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Pedestrian Accidents – Actual Trend in the Czech Republic

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ABSTRACT: There are many factors that play a role in pedestrian and motor vehicle collisions. This paper explores some of the factors on the basis of police records, involving pedestrian accidents in the Czech Republic in the period between 2008 and 2012; the sample consisting of 19454 participants. This paper explores the impact of pedestrian factors (age, gender, behaviour, injury severity, etc.) and other road/environmental factors (visibility, accident location, weather, and so on) on pedestrian collisions. The purpose of the crosstabs analysis was to determine if there is a relationship in these selected factors; the relevance of the factors was examined in a group, not independently. The analysis identified the children and elderly as the most vulnerable road users, with the emphasis given to higher mortality of elderly people and higher tendency of children to violate traffic rules. The majority of pedestrian collisions took place in urban areas, at pedestrian crossings, with the exception of collisions involving children that took place when crossing between parked vehicles (including bus stops) and on unprotected road sections without pedestrian crossings. The results also show that the majority of fatal collisions occurred at night, and that alcohol-impaired walking is a major problem especially for the population of middle-aged male pedestrians.

KEY WORDS: Pedestrian collision, pedestrian safety, accident location.

1 INTRODUCTION

This article is an explorative study focused on pedestrian accidents in the Czech Republic. We focus on factors that have been identified as significant in studies with a similar topic. Then we used them for purposes of our study. As far as pedestrians are the most vulnerable road users (VRUs), the analysis of the pedestrian collisions is an important traffic safety concern. In the Czech Republic the total number of pedestrian collisions is constantly decreasing over time, but on the other hand, pedestrian accidents are still on the increase in urban areas at night-time, and the most vulnerable groups still include the children and the elderly (Police Statistics of the Czech Republic, 2012).

Pedestrians pose almost no threat to other road users, yet suffer almost one quarter of total casualties killed or seriously injured on the roads (PACTS, 2013). The study of overall trends in EU shows that, although pedestrian fatalities in Europe present a decreasing trend, pedestrian fatality rates are still on the increase in Southern European countries, as well as in the new EU Member States, which includes the Czech Republic as well (Yannis et al., 2011). In comparison to other countries of EU, e.g. Germany, Ireland and the United Kingdom, the decrease has been higher than 47% from 2001 to 2010 (49% for the Czech Republic). The rate in Czech Republic was 16 fatalities per million inhabitants in 2010 (Pace et al., 2012). The situation is more or less the same throughout the world (WHO, 2013).

We focused on the factors that were subjects of interest in similar studies. The most common factors that are used to characterize pedestrian accidents and became central to our research are age and gender of the pedestrians (Holland & Hill, 2007; Fontaine & Gourlet, 1997), with the strong emphasis given to the higher vulnerability of children and the elderly (Yannis et al., 2011, Zhuang & Wu 2011, Fontaine & Gourlet, 1997).

According to age, children and elderly are the most vulnerable road users. The highest fatality rate occurs for pedestrians older than 75 years of age. Although a high percentage of children fatalities were pedestrians, they only represent 4% of the total pedestrian fatalities in 2010 (WHO, 2013). The proportion of pedestrian fatalities for children varies widely among the EU countries (Pace et al., 2012), so we try to identify the situation of this age group in the Czech Republic and expect that fact of vulnerable groups will be confirm also in our study.

Another observed factor refers to the higher involvement of males in pedestrian collisions (e.g. Beck et al., 2007; Al-Shammari et al., 2009). In 2010 there were more male than female pedestrian fatalities in almost every EU country. Total distribution shows that 64% of pedestrian fatalities were male and 36% were female (Pace et al., 2012). The results will be compared to our data.

We were also interested in the behaviour and condition of pedestrians, comparing mainly the positive and negative manifestations related to age and gender. One of the most important factors is also the intoxication of pedestrians by alcohol or drugs (e.g., Fontaine & Gourlet, 1997; Lee & Abdel-Aty, 2005).

Contemporary research has also shown an interesting relationship between visibility and the number of accidents. Although it is not a specific accident type, approximately two thirds of pedestrian fatalities occur at night or under low-light conditions. The statistics from 2010 shows, that in the EU countries, 51% of the pedestrian fatalities occurred at night. The rate for the Czech Republic was 47% (Pace et al., 2012).

The next most frequently observed factor which we are interested in is the location of pedestrian collisions, especially in urban areas (Beck et al., 2007), and a certain location where collisions take place. Most of the accidents occurred in urban areas (Gitelman et al., 2012).

The main aim is to identify the characteristics of pedestrians and the environment and how they are associated with pedestrian accidents and its consequences. The information on the collision occurrence may help formulate and implement appropriate prevention measures.

2 DATA AND METHODOLOGY

The data analysed in this study were obtained from police crash reports in the Czech Republic. The analysis focuses on the period between 2008 and 2012. The crash record database used for the purpose of this paper contains records of all pedestrian collisions during the period for all the observed factors.

A frequency analysis focused on factors related to pedestrians themselves (pedestrian factors), i.e. age, gender, severity of injury, behaviour in accident situation, alcohol–impaired walking, pedestrian condition, and also roadway/environmental factors, i.e. type of collision participants, location, weather conditions, visibility or field of view (sight lines). Although in most studies these factors are usually evaluated independently, we tried to find conjunctions to provide a broad picture of concurrent characteristics of pedestrian accidents. For this purpose programmes for statistical analyses SPSS were used to run these operations (crosstabs).

During the analysed period, there was the total of N=19454 reported accidents involving pedestrians. The basic analysis was based on variables such as age, gender and severity of injury.

The age groups were divided into three categories - children (below 15 years of age), adults (15 - 64 years of age) and the elderly (seniors) (65 years and more). This categorization well reflects the results of the current research, where children and elderly pedestrians are supposed to be the most frequent and vulnerable participants of road accidents.

The classification of injuries comes out of the legislation of the Czech Republic and offers the following description: (1) death, (2) severe injury, (3) minor injury and (0) no injury. Minor injury is every injury which is not considered as severe injury and the treatment (including sick leave) is not required for this category (Decree of Ministry of Transport CR, 32/2001 Coll., S. 2, (d)). This classification is, in fact, based on the International Classification of injury (according to injury severity score/ISS): (a) lethal: the injuries are non-survivable even with immediate medical attention. Severe crushing injury and decapitation are examples. AIS: at least one level 6, non-survivable injury - ISS = 76. (b) severe: the injuries pose a serious threat to the individuals' life and require immediate medical attention. AIS: at least one level 5, severe injury, or at least three regions with level 3 or 4 injuries - ISS 25 - 75. (c) moderate: injuries are survivable, but may require medical attention. Without medical attention the injuries could become severe. AIS: no more than two injuries with severity above 3 or 4 - ISS = 13 - 24 (International Classification of Diseases-10th Edition).

