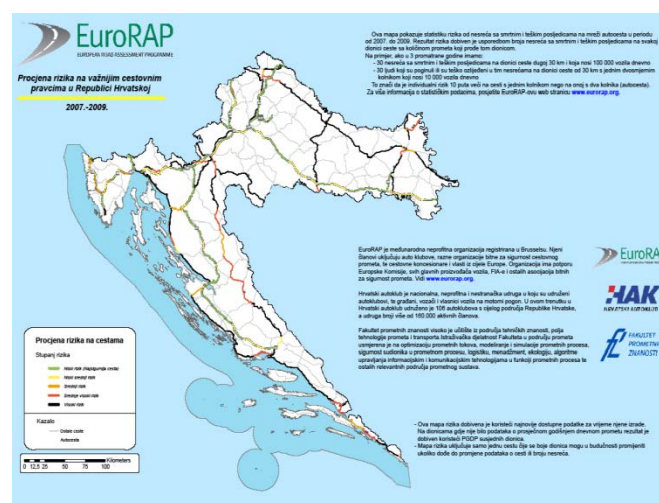


Figure1. Risk assessment on the major roads in Croatia

Source: <http://www.hak.hr/vijest/176/eurorap-mapa-rizika-za-3400-kilometara-naslih-cesta>

3. Elimination of black spots

3.1. Methodological approach

Determination of dangerous places or "black spots" on the roads is an important aspect of managing traffic at places that represent a potential threat. Situation analysis of traffic safety on all roads in Croatia was carried out in three phases:

1. The general analysis of the situation and tendency of traffic safety has enabled the understanding the size of the problem, international comparisons, review the structure of accidents, the time distribution of accidents, trends and other general characteristics of the condition.

Quality information base for the analysis and identification of critical points in the transport system requires the following information:

- Types of accidents (according to the consequences, type of collision, vehicles participants, etc.)
- Type of location (rural/urban, road, street type and class, crossing/not crossing etc.),
- Time (day time, day in week, date)
- Environment (physical conditions, light, visibility, wind, temperature, rain, snow, etc.),
- Participants characteristics (age, ability, experience, behavior, status, influence of alcohol, drugs, etc.)
- Vehicle characteristics (type, age, technical requirements, etc.)
- Road characteristics (the precise location, geometry, visibility, surface quality and condition, equipment, clarity, etc.)
- Traffic characteristics (intensity and structure of the flow, average speed, etc.)
- Expert opinion (factors that have contributed to the accident, estimated speed, position and behavior of participants)...

2. Situation analysis on the traffic sections and risk mapping by sections enabled the better understand the spatial distribution of traffic accidents and specificity of certain road sections in terms such as risk of accidents, risk of injury, the most common types of accidents, the categories of participants, the most common mistakes etc. Thus, the conducted analysis allows the definition of the most dangerous sections or "black spots". For the detection of critical points on the road network it is used different types of criteria:

- Number of accidents during a certain period that is higher than certain norms,
- Weight of accidents during a certain period,
- Combination of the number and severity of accidents during a given period,
- Number of accidents at the point that we observe in relation to other points along the road,
- Opportunities for reducing accidents
- Accidents costs during a given period,
- Danger indicators method
- Rating according to characteristics of place, not by history of accidents,
- Current annual cost of accidents that occur at this point, based on the average cost of accident and by type of accident.

3. Situation analysis by the road kilometer and determination of "dangerous kilometers". Based on a detailed analysis of accuracy, condition and quality of data on accidents it was observed the precision of the location of the accident. In the accidents analysis there are two phases:

- Phase when the driver detects a situation that leads to accidents
- Phase when the driver is trying to avoid accidents.

These phases are related with the appropriate categories of measures that seek to improve safety. One group consists of active safety measures. These are measures that help to stop the occurrence of accidents, help driver to avoid them or to put him to know that there is a situation of increased risk and the possibility of accidents (information about the risk, improving of visibility, controlled direction, etc.). Another group, measures of passive safety, are those measures which are becoming an indicator during the accident. They prevent the serious consequences of accidents (road safe environment without hard solid objects or trees, the equipment on the road that will cause serious injury, etc.). Identifying method of "black spots" on the roads is based on a previous analysis of data on traffic accidents, road and traffic. The aim of implementation method is to highlight the meaning and importance of establishing "black spots" on the roads and stimulate further theoretical and practical work on the consideration of these issues. Interventions at places of accumulation of traffic accidents are considered one of the most effective approaches in prevention of traffic accidents on the roads. Considering the scientific literature

there has been a series of attempts to find and define the most effective method, which would enable the measurement of the security of certain road sections and identify the most vulnerable and dangerous place, or "black spots" of traffic on the roads.

3.2. Traffic signalization

Croatian roads ltd. continually since 1998 in cooperation with the competent police authorities, collects data on the number and consequences of accidents on the micro locations of state roads where is noticed certain grouping of traffic accidents. The collected and processed data basically contains information about accidents, casualties, and micro-location where the traffic accidents occurred. Besides there are collected and processed data on traffic density, road and its surroundings, equipment and road signaling, etc. Data on the road and its surroundings include geometric characteristics of the road alignment (horizontal and vertical), construction elements (longitudinal and transverse slopes, type of paving, drainage), paving condition (cracks, potholes, the state of the macro and micro texture), road equipment (fences, poles, street signs Retro-reflection), visibility, road marking and lighting, etc. In this system very important role is on traffic signs, which represents the basic meaning of communication between road authorities and road users. Factors that help to identify the sign and his understanding are:

- Size of sign
- Simplicity of symbols or used text
- Color of the sign
- Retroreflection.

One of the most important properties of the retroreflective foil for drafting traffic signs except the clarity is ability to restore lights, i.e. reflectivity. There are several principles of classification retroreflective foil depending about the institution which it specifies, but the most common and used by CEN are:

- Class I (closed glass beads, at the present time and micro prisms)
- Class II (embedded glass beads, at the present time and micro prisms)
- Class III (micro prisms).

Materials class I are retroreflective sheeting's made of a durable material with the bounded glass micro beads or prisms. Retroreflection of materials class I with glass micro beads is about $70 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ and because of its low retroreflection it is in most cases used in areas with low-speed and calmer traffic flow. Materials class I that have bounded micro prisms have significantly higher retroreflection (around $200 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$) than materials with glass micro beads.

Materials class II are retroreflective sheeting's that contains encapsulated glass micro beads or micro prisms that are three times brighter than materials class I. The signs made from materials class II are clearly visible, even from a wide viewing angle, and the lighted environment, effectively warning drivers of approaching danger on the roads. Retroreflection of materials class II with glass micro beads is around $250 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ and $500 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$ for materials with micro prisms.

Materials class III are retroreflective sheeting's that are made of highly effective micro prisms that enables retroreflection around $700 \text{ cd} \cdot \text{lx}^{-1} \cdot \text{m}^{-2}$. Therefore, they provide the drivers with adequate visibility in all day and night and adverse weather conditions. The prerequisite for safe driving at night is a sufficient level of visibility for the driver which is consistent with the permitted speed. The different qualities of materials enables certain traffic signs to adjust on higher or lower levels of luminance. Some materials are designed to maximize the durability of the traffic signs, while another intended for short-term use. The different quality of materials for traffic signs, different sign production processes and selection of materials for the surface of the sign will have an impact on the ultimate lifetime of traffic signs. By being placed on the open road signs are exposed to the impact of unfavorable atmospheric conditions; their unfavorable factors such as the influence of

ultraviolet rays in sunlight, humidity, and large differences between day and night temperatures. Such negative effect of weathering at the end reduces transparency, color and integrity of the materials used in retro-reflective road signs and thereby reduces their visibility at night.

The dynamics of “black spots” remediation in Croatia was conducted in a way that in 2001 was remediated 4 dangerous places, during the 2002 remediated 15 dangerous places, 2003 remediated 36 dangerous places, 2004, 51 dangerous places, 2005, 26 dangerous places, 2006, 13 dangerous places, 2007 remediated 12 dangerous places, 2008 remediated 19 dangerous places, 2009 remediated 15 dangerous places, 2010, 8 dangerous places, and 2011 was remediated 16 dangerous places. The most common causes of traffic accidents that occur on the roads which must be taken into consideration in the selection of measures that should be applied are:

- The conflict level in traffic regime,
- Clarity of the road,
- Inappropriate speed (poor conditions that contribute to driver defective estimating of safe speed)
- Conditions imposed by the environment (visibility, slippery, lighting, etc.).

Measures for short-term and long-term remediation of dangerous places can be systematically divided according to time and place of origin and the manner of elimination. With regard to the duration may be temporal or permanent.

I. Class of measures (temporary measures, mostly traffic-technical properties) - those that result from occasional or periodic condition at a specific location (ice, driving traffic, temporary blockages, etc.) or a result of various of other causes (the inevitability of taking action, additional land acquisition, lack of resources, etc.). Traffic signs on the road must meet the following conditions:

- alert the driver to any unusual and non-standard solution,
- inform drivers about road conditions that a driver must be considered at time, and they must adapt,
- guide the driver through an unusual situation (it clearly focus on appropriate behavior)
- direct its movement in zones of conflict and at other road surfaces,
- compensate for certain errors and behavior by drivers with elements that mitigate the effects and help to avoid accidents.

This class of measures are undertaken at those locations where they are not needed construction works, and where are already adequate road signs (better class to create traffic signs, new traffic signs, maintenance ...) sufficient to achieve a higher level of safety in road traffic. Examples of such repairs are shown in Table 1 under regular maintenance program (Karlovac D3, Čibaća, Velika Mučna...), which includes the maintenance or replacement of existing traffic signs. Picture 2 gives an example of taking measures for the rehabilitation of a first-class dangerous place where the existing signs are replaced and supplemented with new traffic signs and road markings.



Picture 2. Displaying dangerous place before and after the implementation of measures of class I

Source: <http://www.skyscrapercity.com>

II. Class of measures (permanent measures) - measures that should completely eliminate the condensation of traffic accidents. This class includes construction-technical measures and adequate traffic signs and represents the most expensive but also the best solution for the remediation of hazardous places. Building technical measures include:

- Extension of the roadway,
- Correction of cross slope,
- Creation of visibility in curves,
- Construction of the rotor,
- Setting of additional protective fence,
- Changing the roadway with new asphalt layer
- Milling of asphalt surfaces to increase friction road surface during the summer rains and winter ice...

In Croatia, this type of measures is usually implemented through programs Betterment and national road safety program (Table 1). The national program of road safety of Croatian basic document and a platform to raise the level of road safety in our country to a higher, more acceptable level than current, while the Betterment Program (a program of increased maintenance and project specific rehabilitation) is the rehabilitation of the road network, and is funded partly of loan funds from the European Investment Bank, and partly from its own resources Croatian Roads Ltd. Picture 3 gives examples of taking action of II. Class measures that include building technical measures and traffic-technical characteristics (Betterment Program).



Picture 3. Displaying dangerous place before and after the implementation of measures of class I

Source: <http://www.skyscrapercity.com>

These measures in the short-term and long-term remediation of dangerous places are based on:

1. Established conflicting events observing traffic on that place;
2. Mentioned traffic technical deficiencies and irregularities of the road, affecting traffic safety;
3. Justification of the measures by the valuation methodology (cost – benefit), established traffic technical irregularities of the road and considering the dangerous behavior of road users.

Table 1. provides data of traffic accidents and the consequences of these accidents (number of minor and serious injuries, and the number of fatal accidents and easier injuries) for the period from the last 3 years (data for the 2012 and 2013 year are processed completely) which include information on traffic accidents three years ago and three years after the measures implemented. Under the program, there are measures which were taken at each dangerous section. On some sections it was enough to replace existing traffic lights, with adequate new traffic signs (regular maintenance program), and in this way reduce the number of fatally injured persons, while individual stocks require more remediation and construction-technical measures and also adequate traffic signs.

Table 1. List of remediated dangerous places in last 6 years
(Source: Croatian Roads Ltd.)