Factors analysed in this paper involve: pedestrian factors: (a) age (b) gender (c) severity of injury (d) pedestrian condition (good condition, inattention, alcohol/drugs abuse, physical disabilities, suicidal behaviour, and other unspecified conditions), (e) pedestrian behaviour (in categories good/adequate and incorrect). roadway/environmental factors: (a) weather conditions (normal, foggy, light rainy, rainy, snowy, icy, windy, others), (b) visibility (day, twilight, or night with/without city lights), (c) field of view (good or poor caused by the construction or the surroundings, vegetation in the line of sight, etc.), (d) accident location (urban/rural areas) and more detailed description of the accident location and circumstances (at pedestrian crossing, at signalized or non-signalized pedestrian crossing, etc.).

3 RESULT

The study was performed on the whole sample of pedestrian collisions (n=19454) recorded by police over the last five years (2008-2012) in the Czech Republic. The quantitative and percentage distribution is illustrated in the following charts.

3.1 Age and gender

The data describing the distribution of participants by gender were compared to the data from the National population census (2011) – it shows that there are approximately 48.9% of males and 51.1% of females in the whole population of the Czech Republic. The number of male pedestrian accident participants is 51.4% and 48.6% females in our sample, so there is no substantial difference.

Differences in total rate of designated age groups are more interesting. In the population of the Czech Republic there are 14.5% of population in the age group 0 – 14 years, in comparison to 21% of pedestrians involved in accidents, 69.5% in the age group 15 – 64 years (59% pedestrians involved in accidents) and the group over the 64 years of age includes 16% of the population (20% of pedestrians involved in accidents). Based on this data and in compliance with the foreign research mentioned above, children and the elderly seem to more often become the casualties of traffic accidents involving pedestrians.

The distribution of pedestrian casualties according to age and gender is shown in Figure 1. As we can see, men seem to be involved in pedestrian accidents more often (except the category over 65 years of age), but the difference is not substantial.

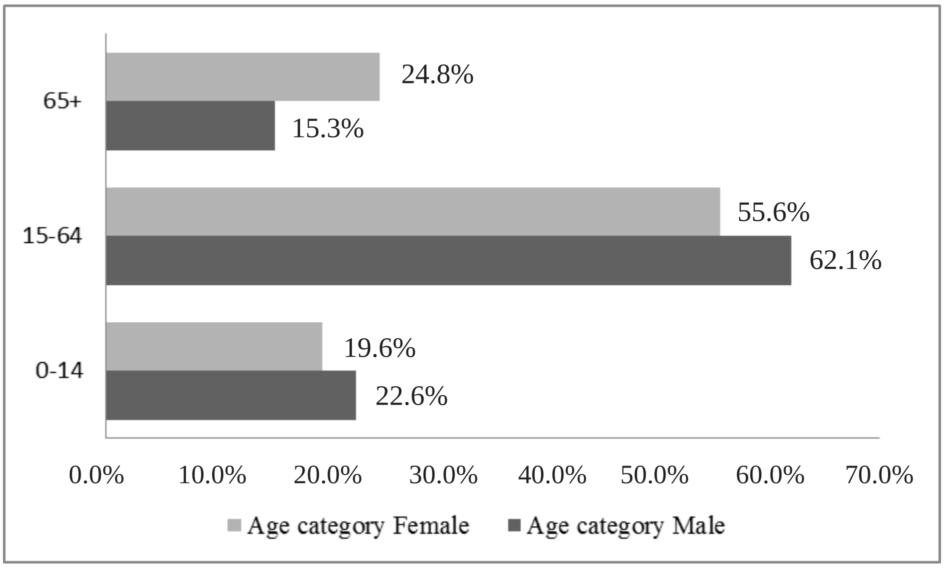

Figure 1: Distribution of the involved in accidents - age and gender.

3.2 Severity of injury

In terms of injury severity in our sample, the greatest amount of injured persons suffered from minor injuries (71.4%), followed by severe injuries (17.8%) and then death (4.5%). 6.4% pedestrians had no injuries at all.

When taking into account the age groups (see Figure 2), the elderly suffered from fatal and severe injuries more frequently (7.0% fatal and 25.5% severe injuries in this age group). On the contrary, within the age group 0 – 14, the fatal consequences were present only in 0.7% cases, but on the other hand, minor injuries occurred within this age group very often (more than 80%). In terms of injury severity, significant differences between men and women were not detected.

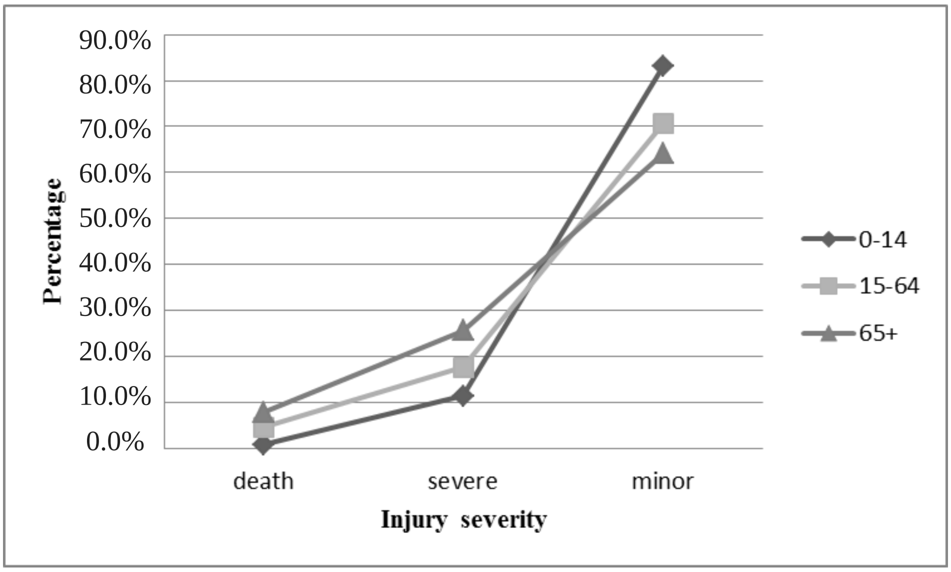

Figure 2: Age and injury severity.