REMEDIED 2009													
DESCRIPTION OF LOCATION	CHARACTERISTICS OF ROAD	POSITION OF DANGEROUS PLACE	COUNTY	ROAD	SECTION	CHAINAGE	NUMBER OF TRAFFIC ACCIDENTS		TRAFFIC ACCIDENTS				MAINTENANCE PROGRAM
							3 YEARS AGO	3 YEARS LATER	DIED		INJURED		
Karlovac D3	intersection	settlement	Karlovačka	D23	Karlovac (D6) - Josipdol (D42)	od km 1+315 do km 1+465	23	11	0	0	9	1	REGULAR (traff. signalization)
Plominsko zagorje	section	outside settlements	Istarska	D66	003 Vozilici (D64) - Matulji (D8)	od km 9+050 do km 10+050	9	3	0	0	1	0	Betterment
Ferovac	section	outside settlements	Požaško-slavonska	D51	001 Gradšće (D53) - Požež (D38)	od km 9+600 do km 9+800	3	1	0	0	2	0	Extraordinary maintenance
Bekešinci	curve	outside settlements	Osječko-baranjska	D7	005 Čepin (Z 4105) - Bakovo (D38)	od km 8+350 do km 8+652	2	2	0	0	0	2	Betterment II
Dubrova	intersection	settlement	Istarska	D66	002 Most Raša (D421) - Vozilici (D64)	od km 11+200 do km 11+400	8	1	1	0	2	1	Remediated OM
Vukušića strana	curve	settlement	Špilitsko-dalmatinska	D39	002 Costa Provo (D60) - Sestanovac (D62)	od km 7+500 do km 8+000	4	1	0	0	3	0	Betterment II
Plominsko zagorje	curve	outside settlements	Istarska	D66	003 Vozilici (D64) Matulji (D8)	od km 2+000 do km 2+200	9	0	0	0	3	0	Betterment
Čepin	intersection	outside settlements	Osječko-baranjska	D7	004 Osijek (D2) - Čepin (Z 4105)	od km 12+540 do km 0+050	14	6	0	0	9	3	Project NPSCP, HAC
REMEDIED 2010													
Srebreno	intersection	settlement	Dubrovačko-neretvanska	D8	029 D223 - Krasnović (D516)	od km 3+200 do km 3+500	24	4	2	0	11	2	Project NPSCP
Butačka Reka	section	outside settlements	Karlovačka	D1	011 Krmjak (D6) Grabovac (D217)	od km 2+700 do km 3+900	2	1	0	0	1	0	Remediated OM
Žudetici	curve	outside settlements	Istarska	D21	004 Ponte Portone (D44) - Višnjani	od km 2+150 do km 2+500	4	2	0	0	1	1	Project NPSCP
Starigrad, D2	intersection	settlement	Koprivničko-križevačka	D2	005 Koprivnica (D41) - Đurđevac (D43)	od km 0+900 do km 1+150	12	4	0	0	5	3	Project NPSCP
Čibača	intersection	settlement	Dubrovačko-neretvanska	D8	029 D223 - Krasnović (D516)	od km 1+300 do km 1+500	21	6	0	0	11	2	REGULAR (traff. signalization)
Velika Mužina	section	outside settlements	Koprivničko-križevačka	D41	003 Koprivnica (D2) - Križevci (D22)	od km 7+530 do km 8+130	0	3	0	0	0	0	REGULAR (traff. signalization)
Vukovar	intersection	settlement	Vukovarsko-srijemska	D57	001 Vukovar (D2) - Orolik (D46)	km 0+680	7	2	0	0	4	1	Project NPSCP
Vinkovci-Nužtar	section	outside settlements	Vukovarsko-srijemska	D55	001 Borovo (D2) - Vinkovci (D46)	od km 12+550 do km 13+100	8	3	0	1	4	2	REGULAR (traff. signalization)
Paležnik	curve	settlement	Bjelovarsko-bilogorska	D45	001 Veliki Ždenci (D51) - Garešnica	od km 13+900 do km 14+200	3	1	0	0	1	0	Remediated OM
Plovanija	intersection	settlement	Istarska	D200	001 GP Plovanija (gr. R. Slov.) - Buje (D21)	-	23	3	0	0	3	1	REGULAR (traff. signalization)
Zapadna obilaznica Osijeka	intersection	outside settlements	Osječko-baranjska	D7	003 Osijek (D2) - Beli Manastir	od km 22+200 do km 22+500	24	4	0	0	11	1	Remediated OM
Vodinci-Ivankovo	section	outside settlements	Vukovarsko-srijemska	D46	001 Đakovo (D7) - Vinkovci (D55)	od km 2+700 do km 3+900	7	2	0	0	7	1	REGULAR (traff. signalization)
Veliki Ždenci	curve	settlement	Bjelovarsko-bilogorska	D5	003 V. Ždenci (D2) - Donji Daruvar (D34)	od km 0+950 do km 1+250	2	0	2	0	0	0	Remediated OM
Most Raša	curve	outside settlements	Istarska	D66	001 Pula (D3) - Most Raša (D421)	od km 31+800 do km 32+000	16	0	0	0	3	0	Remediated OM
Obilaznica Vinkovaca	intersection	settlement	Vukovarsko-srijemska	D46	001 Đakovo (D7) - Vinkovci (D55)	km 39+048	16	2	1	0	8	2	Project NPSCP
Bjelopolje 2	curve	settlement	Ličko-senjska	D1	013 Korenica (D52) - Udbina (D522)	od km 9+000 do km 9+081	10	0	2	0	3	0	REGULAR (traff. signalization)
Barban	curve	outside settlements	Istarska	D66	001 Pula (D3) - Most Raša (D421)	od km 30+000 do km 31+000	26	2	0	0	11	0	REGULAR (traff. signalization)
Pisarovina	intersection	settlement	Zagrebačka	D36	001 Karlovac (D1) - Cerje Polupsko (D31)	od km 31+500 do km 31+650	11	4	0	0	8	2	REGULAR (traff. signalization)
REMEDIED 2011													
Rovinjsko selo	section	outside settlements	Istarska	D303	001 Rovinj - Čvor Kanfanar (D3)	od km 3+000 do km 4+000	16	2	1	0	6	1	Remediated OM
Cerje Nebojske	curve	settlement	Varaždinska	D35	001 Varaždin (D2) - Lepoglava (D508)	od km 14+600 do km 15+200	10	1	0	0	4	1	Betterment II
Karlovac - Smičklova	intersection	settlement	Karlovačka	D1	010 Čvor Karlovac (D3) - Krmjak (D6)	od km 3+000 do km 3+150	15	2	1	0	2	0	Project NPSCP
Pređavac	intersection	settlement	Stiaško-moslavačka	D28	003 Zabno (D22) - Bjelovar (D43)	od km 4+600 do km 4+750	6	0	0	0	1	0	Remediated OM
Spilj, Put Trstenika	intersection	settlement	Špilitsko-dalmatinska	D410	001 Spilj(trajektina luka) - Spilj (D8)	km 1+930	37	0	1	0	15	0	REGULAR (traff. signalization)
Veliko Brdo	intersection	settlement	Špilitsko-dalmatinska	D8	020 Dubci (D39) - Makarska (D512)	od km 15+000 do km 15+300	2	0	0	0	2	0	Extraordinary maintenance
Rijeka, raskrižje Zvonimirove i Benecove	section	settlement	Primorsko-goranska	D8	003 Matulji (A8) - Rijeka (D403)	-	19	5	0	0	9	4	REGULAR (traff. signalization)
Čakovac D208/Z2031	intersection	settlement	Međimurska	D209	001 G.P. Mursko Središće - Nedelišće (D3)	od km 15+700 do km 15+850	11	4	0	0	7	2	REGULAR (traff. signalization)

4. Conclusion

Safety of all road users on the roads is one of the fundamental social objectives. Traffic accidents related to some area, are due to unfavorable interactions between subjective and objective "factors - the road" to "dangerous place", meaning that the some road characteristics have a significant effect on driver behavior, and that such behavior would result in a traffic accident. The road and its effects are not the only or the biggest factor in road accidents. Most common cause is the human factor, but eliminating possible causes of the events of traffic accidents due to road conditions, appropriate amendments to traffic signs and road equipment is quickest and most efficient way to affect the reduction in the number and consequences of accidents at critical locations. Determination of "black spots" on the roads on the basis of registered safety indicators (number of traffic accidents, the number of deaths, and the number of minor and injured people on certain sections of the road) is the first step to be taken in order to later be determined and implemented preventive and repressive measures to increase traffic safety.

Measures for improvement or remediation of dangerous spots in Croatia are carried out in several phases, from planning the envisaged measures, valuation measures, the implementation of measures to observation and assessment derived measures. In the previous period, Croatian Roads, through various programs, have spent to complete the remediation of 215 dangerous spots and partial rehabilitation of 46 dangerous spots around 24 million Euro, while for the same purpose from the funds of the National program of road safety in Croatia, was allocated 0,7 million Euro, which makes a total of 24,7 million Euro spent for remediation of dangerous spots on state roads of Croatia. The success of the remediation projects, expressed through an analysis of the number and consequences of accidents on retrofit dangerous places for three years before and three years after remediation, is evident through a drastic reduction in traffic accidents on those dangerous spots.

In the period since 2001. until 2011., was huge reduction of number of traffic accidents (from 6326 to 1568, which is 75.2% less accidents). The number of deaths on retrofit dangerous places was reduced from 131 to 12 (90.8%), serious injuries from 548 to 141 (74.2%) and the number of light injuries decreased from 1,980 to 555 people (71.9%). This results clearly shows that with even small measures (like changing traffic signalization on some dangerous spots), great reduction on traffic accidents number can be reached.

Acknowledgement

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INCREASE OF ELEMENTS LIFE BY MEANS OF PLASMA ELECTROLYTIC OXIDATION

ПОВЫШЕНИЕ РЕСУРСА ДЕТАЛЕЙ ПЛАЗМЕННО-ЭЛЕКТРОЛИТИЧЕСКИМ ОКСИДИРОВАНИЕМ

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Abstract: Micro arc oxidation (MAO) is one of the advanced methods of obtaining thin-layer oxide ceramic coatings on the elements of machines of different functionality, allowing considerably increasing their life. The work is devoted to investigation of wear resistance and microhardness of coatings formed by micro arc oxidation on aluminium alloys in different electrolyte types. MAO is recommended for application at different engineering and maintenance technical enterprises, that produce, restore and harden elements.

KEYWORDS: MICRO ARC OXIDATION, LIFE, WEAR RESISTANCE, MICROHARDNESS, ELECTROLYTE, OXIDE CERAMIC COATING.

1. Introduction

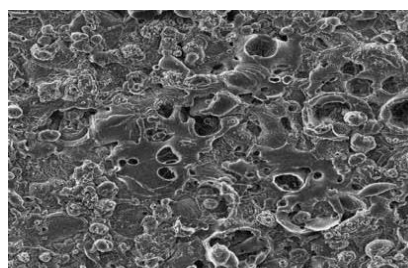
Increase of elements life by means of their restoration and hardening is the principle reserve of material saving, reduction of techniques repair expenses and one of the most important problems in the conditions of raw-material and energy resources price rise. One of the advanced methods of allowing considerably increasing the life of elements produced from aluminium alloys (pistons of internal combustion engines, bodies of hydraulic gear-type pumps, etc.) is micro arc oxidation.

The essence of micro arc oxidation is in forming thin-layer high-strength wear resistance ceramic coating mainly from solid phase aluminum oxides on the element surface under the influence of micro plasma discharges [1].

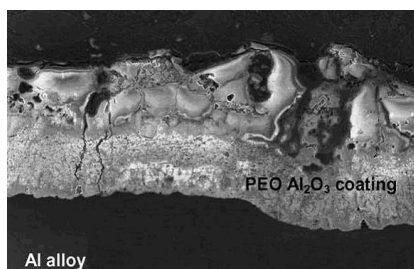
To the main advantages of plasma electrolytic oxidation (PEO) can be referred [2-3]:

- possibility to apply coatings on complicated specialized articles, internal surfaces and hidden cavities;
- obtaining of coatings with thickness to 0,3 mm with adhesion compared with base material hardness;
- low price and availability of chemical agents and materials;
- environmental safety.

Fig. 1, as an example presents morphology and typical microstructure of coatings obtained by MAO on aluminium alloys.



a)



b)

Fig. 1 – Morphology (a) and microstructure (b) of coatings obtained by MAO. Enlargement 600^x and 400^x.

At present many aspects of mechanism of MAO passing are under-investigated: there is no systematic information on the influence of internal and external factors on this process, many new electrolytes are not tested yet, etc.

The results of investigations of wear resistance of coatings being obtained by MAO on different aluminium alloys in electrolytes of type «KOH-Na₂SiO₃» and «KOH-H₃BO₃» are presented below.

2. Experimental procedures

Aluminium alloys of marks: ENAB-42000, 5251, 1235, 2017A and bronze C60800 were taken as material for sample production.

Coatings on aluminium casting alloy ENAB-42000 were formed in electrolyte of type «KOH-Na₂SiO₃» with the following concentration of components per 1 liter of distilled water: KOH – 2 g/l, Na₂SiO₃ – 10 g/l.

Electrolyte of type «KOH-H₃BO₃» with components concentration: KOH – 5 g/l, H₃BO₃ – 20 g/l starch – 10 g/l was used to form the coatings on deformed aluminium alloys ENAB-42000, 5251, 1235 and 2017A. Duration of sample oxidation was 100 min.

Relative wear resistance of sample surfaces was investigated in the conditions of boundary lubrication on the friction test machine ИИ 5018 according to scheme «stone-holder-roller». Boundary lubrication conditions at tests of coatings on alloy ENAB-42000 were provided with uniform feeding of spindle oil to friction surface. For wear speeding the abrasive prepared from siliceous sand with dispersion 3 µm was added into power fluid. Abrasive material concentration was 0,14 % according to oil mass. As working environment at tests of coatings obtained on deformed aluminium alloys 3 % solution of milk acid was used. Values of stone-holder and roller were determined by gravimetric method. Micro hardness of coatings was measured by device ПМТ-3.

3. Results and discussion

In the course of the done investigations it was stated that wear rate of oxide-ceramic coatings obtained in electrolyte of type «KOH-Na₂SiO₃» is in 3-4 times lower than wear rate of aluminium surfaces that were not hardened Fig. 2 (a).

Working surfaces of samples without coatings after tests were covered with numerous deep parietal lines and scratchers – wear tracks resulting from the influence of abrasive particles on metal. Working surfaces of friction pairs with hardened samples in a less degree were subjected to abrasive particles influence. Rollers with coatings actually did not have scratchers and notches. It is conformation of their high hardness and wear resistance. General view of working surfaces after tests for wear is presented in Fig. 2 (b, c).

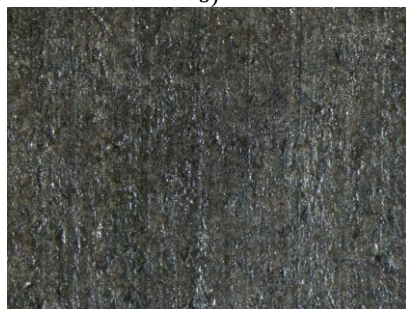
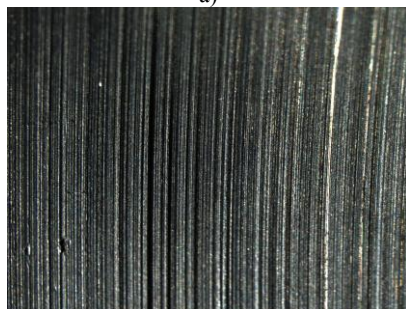
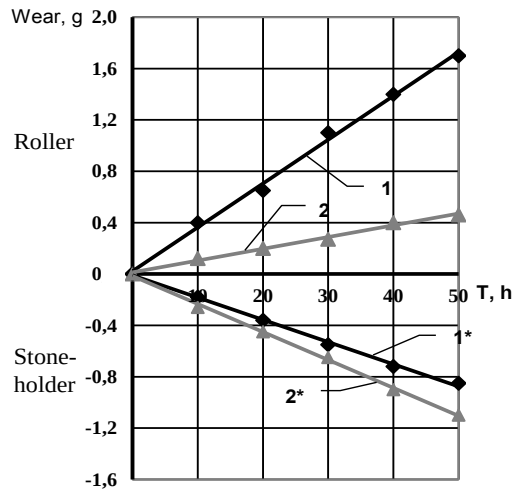


Fig. 2 – Results of tests for wear: a) influence of duration of tests on wear of friction pairs: 1 – roller from alloy AK74 without coating; 2 – roller from alloy ENAB-42000 with coating. 1*, 2* – stone-holder (Steel 18 ChGT, HRC 58-62); b) surface of roller without coating after tests; c) surface of roller with coating after tests.

Special interest was paid to tests of wear resistance of coatings obtained by MAO on aluminium deformed alloys in electrolyte of type «KOH-H₃BO₃». In this case bronze samples were considered as transfer standard. At that wear intensity of reference surface was in 2-3 times higher than wear intensity of aluminium deformed alloys being hardened by MAO (Fig. 3).

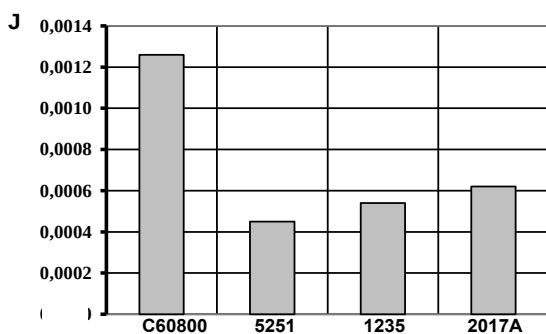


Fig. 3 – Intensity of wear J samples from aluminium alloys with oxide-ceramic coating in comparison with C60800

Reasons of high wear resistance of oxide-ceramic coatings are connected with their structural state [3, 4]. Apparently, those structural modifications of alumina oxide in coatings form the strongest type of intermolecular bounds between each other [4-6]. The number of authors [1-3] is sure that the oxide-ceramic coating obtained by MAO, as a matter of fact, is a composition material, at the same time coating wear resistance can be compared with wear resistance of composition materials on the ground of tungsten carbide, traditionally applied against abrasive wear.

Coatings obtained by micro arc oxidation differ with high hardness. Thus, for example, average value of microhardness of hardened layers, obtained on aluminium deformed alloys is 14-17 GPa, on casting alloy ENAB-42000 – 6-8 GPa. At the same time microhardness of aluminium alloys without coatings is in the limits – 0,86...0,99 GPa. It is necessary to stress that microhardness by thickness of the formed coatings is not uniform (Fig. 4). Maximum value of microhardness falls on the definite layer of coating, higher or lower which its values decrease. The area with maximum values of microhardness is at the distance of 30...50 µm from nominal size of oxidize sample. The decrease of microhardness is observed along the whole thickness of outside hardened layer of coating.

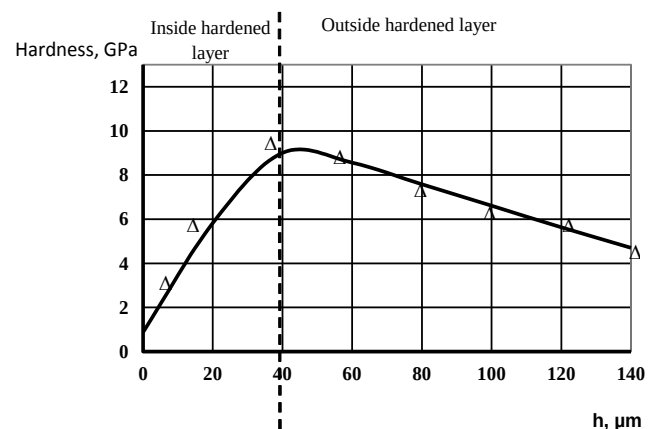


Fig. 4 – Alternation of microhardness of coating obtained by MAO in electrolyte of type «KOH-Na₂SiO₃» by thickness on aluminium alloy ENAB-42000

Increased microhardness of oxide-ceramic coatings obtained by MAO and its nonuniformity by thickness of the hardened layer are acknowledged by other investigators [2, 3]. At the same time it is stressed that in the inside layer contains more of solid phase α - and γ - phases of alumina oxide, than in the outside layer because of higher temperature in coating breakdown paths. Microhardness of coatings also depends on chemical composition of oxidize alloy.

4. Conclusion

The complex of investigations of oxide-ceramic coatings obtained by MAO on aluminium alloys proved that they possess high microhardness and wear resistance. This method can be recommended for application at engineering and maintenance technical enterprises, that produce, restore and harden elements. The anticipated increase of hardened elements life will be not less than 150-200% in relation to new elements.

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LIFE SPAN AND RECYCLING OF MOTOR VEHICLES

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Abstract: *The car is prevalently considered as a technical system that produces costs and pollution, also as a source of exhausted parts and recycled raw material. In the course of entire life cycle it seriously deteriorates natural balance to the extent to appear as a threat to overall ecological biodiversity on the Earth. Due to mass production and use what includes building-in vast number of materials and component that yield adverse effects on human health, engine cars has become one of major problems of today.*

The management of secondary waste requires an established flow of integrated information as well as an complementary system of knowledge and methods regarding landfill remnants reduction and adequate treatment of useful materials. Global automotive industry incites development of national economies and integrates contemporary achievements in the areas of techniques, technology and other scientific disciplines. Thus, the aspects of energy efficiency, waste recycling and environment protection sustainable development environmental shall be taken into account in car designing and production.

KEY WORDS: CAR, RECYCLING, LIFE CYCLE, SUSTAINABLE DEVELOPMENT, ECOLOGY, EXPLOITATION

INTRODUCTION

There have been so many initiatives aimed to establish an integrated system of recycling of motorcars at their life cycle end which actually yielded some effects in renewing car fleet as well as in raising traffic safety and improving environment protection. Although new Law on waste management has been endorsed many ambiguities how to meet requirements still persist particularly related to car registration cancelling, certain car recycling phases, cost reimbursement issues, establishing the market of detached parts etc. Therefore, it appears necessary to define an adequate model of cooperation among manufacturer /importer, corresponding state authorities, recycling entities and other relevant parties.

The development of car recycling industries along with state supporting policies has produced significant effects in this area, like: car fleet renewing and improved traffic safety, increased engagement of human resource in car industry, opening new jobs in car recycling industry, environment conservation, natural resources conservation, energy resources conservation.

A system to monitor cars in life cycle and after their exploitation period termination is to be reliable thus to provide sufficiency of relevant data to interested parties in recycling system. It may be assumed that there is a huge number of unregistered car left by the owners (in garage, public parking places, houses for rest) looking for adequate solution how to get rid of them. However, the problem appears to be harder when parts are detached from the car with the intention to be solved on black market while remaining parts unable to find a buyer (chassis, seats, wheels, parts of motor and transmission) remain partly lying on car waste fields (counting more than thousand in Serbia), partly in recycling entities and unfortunately some are left by local and forest roads, by river and lake banks, on fields and other locations.

To avoid such behavior or to reduce it to a reasonable level, an option might be provide the car be dispatched to auto scrap collection and treatment facility. At first sight this option should be a good solution but it requires auto scrap (end-of life vehicles) companies establish more transparent operation, particularly maintaining control on routes of used parts, primarily for roads safety reasons and for sustainable environment sake. [8]

EU DIRECTIVE ON END-OF LIFE VEHICLES

In order to enhance end-of life recycling process European Union adopted Directive 2000/53/EC in September 2000, imposing EU national governments to implement it by 21 April 2001. Some general clauses of Directive 2000/53/EC regard following principles: The Directive harmonizes national measures for end-of life vehicles recycling, predominantly to reduce their adverse effect on natural environment thus contributing protection, conservation and improvement of environment quality, energy conservation, and unimpeded operation of EU market and prevention of distortion

between member states. Such a framework appears necessary to secure coherence between national approaches in accomplishing phase objectives, i.e.: design, exploitation, recycling (collecting, treatment, reuse and recovery) taking into account the principle of subsidiarity and polluter-pays principle.