3.3 Pedestrian condition

It is not always possible to obtain exact data about pedestrian condition before the collision itself. Even police records usually do not contain detailed information, because it is usually very difficult to find out during the investigation what exactly was the pedestrian doing and what was running through his/her mind. For that reason, in quite a large amount of data (over 15%) pedestrian condition is marked as unknown. Unfortunately, other categories are more or less vaguely defined - over 60% pedestrians were in a good condition, almost 12% pedestrians were marked as inattentive. The definition of inattention in police terminology means other activities but paying attention to other road users (which includes eating, drinking, smoking, using mobile phone, talking to another person while crossing the street, etc.). There were almost 30% of the accidents involving children (0-14 years of age) in this category (inattention). Alcohol-impaired walking was detected in 11% of all pedestrian collisions, especially in the population of the middle-aged men (24.5%) and elderly men (nearly 10%). There were gender differences, too, e.g. female pedestrians were in a good condition in 71% of all cases, in comparison with male pedestrians (50%). In other categories the numbers were unsubstantial. See Figure 3 for more.

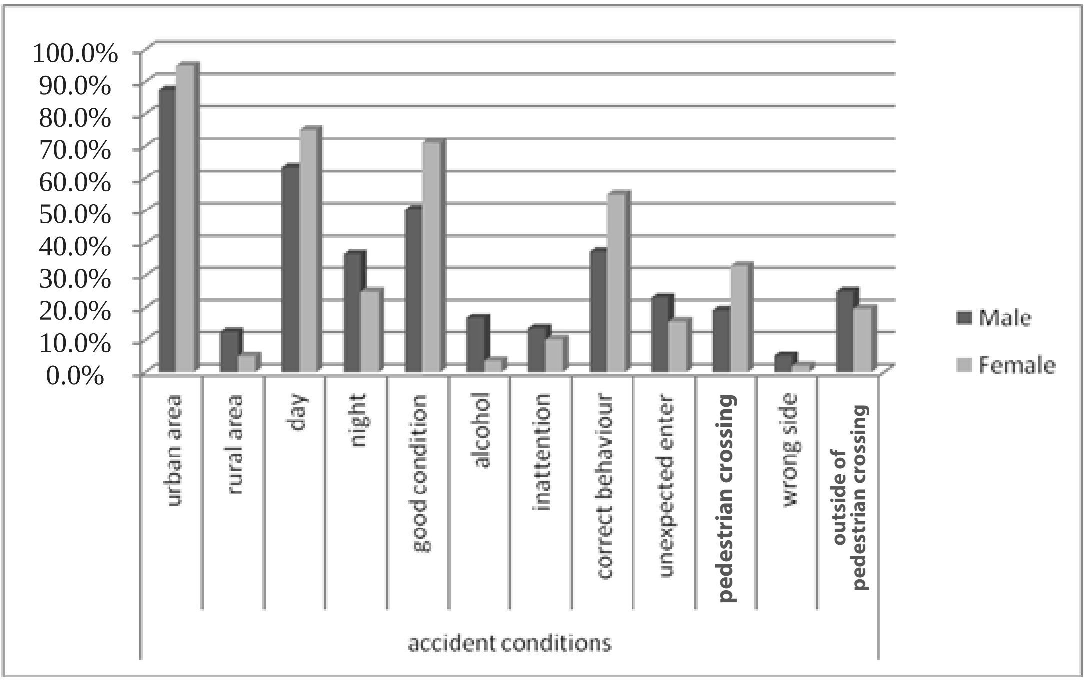

Figure 3: Gender and pedestrian condition/behaviour/accident location/visibility.

3.4 Pedestrian behaviour

Pedestrian behaviour was evaluated as correct in 45.5% cases. Just in the category pedestrian condition (see above), the pedestrian behaviour was marked as unknown in the substantial amount of the data (19%). When looking at other categories, in 17% of all collisions, pedestrians unexpectedly stepped onto the road. The results worthy to notice occurred within the age group 0-14 (see Figure 4), where the correct behaviour was the lowest one of all age groups and concurrently the highest in all other monitored categories (i.e. unexpected enter from pavement in 37%, crossing between parked vehicles in 10% and crossing off a pedestrian crossing in 28%). The difference between male and female pedestrian behaviour is shown in Figure 3. The correct behaviour was detected in 55% of female and 36% of male pedestrians. That could indicate that women comply with traffic rules more responsibly than men.

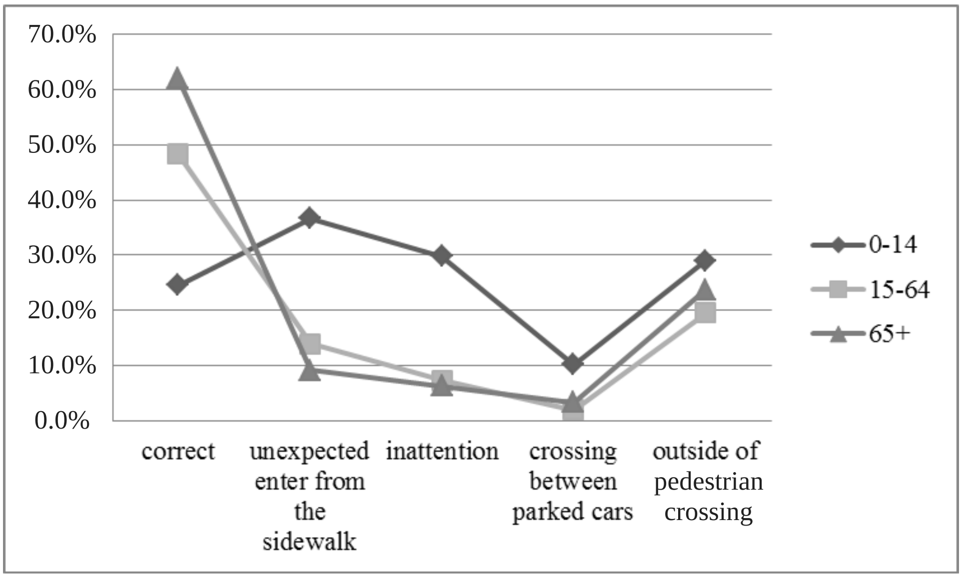

Figure 4: Age and pedestrian behaviour.

3.5 Roadway/environmental factors

Within the categories included in this observed factor (i.e. weather, visibility, field of view and accident location), there were no significant impacts to be found in relation with age, gender or severity of injury. More detailed analysis of the accident location shows that the greatest number of pedestrian accidents occur in urban areas (91.2% in comparison to 8.8% in the rural areas), no substantial differences were found in relation to a certain accident location (at/off pedestrian crossing etc.) and age, gender and severity of injury in our sample.

4 CONCLUSIONS AND RECOMMENDATIONS

The study analysed the police crash records of pedestrian collisions in the period between 2008 and 2012 in the Czech Republic. The aim of this study was to identify and refer to critical points of this type of accidents. Our research results are quite consistent with earlier foreign research.

First, children and elderly are the most vulnerable road users, which is confirmed by our study.

Both these groups become casualties of pedestrian collisions more often than the rest of the population and, therefore, safety measures should be put in place to better support their protection. Other factors related to pedestrian accidents, such as pedestrian condition and behaviour, field of view, occurred in relationship with some of age and gender groups.

Whereas the elderly suffer from fatal and severe injuries most of all participants, the greatest amount of their collisions occur when crossing the road at pedestrian crossings and their behaviour is evaluated as good as well as their condition. So they seem to be less willing to break the traffic rules and tend to behave more responsibly. The reason for the higher frequency and also fatality of their collisions can be added to their higher physical fragility and also motoric and perception limitations and disabilities related to age. Being aware of their decreased locomotive ability, elderly pedestrians integrate their longer crossing time into the decision-making process (Lobjois & Cavallo, 2007).

In comparison to the other age groups, children suffer from minor injuries most often, their fatality is one of the lowest, and collisions occur most frequently when crossing between parked vehicles (including bus stops) and on unprotected road sections without pedestrian crossing. Their behaviour is described as incorrect the most frequently of all age groups, whereas boys are prone to risky behaviour more often than girls while crossing the road. Almost one third of all accidents including a child participant were ascribed to child's inattention.

When trying to find the explanation for the differences in pedestrian behaviour related to age, several studies including this paper were searching for an answer. The possible explanation, for example, is that middle-aged pedestrians have usually good perceptive skills and a high walking speed, but they are more conservative than their younger counterparts, thus likely to improve their safety (Zhuang & Wu, 2011). On the other hand, young people have more positive attitude and intention towards committing violations than adults and report more errors and lapses than adults (Díaz, 2002).

Within the whole sample of pedestrian collisions, the study identified specific gender differences. First, males seem to participate in pedestrian accidents more often than females and also alcohol-impaired walking was detected more frequently, especially in the population of middle-aged and elderly males. Women also seem to comply with traffic rules more responsibly than men, their behaviour is evaluated as correct and their condition as good more frequently than men's. According to Díaz (2002), higher probability of becoming the male casualty of pedestrian collision can be explained by the fact that males violate traffic rules more frequently.

The weather and the accident location have not been proved as a relevant factor influencing pedestrian accidents. However, weather as a potential influencing factor should not be rejected as it needs to be assessed along with other relevant factors, not independently (Edwards, 1996).

In this study, current findings in selected aspects concerning to pedestrian accidents in the Czech Republic were confirmed.

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Supply Chain Security Frameworks Utilization for Analysis and Design of Security Performance Evaluation System – Part 1

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ABSTRACT: This paper deals with highly current topic of supply chain security with a focus on general supply chain security (SCS) frameworks. It analyzes two approaches to supply chain security and presents the author's future research focus in this area, which is aimed at expansion and completion of the general supply chain security management model and the creation of a security performance measurement tool. Such a measurement tool would allow complex comparison of security programs from an attained security level point of view. Initiatives currently aimed at security performance measurement and other perceivably immeasurable characteristics can be found in the areas of operational security and quality.

KEY WORDS: Supply chain security (SCS), SCS model.

1 INTRODUCTION

The provision of Supply Chain Security has been a key logistic issue in the past decades. Its rise is being initiated by governments and global companies on the one hand, and concerned entrepreneurial subjects on the other. Governments try to provide strategic security, which can be violated by illegal migration, smuggling, sabotage, military support of dubious organizations and terrorist acts. The interest of manufacturers and trade organizations is the effective optimization and minimization of delays caused by additional security provision. Effective optimization also lies in introducing commonly shared standards against theft during transportation and other logistical operations. Regional governments (EU, U.S., Asia) have created their own tools represented by a portfolio of compulsory and voluntary security programs and initiatives. Currently, there is a compatibility process on the international level in terms of these programs. Therefore, important scientific contribution created a general model/framework to describe the features of security management and security management system implementation

2 SECURITY MANAGEMENT SYSTEM

A secure state is not a natural state. In the supply chain environment, security threats are naturally present and can be ignited by "favorable circumstances". Complex supply chain security protection can be achieved only by the development of an artificial security management system.

Security management systems (1) define structures – define relations between personnel responsible for security and other nodes, (2) define security rules and regulations – standard procedures, (3) define and execute actions needed for system functionality checks – controlling, audit and evaluation. In the framework of security management process security threats are identified and risks analyzed. The next step is risk mitigation in order to reduce potential security risks.

Each economic region creates its own security system according to the risks it is exposed to due to its business, social and political characteristics. The United States was forced to found new agencies such as the Transport Security Agency (TSA) within its customs administration structures and focus on terrorism-related security threats. Programs such as C-TPAT, CSI, FAST and others originated in the United States. The European Union is focused mostly on smoothening customs declaration processes (AEO programs). Manufactures and transport companies dealing with high-value goods focus especially on theft protection (TAPA EMEA program).

3 COMMON FRAMEWORK FOR SECURITY MANAGEMENT SYSTEM

Security systems of economic regions originate in common platforms that guarantee their compatibility, which is an extremely essential feature. An unnecessary complexity and security approach differences may cause a counter-effect resulting in an actual slowdown of goods flow and an increase of costs due to the necessity of overcoming the incompatibilities between the different security systems.

The common platform is composed of three core international standards: WCO SAFE Framework of Standards to Secure and Facilitate Global Trade (WCO SAFE), International Ship and Port Facility Code (ISPS Code) and Specification for security management systems for the supply chain ISO 28000 (ISO 28000).