According to EU strategy, the basic principle lies in decline waste deposition to extent possible and rather turns to reuse and recovery, including energy production, consequently creating the system aimed to economically justify collection, treatment and reuse of car parts at the end-of life cycle and its integration into new vehicles production.

Every year there is 8 – 9 million tones of waste generated by vehicles requiring to be managed in a proper way.

Directive provides that Member States shall take the necessary measures to ensure that the delivery of the vehicle to an authorized treatment facility occurs without any cost for the last holder and/or owner as a result of the vehicle's having no or a negative market value. This policy relates to components, spare parts and materials regardless applied safety standards (climate change, exhaust gases emission, noise).

Directive 2000/53/EC is preceded by some other directives which treated the issue of waste produced by end-of life vehicles, namely: Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances from 1967, Directive 70/156/EEC relating to the type-approval of motor vehicles and their trailers from 1970 and Directive 75/442/EEC on waste from 1975

Directive 75/442/EEC treats the issue of vintage vehicles meaning historic vehicles or vehicles of value to collectors or intended for museums or other modes of preservation which are to be kept in a proper and environmentally sound manner.

Directive 2000/53/EC include preventive actions starting from conceptualization stage, implementation phase, up to end-of life stage. More specifically it regards reduction and monitoring of hazardous materials located in the vehicle in order to prevent their ingress in the environment and simultaneously to facilitate recycling and avoid hazard waste deposition. It particularly relates to: lead, mercury, cadmium, hexavalent chromium, sulfuric acid and other items. These heavy metals may be used in certain applications only, however under permanent supervision and according to regulations thus to prevent entering to recycle line.

Commissions in charge for improving Directive in the area of plastic material usage and recycling are permanently active trying to reduce PVC adverse effects on sustainable environment upon recycling process.

Recycling systems and the market of recycling materials are to be permanently promoted and supported, particularly in regard of new car design and manufacturing with the aim to prevent environment hazards and to remain economically profitable.

Directive arranges the issues of certificate of vehicle deregistration and notification of authorities about the fact that the vehicle has been directed to the recycling system.

EU member states are obliged to provide Directive implementation and to maintain access to SMEs having license for collecting, decommissioning, storage and other treatment in vehicle recycling process.

Vehicle manufacturers shall be aware of quantified objectives regarding reuse of recycled products yet in design stage thus to meet requirements on safety and environment protection. In that regard, EU shall promote European standards preparing and other measures that would not affect design concept of vehicles, but would meet relevant regulations [10]

By the beginning of 2006 Member States were obliged to attain 85% average weight (per vehicle, per year) through reuse of recycled material and energy return by waste incineration. For vehicles produced before 1. January 1980., Member States may lay down lower targets, but not lower than 75% for reuse and recovery and not lower than 70% for reuse and recycling. Up to January 2015, for all end-of life vehicles, the reuse and recovery shall be increased to a minimum of 95%, but for the re-use and recycling shall be increased to a minimum of 85% by an average weight per vehicle and year. Such EU position resulted in production of vehicles containing materials and parts that can be reused and recycled to the minimum level of 85 % to reach minimum level of 95% in 2015. Fig.1 below shows the application of Directive transitional clauses in time framework.

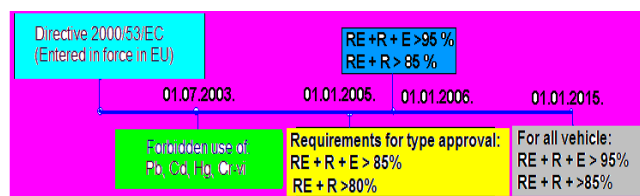


Fig. 1. Directive 2000/53/EC application (RE-reuse, R-recycling, E-energy) [2]

One of major problems in recycling process is parts separation which makes standards for parts and material coding indispensable. European Parliament Commission established the decision 2003/138/EC

on component and material coding standards. Plastic parts which mass exceeds 100gr. shall be appropriately labeled according to ISO 1043-1:2001, 1043-2:2000 and 11469:2000. Parts made of rubber exceeding 200gr. shall have labels following ISO1629:1995.

The essence of end-of life automobile treatment lies in efficient and profitable recycling system capable to yield reduction in unrecycled waste deposition and environment improvement. Highly unified vehicles for all markets thus meet regulation requirements including the laws relating to recycling of end-of life vehicles.

END-OF LIFE RECYCLING OF MOTOR VEHICLES

Expanding number of motor vehicles in the world imposes first to developed countries but also to the others to tackle the development of procedures and equipment for recycling. According to some credible sources, it is considered that there exist about 800 million vehicles in exploitation, 160 there of in European Union. The fact that only in EU that about 17million vehicles are withdrawn from exploitation means that 20million tones of such waste results thus rise the recycling of such waste to become a major issue.

Some sources indicate that the number of vehicles that were not reregistered in 2009 attains 170,000 units, what makes about 11% of car fleet

There is no reliable answer where all of these vehicles might be, if they are not in traffic, since there is no system to monitor paths of worn-out vehicles. On the other hand, significant variations are observed from year to year. For example, average age of unregistered vehicles is constantly increasing in last 15 years with falling trend in last five years, having noticeable variations. It may

be explained with fluctuations in life standard and possibilities to bear costs for vehicle re-registration, exploitation and maintenance.

In order to obtain data on unregistered vehicles it is necessary to identify how many vehicles just omit one or two re-registrations and what makes the rest of destroyed vehicles or by any other reason permanently out of exploitation. The latter group appears to be important for interested parties in vehicles recycling process. Potential quantities of different material that might be obtained from unregistered car recycling are shown in Table 1, below.

Table 1. Recycled car material potential in Serbia [6]

No.	Sort of material	Potential quantity (t)
1.	Plastic	13.500
2.	Fluids	3.500
3.	Rubber	8.300
4.	Glass	5.700
5.	Non-ferrite materials	12.000
6.	Ferrite materials	115.000
7.	Other	6.000

Motor car is highly sophisticated product, composed by several thousand parts of different materials requiring series of different technologies and operations.

A motor car include use of different sorts of materials which participate in the car with percentage as shown in Fig.2.

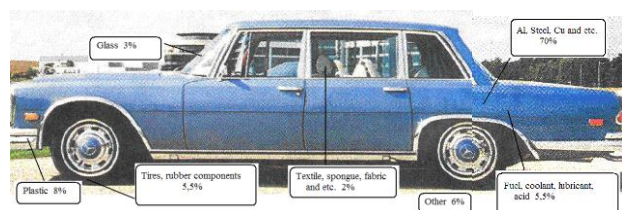


Fig. 2. Percentage of materials in overall car mass

There is not a single plant in the world where the entire vehicle may be recycled since this activity is performed in facilities differing both in sort of material and capacity. Holland and Austria, being the leaders in this area, recycle 50-60% of car waste, while in Serbia, mostly due to capacity shortage and weak legislation, this percentage is rather low not exceeding 10-14% in recent years.

At preparing stage for recycling, the parts that are first to be dismantled from the vehicles are: engine, tires, battery, all liquids (lubricants, fuel, antifreeze and other liquids), seats, wheels and other parts. Battery along with its acid belongs to hazardous substances requiring special treatment and storage in special vessels. Such a car is recycled in special facility with prior separation of: plastics, glass, fabric, etc. the remaining part of car is further compressed in a cuboids with basic dimensions 100x40x60 cm. In this way, starting with 1000kg car several cuboids of 700kg total weight is obtained, meaning that 70% of vehicle parts is ready for further recycling process. This process may be even more effective provided that vehicles for recycling are in better condition, i.e. life cycle is shortened.

It is the vehicle composition requiring recycling process to remain complex. For instance, Glass makes about 3% of car mass. Due to chemical complexity and production technology it is not recycled in glass sector but is frequently used as an additive in construction sector for concrete production. The same applies to plastics which taking part in car weight with 8% which is ultimately destroyed or by special treatment prepared used as semi-product in production of: plastic packaging, containers, box and other product that do not jeopardize human health. Under certain circumstances, plastic may be used for energy generation in special plants provided that it does not violate the requirements of sustainable development of occupational and living environment.

Particular care is given to the car fluids which appear to be rather toxic thus requiring careful collection and storage. Some fluids, like lubricating oil may be recycled with high effectiveness rates.

Tires and other rubber parts making 4% of car weight are directed to further processing in production of some coverings. The remaining part of car counting 70% of car weight is tin, different steel sorts, non-ferrous metals are treated to yield the same material sorts except alloyed steel that is submitted to particular treatment to have construction iron as most frequent ultimate output.

MANAGEMENT OF VEHICLE LIFE CYCLE

European Union has established a set of technical requirements participants in recycling process have to meet in order to prevent any damage car owners or authorized dealer might experience by using certificates, reports or monitoring activities.

The manufacturers of cars, subsystems or components shall apply marking according to valid standards as well as obey principles regarding reuse, recycling and recovery of energy by incinerating futile waste. The same applies to companies involved in collecting and recycling activities which are to obey regulations, instructions and data issued to facilitate further operation.

The management of car life cycle may be presented by a pyramid (Fig.3) having six layers: prevention, reduction, reuse, recycling, energy and waste.

Prevention is grounded on design input data, proper material selection, adequate solutions of technological processes thus creating preconditions for longer car life cycle and for diminishing permanent waste rate when life cycle is up.

Reduction is secured at the stage of design and technology development, through material selection and consumption reduction in first place.

Reuse (RE) means any operation by which components of end-of life vehicles are used for the same purpose for which they were conceived, in current status or upon certain treatment

Recycling (R) relates to the reprocessing in a production process of the waste materials for the original purpose or for other purposes but excluding energy recovery

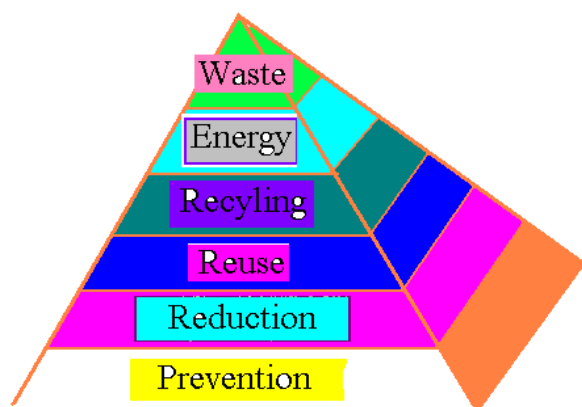


Fig. 3. Management objectives of car life cycle [2]

Energy (E) is the last level of management that relates to use energy generated through direct incineration of materials which cannot be reused or recycled in the new production but still may be converted in thermal energy in an economic way.

Waste denotes the remainder that can not be used for any of above mentioned objectives thus representing an unfavorable product. Consequently, it is necessary to make efforts at design stage to reduce this amount to the smallest possible extent and to provide its storage following regulation.

The analysis of motorcar life cycle includes beside product life cycle phases, all stages that relate to sustainable development and recycling of materials, assemblies and parts.

On the other hand, motorcar life cycle may be defined by keeping track of the sequence of events/activities. These events include issues like: registration, deregistration and ownership at the end-of life cycle.

CAR RECYCLING IN SERBIA – POSSIBLE APPROACH

To conceive activities of an integrated and sustainable end-of life vehicles recycling in Serbia the following issues are to be highlighted:

- Vehicle stream definition (production, import, registration, exploitation, maintenance, average life cycle, withdrawal from use, disposal, storage, etc.),
- Identification of material resources and overall waste from end-of life vehicles (quantities, dynamics, recycling possibilities),
- Recycling system data (recycling level, modes of recycling, possibilities for recycling),
- The market of end-of life vehicles (current, potential, business activity rate),
- Establishing the information system on general flows of vehicles with special reference to vehicle recycling activity (IS architecture and needed software).