These platforms have certain differences, however, even though they create a common framework encompassing supply chain security issues and pave the way to a mutual recognition of certified security programs. As the platforms cover a wide area of supply chain security issues they incorporate government bodies, non-government organizations, private enterprises, customs administrations, manufacturers, transport companies, forwarders, etc. across all means of transport. Common interest here is the maintaining of compatibility in supply chain security on an international level. The European program AEO, which is focused on establishing a certified economic entity, was inspired by WCO SAFE and uses ISPS Code, ISO 28000 and ISO 28001.

The next chapter introduces basic approaches defining general security management system components. The focus of the author's research is on the expansion of these general models and the definition of a new framework for measuring and evaluating supply chain participant's security performance.

4 BASICS OF GENERAL MODELS

The functionality of supply chain security programs is founded on different principles that all lead to one common goal. The security programs contain basic components that combine measures, tools and procedures. These measures, tools and procedures are present within these components in a proportion that ensures the efficient maintenance of security. The components form independent entities within the security programs and their combinations ensure an efficient security systems management of the future.

General models cover most of the security measures suggested by the current leading supply chain security programs; it is important to note that there is no exact formula for establishing an adequate supply chain security management system. The security measures that constitute the framework are not all-inclusive, meaning that implementing them all does not necessarily mean that the security system will be complete, and that implementing only part of them does not necessarily mean that the security will be inadequate (Gutierrez & Hintsa, 2006).

In 2005, the APEC (Asia Pacific Economic Cooperation) consortium created a conceptual model based on 9 basic components (APEC, 2005). Its model was inspired by the 2004 IBM initiative (Closs & McGarrell, 2004) that focused on a multi-organizational and cross-functional approach to supply chain security.

In 2006, Gutiérrez and Hintsa from the Cross Border Research Association based in Lausanne, Switzerland, published a study based on the analysis of the 9 security programs in which they created a general supply chain security management system (Gutiérrez & Hintsa, 2006). Their model has 6 basic components.

These general models give the necessary framework needed for the better understanding of concrete security measures proposed in each of the security programs and may be used for the evaluation of how much the programs have in common. The general models thus allow the comparison of security programs and the finding of their common features that create systems interconnection. Detailed analysis is able to identify the different levels of security measures implementation and offer possibilities for their completion.

4.1 APEC Model

The APEC model is based on 9 basic elements (Figure 1) which describe all security layers in the supply chain system. Recommended features and procedures are recommended for each element.

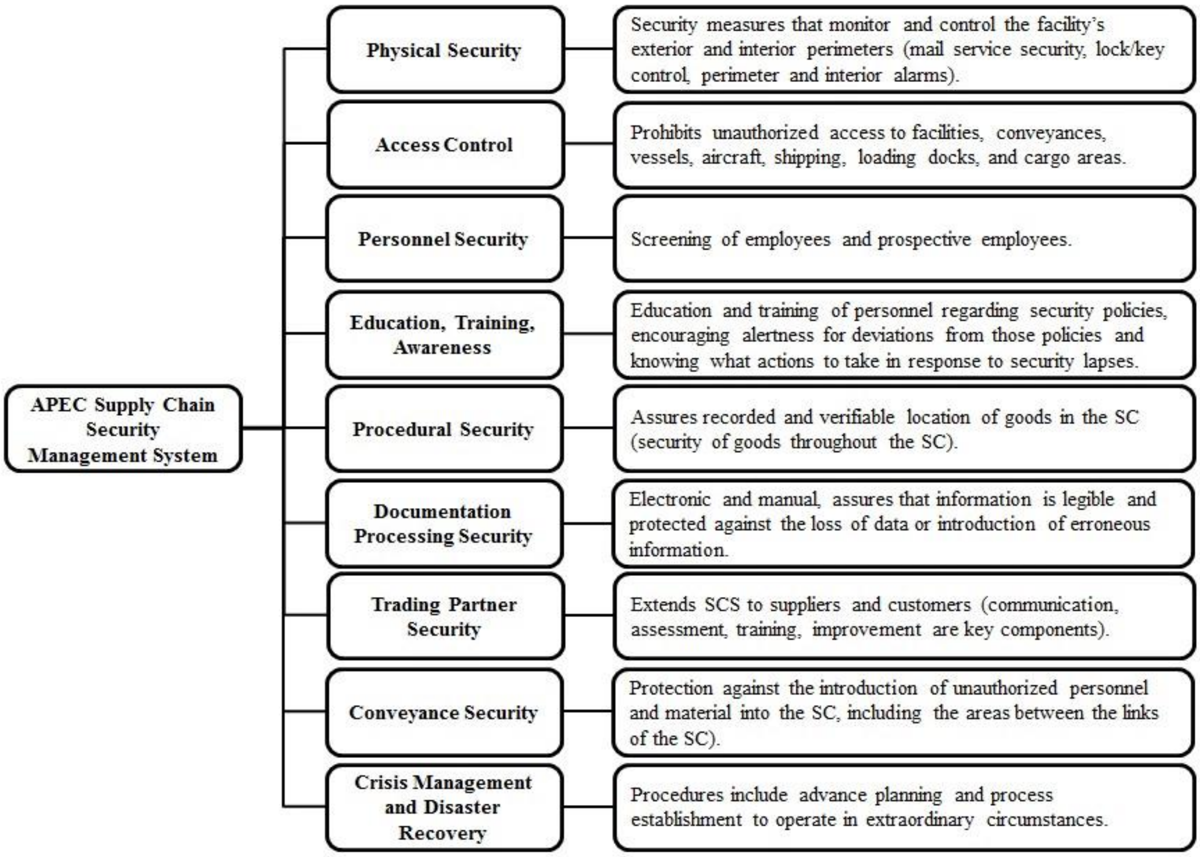

Figure 1: APEC Supply Chain Security Management System (APEC, 2005).

(1) Physical security includes security measures that monitor and control the facility's exterior and interior perimeters. For fulfilling the function of this layer peripheral and perimeter barriers,

electronic security systems including CCTV, segregated goods systems within the warehouse and other features are suitable for implementation. Procedures will include supervision of gates, separated employee and visitor parking, etc. (2) Access control prohibits unauthorized access to facilities, conveyances, vessels, aircraft, shipping, loading docks, and cargo areas. If access control is not possible, increased precautions in other security aspects may be needed. (3) Personnel security is concerned with the screening of employees and prospective employees, as appropriate and as allowed for by law. (4) Education, training and awareness encompass the education and training of personnel regarding security policies, encouraging alertness for deviations from those policies and knowing what actions to take in response to security lapses. (5) Procedural security assures the recorded and verifiable location of goods in the supply chain. Procedures should provide for the security of goods throughout the supply chain and contingency procedures should be included within the scope of procedural security. (6) Documentation processing security both electronic and manual, assures that information is legible and protected against the loss of data or the introduction of erroneous information. (7) Trading partner security extends supply chain security to suppliers and customers. Communication, assessment, training, and improvement are key components.

(8) Conveyance security provides protection against the introduction of unauthorized personnel and material into the supply chain, including the areas between the links of the supply chain. (9) Crisis management and disaster recovery procedures include advance planning and process establishment to operate in extraordinary circumstances (APEC, 2005).

4.2 Gutiérrez and Hintsa General Model

Gutiérrez and Hintsa (2006) mean securing premises for the production of goods and handling, the storing and loading of cargo. Unlike the APEC model, the Gutiérrez and Hintsa model facilitates six elements that express how to manage a complex environment of supply chain facilities (Figure 2).

For proper (1) Facility management, facility layout design is developed. This part of security system management should ensure entry and exit controllability, clearly marked control areas, adequate product marking, sufficient light conditions, etc. Inventory management and control require the adequate management of inventory information, use of product marking standards, etc. Protection of the facility includes fences, locks and walls. Subsequent measures involve facility monitoring through 24 hour camera systems, security guards, filming the activities of loading containers, etc.. For access and presence control processes and technologies, including RFID and biometrics, should be used. (2) Cargo management means protecting the goods during all stages of their transportation. In this part of the system, five subcategories are involved. Prevention, detection and reporting of shipping process anomalies, inspections during the shipping process, exploitation of cargo inspection technical solutions, exploitation of cargo tracking technical solutions, exploitation of cargo and vehicle anti-tampering technical solutions. (3) Human resources management means ensuring that the background of all personnel is checked and that they are reliable and aware of the risks. This part involves employee hiring and exit process, personnel training process and continuous training on security issues and risk awareness. Information dissemination process facilitates internal and external publication of the company security policies. Organizational roles and responsibilities lie in establishing security goals, assigning security responsibilities to personnel and identifying security required skills. Role of (4) Information and communication management is in protecting important data and using information as a tool for tracing illegal activities and shortcomings in security. In the case of this element we can mention quality information and data management as a tool for managing more complete and accurate shipment information and to establish error-proof documentation processes data integration. Protection of business information and data uses procedures and storing methods designed to protect information from unauthorized access and usage. Recordkeeping of shipping information for potential security audits can maintain complete records of the custody of cargo, improved recordkeeping methods, quality control of records and errors correction. Other measures for information management are data exchange with customs administrations and the use of international standards for data management (WCO Customs Data model, Unique Consignment Reference, digital signatures, digital certificates, etc.). (5) Business network and company management systems include security in the internal and external structure of the organisation and in the company's business systems. The company security management system involves defined and documented security processes, defined and controlled security indicators, internal and external audits. Evaluation of scenarios of natural risks, accidents, intentional human acts, or terrorism is a part of the logistic system which is designed for reducing risks. Contingency plans, additional capacity, and alerts management system provide quick eventual disaster or failure recovery. A selection of low risk and high security compliant suppliers, clients and subcontractors is a function of Business partner evaluation system. (6) Crisis management and disaster recovery cover issues of Business continuity plans, Formal security strategies, Emergency control centres and Incident management.

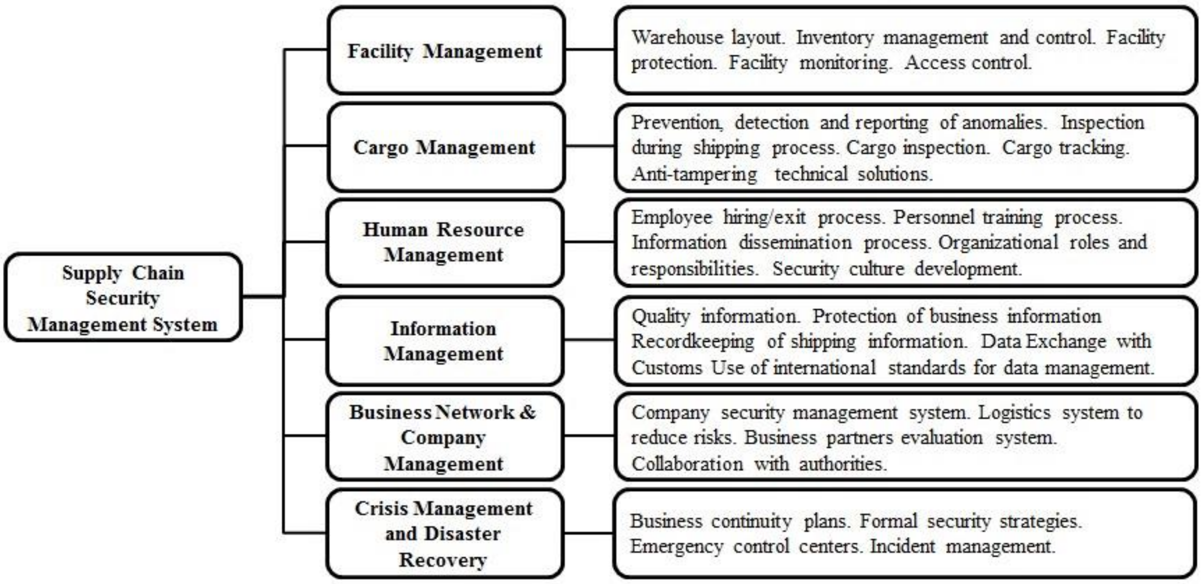

Figure 2: Gutiérrez and Hintsa Supply Chain Security Management System (Gutiérrez & Hintsa, 2006).

Security management systems structural analysis is important not only from the practical application point of view. Results of such analysis form the base for a better understanding of security measures and their impact on the whole security system. The expansion of the general model as well as common and different features location allows for a further detailed analysis of the core problem and the creation of new applications. The expanded model will be used for security performance quantification of organizations and will allow the creation of a security index that could be used for a comparison of organizations. Based on the measured general model components performance the security recommendations could be adopted more easily. System characteristics measurement is currently a problem that is related not only to reliability and quality but also to the operational security of organizations doing business in high-risk industries.

Due to possible financial losses and the maintenance of economic region strategic security, security is not a risk-free part of supply chains. Finding solutions for these security-related issues allows for the application of acquired information as well as active participation in security programs optimization initiatives. Establishing a compatible environment and the simplification of operations connected to the maintenance of security in the EU and other economic region borders will be the subject of the upcoming research.