It is necessary to define legal aspects of end-of life cycle vehicle recycling including determination of current legislation state in Serbia and comparison with the corresponding state in EU. Further steps will include:

- Establishment of an integral and sustainable model of vehicle recycling from production to end-of life,
- Development of technological pilot project for Center for vehicle dismantling and backing documentation,
- Analyzing the techno-economical effects of end-of life vehicles recycling,
- Analyzing direct and indirect effects of vehicles recycling in ecological sense,
- Establishing the Serbian association for vehicles recycling.

At the first stage, major part of activities would be oriented towards current state definition and its influence on the environment (disposal/landfills of worn vehicles, worn vehicles handling, liquids leakage, heavy metals, plastics, rubber, etc.)

At the second stage, the effects on environment improvement through the implementation of the recycling system would be in focus (landfills decommissioning, proper handling with liquids, material recycling, reduction of energy consumption for production of steel, aluminum, non-ferrous metals, etc.). Also the effects on employment by the implementation of the model for vehicle recycling would be monitored.

Fig. 4 shows, an option of positioning the Association within the motor vehicles recycling system for end-of life vehicles.

LITERATURE

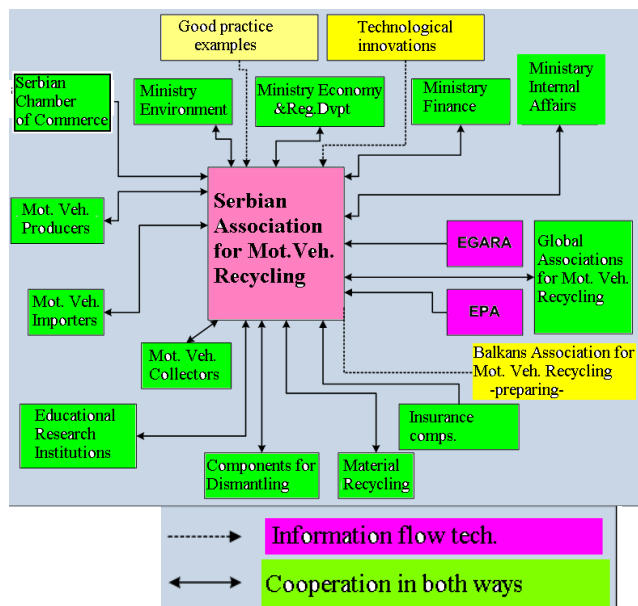


Fig. 4. The position of potential association in the recycling system [9]

The Serbian association for MV recycling would be grounded on: Transfer of technology and good practice to Serbia, Education which is to provide the development of knowledge, technology and skills and getting acquainted with meeting legal requirements, Integration of companies and research units to meet sustainable development, Providing expertise for preparing legal documents, Integration of national and international entities on commercial basis, Development of projects in this area and on resources protection,

Establishment of international cooperation with allied institutions, It is quite realistic that such an approach along with further development of the recycling system would have significant positive impact on sustainable environment protection in Serbia. [10]

CONCLUSION

Taking into the account numerous analyses done on this issue worldwide, it may be inferred that in case of omission to make serious steps in this regard, adverse impact of passenger and other vehicles will appear as a major global ecological problem. Developed countries and their governments, mostly turned to profit and power increase, have neglected the influence of mass production of motor vehicles on global environment.

Establishing the law covering issues of adverse effects reduction on global eco-system (exhaust gases emission, oil/lubricants quality, noise and vibrations, ergonomics and comfort, recycling etc.) is only one but inevitable step in right direction. Vehicle recycling issue is becoming more apparent in the world thus compelling every producer and every country to tackle the problem in order to prevent quite realistic ecological catastrophe.

The response to end-of life vehicles recycling problem is not sufficiently prepared in Serbia. Therefore, urgent legal solutions and the implementation of an integral model for sustainable recycling according to EU legislation are indispensable.

The issue of motor vehicles recycling in Serbia is not coordinated enough with environment sustainable development program thus requiring enhanced mobility of all relevant state authorities which would, along with the Association for vehicle recycling, be capable to face and solve the problem and make Serbia compliant with EU in that regard.

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STUDY AND COMPARATIVE ANALYSIS OF THE MODELS FOR TRAFFIC SAFETY PREDICTION

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Abstract: *The need of development and implementation of effective measures to increase the level of traffic safety is of utmost importance when it comes to road transport. Numerous studies on factors affecting road safety are the core of transport approaches and models made to reduce the occurrence of accidents. The purpose of this article is to make a comprehensive study of the models for analysis of the traffic conditions and their impact on traffic safety and to define the fundamental ones for implementation in Bulgarian conditions.*

Keywords: TRAFFIC ACCIDENT, TRANSPORT, TRAFFIC SAFETY, PREDICTION MODELS, ROAD TRANSPORT SAFETY, APPROACHES, VEHICLE

1. Introduction

Reducing the number of road accidents and their consequences can be sought in the amendment of factors, which determine the accidents rate, such as behavior of road users, the level of conflict of road infrastructure and its active and passive safety.

The purpose of this article is to explore accident prediction models in order to be considered working methods for predicting traffic accidents in Bulgaria and to reduce their number. By examining the current state of the problem, the interrelationships with other types of accidents and the overall situation on the road, the resources and tools that would lead to an integrated, safe, responsible and maintained transportation system, can be identified.

In recent years engineers tend to focus on human and technical errors as causes of accidents. Responsibility for the accident should not be thrown solely on drivers, but also on other elements that build the transport system: planning and maintenance of the infrastructure, organization and traffic conditions in the settlements, increased knowledge of the population and specialists who define harmony in movement and the degree of conflict of infrastructure.

The reduction of casualties on the roads requires the combined efforts of a large number of institutions and the will to undertake specific activities for better performance and decrease errors in system 'Driver - Vehicle - Road'.

This study examines models for prediction of accidents (Accident Prediction Models) for signalized intersections and crosswalks. These models are developed to calculate the likely change in accidents involving motor vehicles and pedestrians and also the degree of risk of accident to one participant, even in case of his transport mode. Large flows of vehicles can often compete with moving pedestrians, mutually cross their planned directions, which in turn leads to delays and creates conditions leading to the separation of the city to different areas.

2. Choice of method for traffic safety evaluation

2.1 General characteristics of road accidents

Scientifically based system for limiting and eliminating the negative effects of the increasing number of vehicles on the road can be built only after a thorough and comprehensive study and analysis of the causes and conditions, facilitating the occurrence of accidents. The analysis of accident allows detection of the organization of traffic and pedestrian flows, verification of planning effectiveness, reconstruction and control events.

The analysis can be done by studying in detail an individual or a group of accidents that occurred on a section of the road network. The purpose of the analysis is to provide information for the majority of accidents to find out whether the statistical data actually contributes to the occurrence of the accident, what are the trends, if

this process continues, what to expect, how to concentrate and allocate the available forces and means of prevention.

Traffic safety can be evaluated using statistical data and by measuring the parameters of indirect assessment.

2.2 Statistical Methods

Statistical methods allow researchers to obtain the summary and accurate assessment of road safety and should be used for controls of indirect estimates. The use of these methods is associated with certain difficulties - the need of accident data for 1, 2 or more years, without change in the traffic conditions. Since these methods are used in many countries, there is a possibility to make a comparative analysis of individual indicators.

2.3 Indirect methods

Indirect methods for the evaluation of traffic safety have one very important advantage over statistics – there is no need for data on accidents.

a) Method of conflict points - this method is used to assess the potential risk of an intersection or junction [8, 15]. It has been discovered that the degree of risk of a conflict point of intersection depends on the angle between the trajectories of the two vehicles.

b) Method of conflict situations - this method was proposed by C. Perkins and J. Harris (USA) in 1968. Specialized organizations connected with traffic safety appreciate the positive qualities of the method and it is one of the most used and the most promising for visual assessment of road safety nowadays. According to the authors of the method, conflict situation is a situation that can lead to accidents if the participants do not take protective actions or adequate rescue maneuvers. There are still differences in terminology, methodology and grading the risk of conflict.

c) Method 'sound/noise on acceleration' - the basis of the method lays on the hypothesis that travel is safe and that the relative speed between the vehicles is close to zero. Dispersion of the longitudinal acceleration of the vehicle while driven is used as evaluation indicator. Increase in 'sound/noise on acceleration' is a sign of potential danger to traffic.

d) Methods of complex measurements - in these methods quality parameters are used, which are obtained from the values of the various parameters of the movement - time, path, speed, deviation of the steering wheels etc. [9, 13].

2.4 Registration and analysis of traffic accidents

A traffic accident is an event that occurs during the movement of the vehicle and causes death or injury, damages to the vehicle, road, road infrastructure, cargo or other property damage [12]. The definition shows that in order an event to be classified as a road accident, it is necessary a vehicle movement and harmful effects to take place.

- *Registration and reporting of accidents* - the total number of accidents that are not subject to registration is from 6 to 8 times greater than officially recorded. Although the damages are smaller, their analysis would contribute to a more objective assessment of safety and a more precise determination of the causes for accidents. Accident register is enrolled in the 'traffic police' of the territorial unit. They do not keep records of accidents, which started deliberately in order to suicide, homicide, injury or damage caused by natural disasters and others. Operating services prepare daily, weekly, monthly and annual report of the accident area or for the country. A detailed compendium on traffic accidents' statistics is issued every five years.

- *Analysis of data on accidents* - the main objective of the data analysis for accidents is to obtain complete information on the conditions and causes of accidents. Achieving this goal is limited by two reasons. It is practically impossible to get all the information about an accident because the elements of this event pass irreversibly with time and purely due to technical reasons. The second reason is related to the accuracy of the information and its transmission. The main tasks of the analysis of accidents are: receipt of sufficient quantity and quality of information, processing of the information by various methods (statistical probability, topographical characteristics, etc.), analysis of groups of accidents, analysis of individual accidents.

Quantitative method - the purpose of this analysis is to obtain estimates of absolute and relative indicators of safety using accidents data. Absolute statistical indicators are: total number of accidents, deaths and injuries. They are calculated for a given period and comparing them with past years allows conclusions about the level of safety to be made. The comparison can be done for the same periods between separate administrative territories or countries in comparable conditions.

Topographic analysis - the purpose of topographical analysis is to identify the places where road accidents are concentrated. These places are called black spots, hazardous areas and outbreaks of accident record, but their essence is one - places where accidents occur frequently. Areas with a concentration of accidents can be separated into two groups. The first relates to intersections and junctions, railway crossings, bridges, tunnels and other road facilities. The nature of traffic on such sites is determined uniquely by the highest probability of occurrence of accidents. The second group should join the rest of the roads and streets. Analysis of individual accidents is to identify its causes, mechanisms of development and possibilities for its prevention and to provide a so called expertise of accidents.

2.5 Literature review of sources related to accident prediction models

There is a large number of scientific papers and publications on methods and approaches for assessing road safety and influencing factors. What unites all of them is the search for an appropriate solution for improving road safety depending on individual characteristics: areas designated as hazardous after conducted surveys (black spots or black sites); roads and areas associated with particular types of accidents at a number of individual sites throughout the area.

The issue of safety is reviewed in [4]. The main purpose is development of reliable transport system on the territory of Sofia Municipality in the Republic of Bulgaria as well as detailed analysis of the contemporary transport system and projections for future growth and development of the city. During the development of the plan some key conclusions are made: the density of the road network in the city is unsatisfactory; the structure of the network traffic is not complete; the frequency and duration of trips, as well as the number of private cars, are increased; there is a decline in people traveling by mass public transport at the expense of private car users. The main priorities for the city are to improve the living conditions and quality of the environment in Sofia.

Studies [5], [17] and [18] analyze traffic counts and data of signalized intersections in many urban centers in New Zealand. In different periods of time accident prediction models for common types of accidents were developed. One of these models was adopted in the present article for safety assessment.

Works [10] and [11] reveal that during his study Jackett uses information about accidents, traffic volume data from the environment and geometric data taken for 523 urban roads to calculate average accident levels in order to take timely measures.

Law on Road Traffic and the Regulations for its implementation [12] governs the rules of the road, open to the public, the requirements for vehicles, the requirements for driver qualification, the rights and obligations of participants in the movement and the relevant departments and officials, as well as coercive measures to be applied, and the penalties for violating the contents of this law and the issued hereunder regulations. The purpose of this law is to protect the life and health of the participants in traffic, to facilitate their movement to protect the assets of companies and individuals, and the environment from pollution by motor vehicles.