5 CONCLUSION

The next research of this topic is to widen the general model/framework and describe coherence among programs, with emphasis being primarily on regions with a strong potential for growth. In the short term we also expect an increased interest from Czech exporters to conquer new markets. Therefore it is vital to present these findings to experts/personnel that will deal with supply chain security in their professional lives. An additional task for research will be the formation of a model to measure the security performance of different subjects. This task follows solutions of quantificational problems in different fields. Currently, one can measure, for example, the performance in operational security and quality.

ACKNOWLEDGEMENT

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WCO, 2012. *SAFE - Framework of Standards to secure and facilitate global trade.* WCO - World Customs Organization.

Circular Colouring for Emission Minimalization

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ABSTRACT: The standard time allocation of classic road junctions in major towns and cities are often the main indicators of the government policy and management strategy in reducing traffic jams with its associated emission production from the traffic flow. In this paper, we apply the circular colouring method of Graph Theory (Vince, 1988; Zhu, 2001), to the emission reduction problem at a traffic road junction. The result of this paper is addressing this problem by optimizing the waiting time interval for two selected models. A traffic road junction is modelled as a finite graph G = (V, E). Each vertex v of G represents a given traffic light. Two vertices v and u are connected with an edge if their corresponding represented traffic flows collide and each time in such case they are given an overlapping green light time interval.

KEY WORDS: Circular colouring, traffic flow, circular chromatic number.

1 INTRODUCTION

In day to day life, in every major town or city the problem of human – machine interaction has been a major issue for decades. Vehicles, automobiles and other self-propelled machines play a vital role in the economic infrastructure of both state and private companies. However, the communication network and road capacities of major cities are not efficiently solved. In most cases, this leads to catastrophic traffic jams on road junctions due to ineffective traffic light arrangements. This paper is expected to give guidelines and emphasis on how to minimize emissions at different types of classic road traffic junctions applying the circular colouring method (Zhu, 2001). This paper shows a partial improvement in network and traffic management policies which might contribute to reducing carbon emissions and associated problems such as public transport priority, traffic signal control and coordination, as well as their layout. The development of Intelligent Transport systems and associated improvements in urban traffic control quality has a crucial role in the road traffic junction quality impact of road traffic.

Polluting emissions, aggravated by traffic composition, i.e. the number of vehicles and their categories, the drivers' experience as well as their behavior, seasonal weather, gradients and the technical conditions of vehicles and the waiting time at traffic lights, are the burning issues for the individual management and government policies of a given country or institution. For effective traffic management strategies, we have to investigate the relationship between traffic flow, the emission pollutants and dispersion in the atmosphere and the potential impact on the processes of the network and traffic management policies.

In this paper, we assume a graph G is finite and simple; (no loops and multiple edges). More specifically, a graph G= (V, E) is a pair, such that V is a finite set of vertices and E is the set of edges such that $E \subseteq V \times V$ (unordered pair). If u and v are connected by an edge, then we write $uv \in E$.

Let n be a positive integer. Consider a crossroad with n traffic lights. Let v_1, v_2, v_n denote the n traffic lights.

Definition: We say v_i and v_j are incompatible if assigning an overlapping green light time to v_i and v_j green causes a traffic collision.

Then, given a crossroad A, an undirected graph G= (V, E) corresponding to A is constructed as follows: The set of vertices is the set of traffic lights $V= \{v_1, v_2, v_n\}$ and the set of edges is the set of incompatible pairs of vertices. That is, $E= \{v_iv_j: v_i$ and v_j are incompatible$\}$.

Therefore, cars are allowed to proceed by v_i and v_j, while $v_iv_j \in E$ avoid collision if v_i and v_j are allocated to non-overlapping time intervals. This is where circular colouring plays a crucial role, as we shall see shortly.

2 OBJECTIVE

This paper examines the character of two models of classic road junctions. Model I is presented as a twelve traffic light road junction and model II as an eleven traffic light road junction. These two models appear in almost all major towns and cities. For the traffic optimization of our selected two models, the authors applied Graph Theory, in particular the “circular colouring” method. This corresponds to what is known as the “circular chromatic number”, $\chi_c(G)$ of a given graph G, which we will formally define in Section 4.

3 MODEL I: CLASSIC FOUR WAY TWELVE TRAFFIC LIGHT ROAD JUNCTION

There are four roads in Figure 1, with 4 orientations, for example north, south, east and west. Each road has three directions: left turn, straight and right turn. Lights number 1, 2 and 3 correspond to left, straight and right turn, respectively. A similar pattern applies to lights numbered 4, 5, 6; 7, 8, 9 and 10, 11, 12 (see Figure 1). Figure 1 also demonstrates how traffic light number 1 is in a collision course with 4 traffic lights, namely traffic lights 4, 8, 10 and 11.

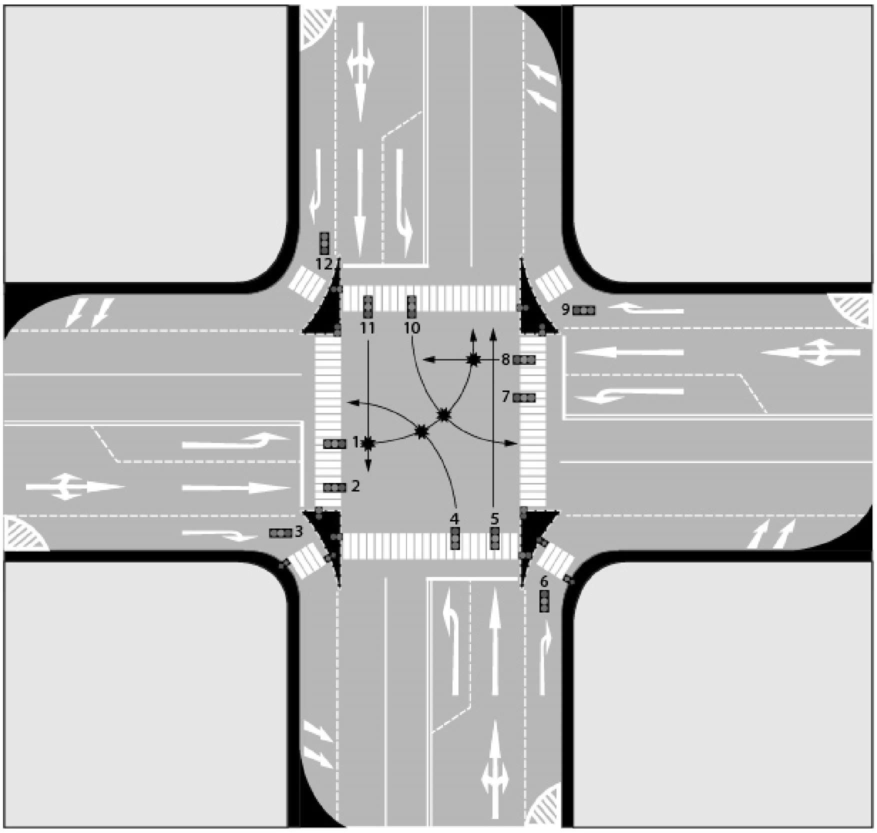

Figure 1: Model I: a classic road junction with twelve vertices.