Labor [7] informs about urban intersections with four lanes in one direction, the most common form of roads in the UK. Accidents at intersections are 1772 over the period of 4 years. Accidents involving pedestrians are more than 28.8% of all accidents.

Labor [16] examines 300 road links between major junctions in the United Kingdom. During the 5-year study 1590 accidents occurred on the territory of these road links. Some of the more important discoveries of the study are that the models predict more than the average number of accidents with links connecting pedestrian crossings than segments without pedestrians in any stock vehicle and pedestrian density; some of the physical variables in the model appear to be related to speed. For example, increased visibility in the opposite direction of travel affects the general increase in accidents, accidents with motor vehicles and accidents with pedestrians.

In labor [2] a deterministic model is developed for accidents with pedestrians and vehicles. According to the study accidents have a random character. The Davis model is designed to allow comparison of the possible accident (reducing effects through a variety of techniques) to 'calm' traffic. It focuses on the volume and speed of traffic, borrowing default values for the other variables: distance from the pedestrian lane before the collision; the speed of a pedestrian moving towards the road; time perception and reaction; reducing speed after brake (braking distance).

Study [14] addresses the measurement of risk, based on the theory that each type of activity is related to exposure to a certain degree of risk. Risk measurement, by distance only, offers a broad risk assessment of accidents. Drivers are exposed to different types of risk while traveling in different sections of a road. Risk and Shaoul (1982) pay attention to the classification of the intersections along the way with different levels of risk based on the number of side roads, expected maneuvers in the intersection and the number of expected points of conflict. They believe that a better level of risk assessment can be achieved if assumptions about the number of movements of pedestrians and traffic on the road segment are made. The models show that the risk to pedestrians increases with the traffic flow, but decreases with increasing number of pedestrians. This effect is called 'safety in numbers'.

In study [3] the safety of pedestrians using crosswalks and signalized intersections is investigated and compared to crossing the street without signaling elements. Labor [4] places a table of studied intersections that is used as a basis for counting the number of transport vehicles and pedestrians. It was found that the data is typical for the selected study area of Sofia, Bulgaria.

It is essential to mention it is advisable that the chosen accident prediction model should be a consequence of expert opinion. This is where the expert evaluation method and its feasibility for analysis

of safety management system can take place. The basic objectives of safety strategy are:

- clear definition of the analyzed problem;
- creation of a certain questionnaire connected to the problem;
- implementation of a poll;
- analysis of poll results.

The method of expert evaluation has been used in a study of Safety Management Systems functioning of a Bulgarian railway carrier. This type of model is proposed in study [6], and it is not applied in road transport in Bulgaria yet. By weighing the expert assessments, calculation of parameters and determining the statistical significance of evaluations, it would be possible to determine the degree of influence of respective factor on operating safety not only in rail, but also in road transport.

3. Accident Prediction Models for vehicles and pedestrians

This paper uses the aforementioned model of work [17], statistical data on volumes of flows of vehicles and pedestrians, taken from the Bulgarian Ministry of Interior and Sofia Municipality and data on the characteristics of the accidents. It was considered that this data is relatively old or less complete, and counting was performed in volumes of flow of vehicles or pedestrians according to the method shown in [18].

Models for predicting accidents (APM) can be implemented by transportation engineers and transport planners to predict the rate of accidents, and to assess the effects of changes in safety at various travel modes.

Accident prediction models can be used to determine the possibility of change in the number of accidents involving a motor vehicle, a pedestrian, also the level of accidents for each street and to change the organization of the movement.

One of the most important reasons for accident modeling is the prediction of the number of accidents. For this reason the task of selecting the most appropriate methodology and feasibility study for implementation in Bulgaria was given.

When it comes to modeling small samples, the Poisson-gamma model (low mean problem) is usually the choice of transportation safety modelers. Other modeling techniques are related to the non-linear models and geographically weighted regressions but according to the works in the field of transport modeling the best model is the basic, which is a regression. That is because of the fact that each of the approaches has its own strengths and weaknesses. Difficulties arise from the collection of extensive statistical database if it does not exist so far.

An examination of the literature and research in the field of models for predicting the number of accidents (Accident Prediction Models) shows that the most widely used model is of the following form [17,18]:

$$(1) A = b_0 x_1^{b_1} x_2^{b_2},$$

Where:

A - accidents (number of accidents per year);

x_1, x_2 – traffic flows (total number of vehicles or pedestrians per day);

b_n – parameters of the model.

It could be used with other variables characterizing the influence of other traffic safety factors (width of the roadway, crosswalk width, etc.). This further complicates the model and it will not be used in this article. The coefficients b_0 , b_1 and b_2 can be determined by the use of relevant statistical data. Due to incomplete

statistics for some accidents involving pedestrians the article checks only the relevance of the above-described model in Bulgaria (using coefficients is proposed in the works [17,18]).

4. Application of accident prediction models for Bulgarian conditions

Accident prediction models can be used to determine the possibility of change in the number of accidents involving a motor vehicle, pedestrians, also the level of accidents for each street and to change the organization of the movement. It could be used for variables characterizing the influence of other factors on traffic safety too.

This paper examines two variants of accident prediction models. For each of the models coefficients proposed by New Zealand authors were selected to check their adequacy for Bulgarian conditions.

Based on the volume data streams of vehicles, pedestrians, and data on the characteristics of the accident the adequacy of the above-described model was examined (expression 1) for the conditions in the country.

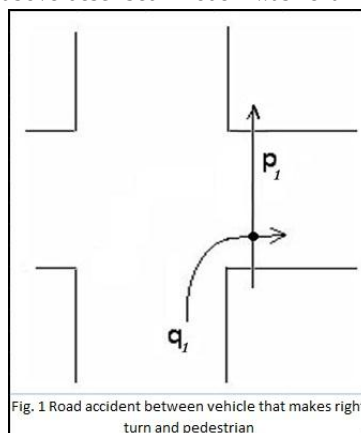


Fig. 1 Road accident between vehicle that makes right turn and pedestrian

The daily volume of the traffic flows of vehicles and pedestrians were taken from the Sofia Municipality and enriched by observations (counts) and use of the method described in works [17, 18]. Due to the limited volume of statistical data on the investigated types of accidents (complete data, but only for the years 2009-2012) it was decided coefficients obtained in

[17, 18] to be used. The applicability (the relevance) of the models was reviewed and verified for the following types of accidents: Model 1: An accident between a road vehicle that is making right turn and pedestrian crossing the intersection (Fig. 1). The type of the model for this type of collision is as follows:

$$(2) A_1 = 0.0000543 q_1^{0.4343} p_1^{0.5127},$$

Where:

q_1 - daily flow of right cornering vehicles for one direction;

p_1 - daily flow of pedestrians in the same direction.

The number of actually admitted and registered by the Police and the State Automobile Inspection (SAI) estimated number of accidents and incidents, obtained by the expression 2, distributed in intervals in accordance with the daily flow of pedestrians are compared in Figure 2.

Correlation between actual and estimated number of accidents in model 1 is shown in Figure 2.

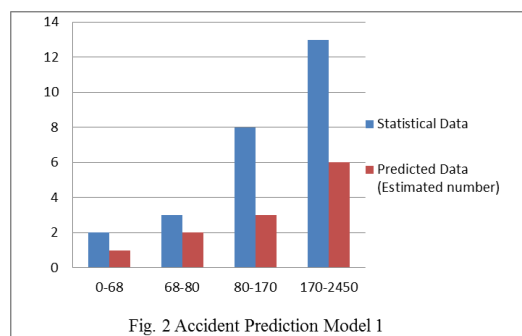


Fig. 2 Accident Prediction Model 1

Model 2: An accident with a transport vehicle and a pedestrian on a walkway (Fig. 3): The type of the model for this type of collision is as follows:

$$(3) A_2 = 0.00003064 q_2^{0.6584} p_2^{0.2041},$$

Where:

q_2 - daily flow from motor vehicles;

p_2 - crossing pedestrians.

Figure 4 compares the number of actually admitted and registered by the Police and the SAI accidents and the estimated number of accidents (obtained by the expression 3) distributed in intervals in accordance with the daily flow of pedestrians.

Studies show that both models work well and can be used to solve practical problems of safety in Bulgarian conditions. The exception

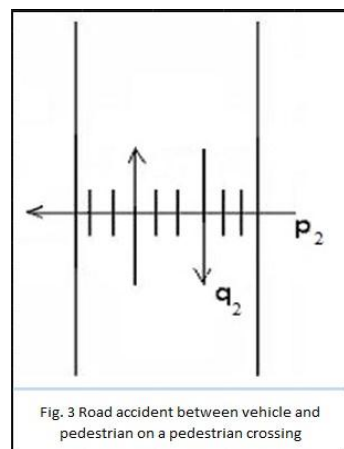


Fig. 3 Road accident between vehicle and pedestrian on a pedestrian crossing

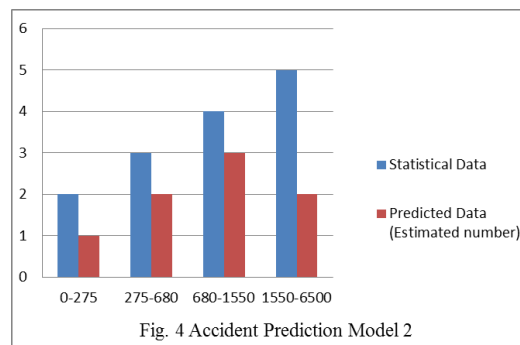


Fig. 4 Accident Prediction Model 2

is the prediction of the number of accidents involving large volumes of vehicle and pedestrian flows. This fact suggests further research and determination of the coefficients of the models based on more complete statistical data on the number and characteristics of the admitted accidents.

Based on the analysis the following main conclusions can be formulated. First - the analysis of the models found that they generally work well and can be used to predict the safety of vehicles and pedestrians in Bulgaria. Taking into account the safety of this type of road users the following recommendations can be given: development of guidelines to assist local governments in the successful planning and implementation of programs for traffic safety; updating the regulatory framework regarding the terms and conditions of the road; development of programs with concrete measures to improve the organization of the movement. Models for predicting accidents could be used as a basis for helping to reduce accidents involving pedestrians by providing data at what traffic density a number of incidents will occur and how they should be avoided or sufficiently reduced.

5. Conclusion

The forms and types of accident models vary considerably. Individual types of models (e.g. different types of models for each intersection) are of great interest but do not lead to the production of significantly improved model for each accident than the so called 'all accidents model' (basic model). Furthermore, the basic model has proven its stability over the years and enjoys the confidence to predict future levels of safety. The experience in the studies of road accidents shows that they are due to a combination of the following factors: highway geometry, driver and vehicle characteristics and the environment. Accidents are typically caused by an interaction of more than two of these factors. The proposed models can be successfully used in decision making to improve traffic safety in the

cities of Bulgaria where it is necessary to estimate the potential number of accidents that could be expected at a given workload of the respective intersection.

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ANALYSIS OF HAZARDS OF SEA ENVIRONMENT FROM WEST POMERANIAN SEA FISHING FLEET

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Abstract: The paper presents analysis of hazards of sea environmental pollution by lubricating and hydraulic oils based on the west Pomeranian Sea fishing fleet. The analysis of hazards of environmental pollution has been presented here while on lubricating and hydraulic oils are used. The purpose of the Paper is to provide additional controls mitigate potential hazards.

Keywords: ENVIRONMENT, POLLUTION, OIL, FISHING FLEET

1. Introduction

Factors influencing sea environment could be formally divided into 2 groups: influencing sea waters and influencing atmosphere.

All the wastes from fishing crafts sent to sea waters directly or indirectly, intentionally or unintentionally can be included in group 1. The quantity and type of these wastes depend on many factors, such as:

- technical equipment,
- size of the craft,
- craft equipment with fishing devices,
- craft equipment with accommodation equipment,
- crew members number,
- pro-ecological education of the crew

Following the subject of the paper the hazards analysis for the environment as a result of oils disposal on cutters and fishing boats has been presented.

2. Hazards associated with lubricating oils

Engine lubricating oils pollute the environment while being produced and on every level of their usage: being transported to the users, being stored, during engine operation and during their disposal and recycling after their time of operation. Each of the mentioned levels presents different type of hazard and depends on the following factors:

- possibility of the recycling of oil wastes or the used oil,
- working conditions of the device in the diesel engine,
- chemical compound of the oil,
- possibility of the oil biodegradation,
- way of using the oils

Working conditions of the engine oil determine its consumption and quality (temperature influences the intensity of physic-chemical processes mainly, e.g. oxidation.)

Chemical compound of oil is a decisive factor for the environment and it also determines the most ecological and economical way of oil recycling.

The level of toxicity is different and it depends on the components structure, yet they are generally hazardous to soil and water.

There are installed engines of total power 31827 kW [7,8] on cutters and fishing boats on the west Pomeranian Sea fishing fleet.

It is estimated that the quantity of the required lubricating oil during normal operation of engines amounts from 0,3- 0,5 kg of oil/engine power in kW.

Considering the fact that there are old generation engines on cutters and fishing boats, their operating consumption should be estimated for 5g of oil/kWh. For new generation engines the consumption of oil is about 3g/kWh.

The consumption of oil in the fishing float can be calculated according to the algorithm:

$$C = (3 \text{ or } 5) \cdot P \cdot UP \cdot FD \cdot 24 \cdot 10^{-6} [\text{ton}]$$

Where :

C – Consumption of lubricating oils in fishing fleet

P – Total power of the installed engines on fishing crafts

UP –Simultaneity coefficient of the used power for the installed engines

$UP = \frac{\sum \text{used power during fishing days}}{\text{total installed power}}$

FD – Number of fishing days

3. Hazards associated with emission to atmosphere.

Quality, composition and physic-chemical properties of the engine oil are an important operating factor of the engine which may influence highly the composition and level of toxic emissions being created during the engine operation process. Oil influence on the m/a factors is a complex phenomena and not totally known. The research was done by Manni, Flori and Gommellini [4,5].

Toxic components emission is connected strictly with oil consumption by the engine. The relation of cause and effect between the intensity of oil consumption and the level of toxic compounds emission has been described in publications [2,3]. It refers mainly to hydrocarbons (PAH as well) and diesel particulate filters.

The increased consumption of the engine oil is connected with many processes inside the cylinder and their effects, such as: [1]

- Scraping oil by a set of rings to the combustion chamber.
- Increased and thicker oil layer remaining on the cylinder after piston movement and average temperature rise of this layer.
- Absorption and desorption processes of fuel vapours and oil.
- Adsorption by soot (or other particles) of fuel vapours.
- The increase of vaporized oil because of cavitation

The main influence on the harmful factors emission coming from lubricating oils to atmosphere is caused by technical equipment such as:

- Type of the oil used,
- Engine construction
- Technical condition of the engine

From 50 % to 70 % of the used oil is emitted to the atmosphere. Having in mind the m/a data it is possible to calculate the quantity of toxic substances emitted to atmosphere (E) from lubricating oils of fishing boats engines, applying the given below algorithms.

$$E = (3 \text{ or } 5) \cdot 0.5 P \cdot UP \cdot FD \cdot 24 \cdot 10^{-6} [\text{ton}]$$

Where :

E – quantity of harmful substances emitted to atmosphere from lubricating oils

P – Total power of the installed engines on fishing crafts

UP – Simultaneity coefficient of the used power for the installed engines

$UP = \sum \text{used power during fishing days} / \text{total installed power}$

FD – Number of fishing days

Taking into consideration the received calculated values of toxic substances emissions from lubricated oils used by fishing fleet to atmosphere, it should be noted that the quantities are frighteningly huge, despite the fact that they are calculated as minimal ones and they can be higher practically. The errors in real calculations come from difficulties of coefficients practical determination for calculated algorithms and that is why the received calculated coefficients could be regarded quite optimistic. Due to their peculiar toxicity, atmosphere pollution coming from this source is extremely high. The quantity of emission depends strictly on annual average number of engines working hours.

It is worth-noticing that for new generation engines calculated average toxic substances emission from lubricating oils is more than twice lower in comparison with the old engines emission.

Oils coming from kerosene or esters which lost their operating properties and cannot be applied for their primary purposes any longer are considered the used ones, as well as oil – water mixtures.

According to Polish ecological law, the used oils are recognized as hazardous.

Fishing boats engine operation is the source of the used oil “production”. The used oil can enter sea waters because there aren’t any recycling devices for the used oils on fishing boats and there isn’t any system for their disposal/collection in ports or fishing berths. Due to outdated engine construction and their sealing systems, we may say that the used oil as leakages enters bilges and it is next pumped out to sea waters. There are no oil separators because of the size and complexity of their installations. It is estimated that leakages amount up to 10% of the used oil. Fishing boats leakages could be regarded as simple drop to sea waters.

“The drop” with reference to toxic substances or outflows containing such substances means any, without any reason, discharge, removal, spillage, leakage, pumping out, emission or emptying.

The quantity of used oils coming to bilges as leakages is the function of engine working hours and their technical condition. The quantity of used oils coming to bilges as leakages on boats (B) can be determined according to the algorithm:

$$B = (3 \text{ or } 5) \cdot 0.1 P \cdot UP \cdot DP \cdot 24 \cdot 10^{-3} [\text{ton}]$$

Where:

B – Quantity of lubricating oils leakages

P – Total power of the installed engines on fishing crafts

UP – Simultaneity coefficient of the used power for the installed engines

$UP = \sum \text{used power during fishing days} / \text{total installed power}$

FD – Number of fishing days

It can be noticed that hundreds tons of oils coming from engines operation on fishing boats and cutters can enter sea waters. Such quantity of harmful substances coming into sea

waters influences biological life development there very badly - because:

- It limits light access for the development of zoo and phytoplankton due to creation of oil film on the water surface.
- Living organisms, fish and zooplankton absorb harmful substances from lubricating oils (PAH).
- The quality of fish food gets worse (zoo and phytoplankton) with toxic chemical substances and leads to limited reproduction of fishes.
- Seaside areas get less attractive for tourists.

4. Hazards associated with hydraulic devices

West Pomeranian Sea fishing fleet crafts use hydraulic fishing devices –hydraulic winches. Hydraulic oils used in their hydraulic systems are a potential pollutant for the Baltic Sea. Hydraulic oil high working pressure, lots of load and often overload of hydraulic winches, outdated construction and the age of the devices are the reason of frequent pipeline, hydraulic joints or seals breaks leading to hydraulic oils leakages to bilges in the boats. The oil is a potential “drop”, similarly as the used oil or the oil from operating engine leakages.

Having in mind the specific hydraulic systems described above, probability of the hydraulic system breakdown resulting in oil leakage can be estimated as 0.25. There is about 150 l of hydraulic oil on average in hydraulic systems of fishing boats and cutters. The average oil leakage quantity from the system due to a breakdown amounts to about 10% of the used oil volume in the hydraulic system. The quantity of the hydraulic oil used on fishing boats can be determined according to the algorithm:

$$CHO = 0.25 \cdot 0.1 N \cdot C \cdot HW \cdot FD / 365 [\text{litres}]$$

Where:

CHO – consumption of hydraulic oil by west Pomeranian Sea fishing fleet

HW – simultaneity coefficient of the hydraulic winches used

$HW = \sum \text{crafts using hydraulic winches during fishing days} / \text{total number of crafts with hydraulic winches (205 crafts)}$

FD – Number of fishing days

C – Average capacity of the hydraulic system (150 L)

N – Number of crafts with hydraulic winches

Summary

In order to improve the situation and reduce the risk of marine environment pollution, active and reactive policy of risk management should be introduced:

- Introduction of pro –ecological education for fishing crews.
- To modernize the fishing craft to match the eco-friendly standard.
- Effective introduction of the best accessible technology and the best ecological procedure.
- To modernize or exchange the propulsion engines to meet the requirements of emissions ecological criteria. It is extremely important to use proper constructions and materials for different sealing in engines, in order to limit the negative influence of lubricating oil on natural environment. The choice of elastomers used for sealing has to be exceptionally careful - having the working temperature in mind and the chemical composition of the used oils. At present, up-to-date elastomers provide proper interaction with basic mineral oils.

- Introduction of the disposal for used oils, bilges polluted with lubricating or hydraulic oils and the improvement of fishing ports and berths to match the standards determined by conventions.
- Introduction of understandable to fishing crews, ecological procedures for each operation and emergency procedures as well.
- Introduction of clear and effective control procedures for wastes and their disposal management by state administration
- The use of lubricating oils following EKO and Energy Conserving criteria, biodegradable.
- To exchange or modernize the existing hydraulic systems on the crafts - if applicable.

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POSSIBILITIES FOR OPTIMIZING MAINTENANCE OF MILITARY VEHICLES ON THE RESULTS OF TRIBOLOGICAL DIAGNOSTICS

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Abstract: Tribological diagnostics is a non-destructive and non-disassembling diagnostic method, that uses lubricating oil as a source of information about processes and changes in mechanical systems, to which it is applied. The paper deals with the mathematical processing, monitoring and analysis of the oil field data obtained from the atomic emission spectrometry in frame of the tribodiagnostic oil tests. The mathematical methods based on a regression analysis and calculations are used in the paper for oil data analysis. The whole assessment procedure and their outcomes serve as identification of a suitable approximation trend. With the same result we are capable of determining in-service operation history as well as giving inputs to maintenance optimisation. Nowadays the system requirements are set up and evaluated in various manners. We would like to keep both preventive and corrective maintenance costs as low as possible. A system design and a maintenance system help to fulfil this task. We propose to use one of the approximations presented in order to track the system operation behaviour.

Keywords: TRIBODIAGNOSTIC, WEAR, OPERATION ASSESSMENT, MAINTENANCE OPTIMISATION

1. Introduction

The growing dependability and operation safety requirements for modern equipment together with the increasing complexity and continuous attempts to reduce operation and maintenance costs might be satisfied among others by the consistent use of modern diagnostic systems. The main task of object technical state diagnostics is not only to find out incurred failures, but also to prevent from the failure occurrence with the help of sensible detection and changes localization in the object structure and in its behaviour changes. A tribotechnical system (TTS), friction in it, wear and lubrication, and especially the outcomes of it are the subjects of our major concern. Regarding the tribotechnical system, the basic information about tribological process, operating and loss variables are provided. Tribology is the science and technology of interacting surfaces in relative motion. The function of a tribotechnical system is to use the system structure to convert input variables (e.g. input torque, input speed, the input type of motion, and the sequence of motions) into technically utilizable output variables (e.g., output torque, output speed, output motion) [1, 2].

The type of interaction occurring primarily depends greatly on the friction state. Thus, when a lubricant is present, the atomic/molecular interaction can be disregarded more often than the mechanical. Friction and wear in a given TTS ultimately depend on the interactions between the elements. The friction state, the effective mechanisms of friction and wear, and the contact state can be used to describe the interactions. The tribologic loads occurring in the real contact areas produce tribologic processes. They subsume the dynamic physical and chemical mechanisms of friction and wear and boundary-layer processes that can be attributed to friction and wear.

Owing to the TTS we have got a lot of diagnostic oil data. In view of tribo-diagnostics this data is considered to be the final outcome. This data can tell us a lot about lubricants / life fluids quality itself as well as about system condition. From the reliability, maintainability and safety point of view we consider such data to be very valuable. We distinguish different methods for oil / life fluids samples analysing. These methods are used to determine physical quality of the sample. Since the system operation, taking the oil samples and the outcomes themselves, are very fuzzy, we later expect to adapt some approaches from the fuzzy logic theory to help.

The procedure and results presented below are based on standard mathematical principles – a regression function and a regression analysis. Later these will be supported by fuzzy logic approaches.

We present results which contribute to general approach when considering both the maintenance procedures and the cost analysis optimisation. From both presumptions we are expecting some costs savings. As for the military point of view we would like to determine remaining “time units” in order to perform the mission.

Following the regression analysis performed beforehand it is possible among others to assess the operating history of an observed vehicle. When analyzing the data we focus on such chemical substances in oil which are somehow interesting for us. These are the products of mechanical processes and wear. The elements originated either in bearings or different parts of kinematic accouplements. We do not take into account any additives. The elements of our primary concern are ferrum, cuprum and lead. It results from the observations and performed analyses that ferrum behaves presumably in the most interesting manner. Therefore we are going into it in a more detailed way.

We do not mention all the results of regression analyses in the paper (especially not for lead and cuprum).

However, after comparing them, we have come to the following conclusions:

- The dependence of cuprum on operating hour (Mh) is not evident so it does not bring us to any common conclusion.
- When dealing with the dependence of lead on operating hour (Mh), there are similarities among all kinds of vehicles, but the multiple correlation coefficient of a tank and infantry fighting vehicle data is too small for a relevant regression function to describe selected data well.
- When dealing with the dependence of ferrum on operating hour, there are also similarities among all kinds of vehicles, but a multiple correlation coefficient is higher. Therefore it is convenient to concentrate only on the dependence of ferrum on Mh.

Oil analysis methods:

Atomic emission spectrometry (AES) is a method that uses arc or spark sources to get the oil sample into the gaseous state and atomize it. As a result of atomic collisions or energy quantum absorption, the electrons of individual atoms are transiting from the ground state to the excited state. During the transition back to the ground state, atoms emit energy that equals the proportion of the energy levels in question in the form of luminous energy. The wavelength of light value is specific for each element [1,2,3,].

2. Objects of diagnostics and diagnostics methods

The assumed objects of diagnostics, i.e. the tank engines T-72M4CZ, TATRA 810 and BMP II have not been ready yet in terms of design to use the ON-LINE system, though in practice similar possibilities for other applications have already existed. It results from the information stated above that we are still supposed to use OFF-LINE engine diagnostics system when sampling lubrication fluid at certain intervals, and using known and optimised special tribodiagnostic methods [4], [5], [6] and [7].

The recognition of a technical state is a basic assumption for making a diagnosis used for determining either operability or non-operability, or for the detection, recognition, distinction, and localization of system parts faults. Although the data on the object condition obtained from a lubrication fluid is available, little importance is attached to it when changing the oil. If the condition of lubrication fluid affected not only evaluation of the object condition, but also modification and optimisation of exchange dates, it would be notably positive in terms of economic optimisation. When evaluating data, the information is transformed many times and provides only estimated reality which might be different from reality itself. That is why the pattern recognition is an important and very complex area of technical diagnostics. Generally the recognition is divided into two groups depending on which methods are used - syntactic or signature. A Parsing/Syntactic Method – is based on recognizing a qualitative way. A word or a symbol string represents the pattern reflecting an object, an event or a process. A Signature Method – is based on recognizing objects, events, or processes with the help of an arranged set of numbers which describe the object characteristics. In diagnostics in many cases there is no exact line between an up state and fault, i.e. there is no mutually explicit representation among points spaces and points classes spaces and corresponding technical states – diagnoses. The failure classes intersect which means that the same magnitudes of measured characteristics might correspond with different diagnoses. If the vagueness in classes distribution is not given by a stochastic character of measured characteristics but by the fact that the exact line among states classes does not exist, it will be later on good to use fuzzy set theory and adequate multi-criteria fuzzy logic. One of the most important information sources might be the results of ferographical analysis (a type, a size, material composition, distribution, morphology, speed of generation, etc.) and particles wear in real time, or lubrication oil degradation got by the methods FTIR, etc. However, it has not been possible to get this information in real time yet. In our case we use the results and information from atomic emission spectrometry. Following this analysis we can obtain the information about the presence of the elements of a specific kind and the amount of elements. However, we cannot identify their origin – e.g. as a result of fatigue, cutting or sliding. Therefore in our further research we try to identify where the elements might come from.

3. Oil field data assessment

Having enough field data obtained from a statistically important set of diagnosed objects is a basic assumption that we will solve this problem successfully (e.g. the engines themselves, etc.). Since the data sets are very extensive, we are not going to introduce them here except for a part/example of ferrum particles found in an infantry fighting vehicle engine. But we deal with dozens of samples taken and analysed at different types of observed engines. In certain aspects we consider the engine in an infantry fighting vehicle II to be a reference object, because the event of a failure type has occurred in it. All tribodiagnostic processes related to the failure occurrence have been recorded.

Technical state diagnostics and engine monitoring includes system approach which deals with sampling, analysis and information utilisation which is important in relation to a mechanical or thermodynamic engine state. Generally it is about monitoring and assessing wearing particles and pollution in life fluids (e.g. hydraulic and engine oils), or metal wearing particles

monitoring, non-metal polluting particles monitoring, products of burning process by high or low temperatures, soft pollutants of organic origin which form oil resin, so called cold sediments, oil and fuels oxidation products, hard-solid pollutants of inorganic origin, dust particles of silicon origin, etc. The monitoring covers a life fluid sample collection and its off-line analysis using easy, standard or special – instrumental methods. The increased forming of metal magnetic wearing particles is usually monitored too, using magnetic detectors with recording and signalization. Using the on-line diagnostics based on a laser particles analyser appears to be a very progressive method. This method enables us to find wearing particles according to a corresponding wearing mechanism (fatigue), adhesion, abrasion, cavitations, corrosion, vibration, combination of the situations mentioned above together with expressing the state, prognosis, trends calculations, etc., supported by intelligent software in the future in real time [3].

Utilisation of regression model

Exploring and analyzing variable dependencies, the values of which are obtained when performing an experiment, is considered to be an important statistical task. In view of their random character, a random vector $X = (X_1, \dots, X_k)$ represents independent variables and a dependent variable is represented by a random variable Y .

When describing and examining the dependence of Y on X , we use a regression analysis, and this dependence is expressed by the following regression function:

$$y = \varphi(\mathbf{x}, \boldsymbol{\beta}) = E(Y | \mathbf{X} = \mathbf{x}), \quad (1)$$

where $\mathbf{x} = (x_1, \dots, x_k)$ vector of independent variables, y is a dependent variable, $\boldsymbol{\beta} = (\beta_1, \dots, \beta_m)$ vector of regression coefficients β_j .

For our data we will look for a regression function in a linear form and we will apply a linear regression model:

$$y = \sum_{j=1}^m \beta_j f_j(\mathbf{x}), \quad (2)$$

where $f_j(\mathbf{x})$ are well-known functions where $\beta_1, \dots, \beta_m$ are not involved.

4. Proposals for system health and condition monitoring based on the results of tribodiagnosics

In the case of taking single oil samples a time line might be possibly not stationary, and before making next calculation it needs to become stationary (non-constant mean value and dispersion); standard transformations do not provide satisfactory results.

The analysis results detected from the oil provide a potential space for the modification of oil exchangeable date considering the number of particles present in the oil before the actual change. The situation is interesting especially with regard to the velocity of their occurrence. A recognized number of particles before the actual change would not necessarily mean a critical number which could threat reliable engine function or cause an accident. However, the exchange date is determined by an oil producer, and the time period in which the exchange is performed might be significantly affected by other characteristics. The presence and the number of particles which occurred in a lubricating system by mechanical processes should be viewed in the future as one of the most important factors in the process of lubrication fluid state assessment.

Following the results it is also necessary to decide on the approximation of real course of particles generation. On the basis of the calculations already made we estimate that the linear regression model will be the most suitable for many reasons. In Table 1 there are single regression analysis models for the observed type of a vehicle.

Table 1: Regression models comparison – outcomes.

Regression function	$y=\beta_1$	$y=\beta_1+\beta_2x$	$y=\beta_1+\beta_2x+\beta_3x^2$
Vehicle type			
Tank	$y=17.945$ $r^2=0$	$y=13.712+0.0949x$ H: $\beta_2=0$ is rejected for $\alpha=0.05$ $r^2=0.3856$	$y=13.816+0.0882x+0.00055x^2$ H: $\beta_3=0$ is not rejected for $\alpha=0.05$ $r^2=0.3859$
APC	$y=24.069$ $r^2=0$	$y=14.099+0.0723x$ H: $\beta_2=0$ is rejected for $\alpha=0.05$ $r^2=0.5022$	$y=10.373+0.1333x+0.0002x^2$ H: $\beta_3=0$ is not rejected for $\alpha=0.0005$ $r^2=0.5474$
T-810	$y=15.604$ $r^2=0$	$y=13.561+0.0282x$ H: $\beta_2=0$ is rejected for $\alpha=0.05$ $r^2=0.3488$	$y=12.9132+0.0525x+0.000079x^2$ H: $\beta_3=0$ is not rejected for $\alpha=0.001$ $r^2=0.378$

It results from the Table that in all the cases it is convenient to consider the regression function in the form $y=\beta_1+\beta_2x$. The regression function $y=\beta_1$ is too simple, and does not reflect the dependence. The regression function $y=\beta_1+\beta_2x+\beta_3x^2$ reflects the dependence better than $y=\beta_1+\beta_2x$, but the coefficients β_3 are statistically unimportant and the growth of a multiple correlation coefficient is not that fast as compared with the regression function value: $y=\beta_1+\beta_2x$.

On the basis of the performed analysis we can say that we are able to assess/observe operating history. Owing to this fact it is possible to plan and verify maintenance actions or other operation of vehicles. When following the analysis results we can also come to a conclusion regarding a type of operation under which a vehicle was run. The dependencies found are shown in Fig. 1.

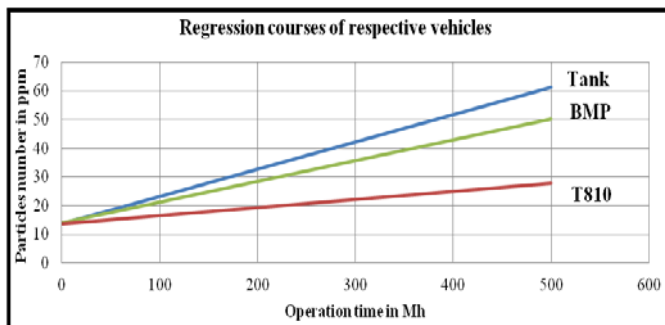


Fig. 1 Regression courses of respective vehicle .

Taking into account the presented results we can state that there is an objective connection between the amount of generated Fe particles and the number of operating hours. In the paper we do not address other interesting elements like cuprum or lead. The reason why we did not do it is that during performed analyses we could not

verify the mathematical dependence of particles generation per operating hour.

5. Conclusions

The aim of the paper is to shed light on the area of tribodiagnostics including the methods which are applicable and suitable for oil analysis.

The data regarding lubrication fluid which is available due to performed analyses is a good source of information when considering the cost savings provided the oil is changed systematically. It would be also good to see the results of the analysis in a broader context as an interesting reflection of an actual state of a technical object from where the oil was taken. When taking into account the results of the tribological analysis, the cost savings might be manifested as the extension of oil changes time and relating maintenance costs and downtime resulting from object unavailability by extraneous causes [3]. Since there is a wide spectrum of suitable methods while analysing an immediate state and prognosis (PHM – Prognostics and Health Monitoring), and because the area falls very deeply into interdisciplinary studies, the specification of relevant dependencies of the analysis results on a real technical state is not at all an easy task to do.

Having this tool we are capable of understanding the mechanisms of failures better. Such procedures enable us to be prepared for coming failures and progression to faults. The diagnostics is cheaper than on-line assets and failure mechanisms are determinable in advance. Some specific classifications of failures are also used in relation to risk sources and they are recognised due to oil and other life fluids diagnostics [7].

The results shown in Figure 1 for example demonstrate quite clearly that it is possible to assess the state of a system depending on oil data. It is obvious that a type of a motor data corresponds to the obtained results of the analysis and an assumed operating profile.

We believe that later in our research we will determine recommended optimum period for changing the oil. By the help of fuzzy logic [8] we expect to specify our information about operating history or the estimation of remaining operating units.

6. Literature

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