The following graph (Figure 2) is derived from the above four way classic road junction (Figure 1). This graph has twelve vertices. Each vertex represents a specific traffic light. Recall that the adjacency of two vertices u and v implies u and v are incompatible**.**

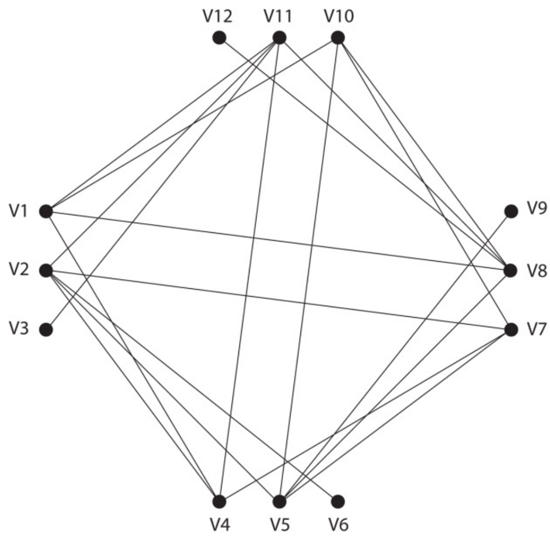

Figure 2: A Graph for model I, with 12 vertices (lights) and edges connecting incompatible vertices.

Vertex 1 (left turn) is adjacent to vertices 4, 8, 10 and 11; (as depicted in Figure 1 a vehicle moving from position number 1 is incompatible with vehicles moving from positions 4, 8, 10 and 11); vertex 2 (straight) is adjacent to vertices 4, 5, 6, 7 and 11; vertex 3 (right turn) is adjacent only to vertex number 11. This goes on in the same pattern (by symmetry) as it applies for the whole cycle up to vertex number 12, as shown in Figure 2.

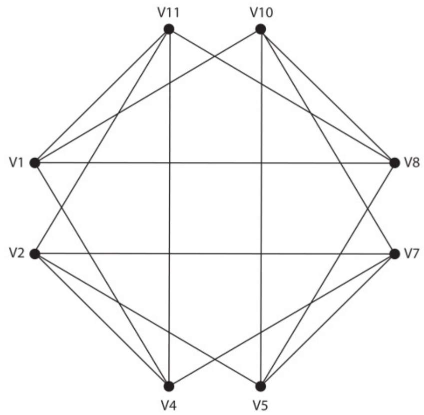

Figure 3: Reduced graph G_1 of model I with 8 adjacent vertices.

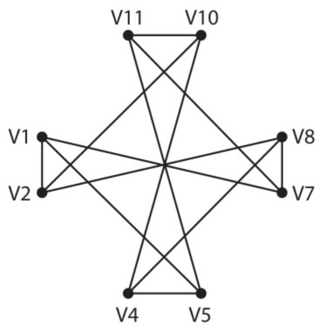

Figure 4: Model I: The complement graph G_1' of G_1; (to Figure 3 graph of incompatibility).

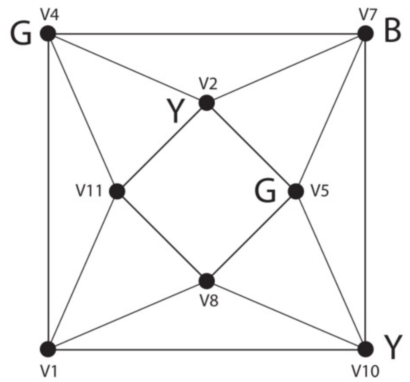

Figure 5: Model I: A symmetric representation of G_1.

4 CIRCULAR CHROMATIC NUMBER OF A GRAPH

DEFINITION: The “chromatic number”, $\chi(G)$ of a graph G is the minimum number of colours required to colour G properly. By proper colouring, we mean no two adjacent (connected by an edge) vertices should get the same colour.

In a traffic flow, proper colouring corresponds to requiring no two incompatible traffic lights should have an overlapping green light time interval. The number of colours used to colour a graph G corresponds to the total of one complete traffic period. That is, a period where each light gets exactly one green light interval. In other words, the maximum length a car has to wait before it gets a green light to proceed. Therefore the “chromatic number” seems to be an optimal solution since it minimizes the number of colours. In other words $\chi(G)$ is a complete traffic period length. For example, the “chromatic number” if each green light time is a half minute interval and if we colour G with 4 colours, then the total traffic period is 2 minutes. However, we shall show in Section 5 that this is not the case.

Denote by S_p the circle in R^2 (the usual X-Y plane) with circumference p centered at the origin of R^2 and by A (S_p) the set of open arcs of S_p.

DEFINITION: Let G=(V, E) be an undirected graph without loops. A circular colouring of G is a mapping c_p: $V \rightarrow A(S_p)$, such that the length of c(v) is (greater or) equal to 1 (and in general the weight of the vertex v) and $c_p(v) \cap c_p(w)$ is empty whenever v and w are adjacent in G ($vw \in E(G)$).

DEFINITION: Circular chromatic number $\chi_c(G)$ of a graph G=(V, E) is the infimum of all real numbers p, for which a circular colouring c_p of G exists.

There are several cases where $\chi_c(G)$ is strictly less than $\chi(G)$. Therefore, $\chi_c(G)$ is more efficient than $\chi(G)$ as is shown in this paper. In other words, the total one traffic cycle period can be less if we use $\chi_c(G)$ instead of $\chi(G)$.

The classic approach to set a stop-go cycle for a crossroad is to determine the chromatic number $\chi(G)$ of the graph and to assign an interval to every colour in the minimal colouring of G. Since this approach is not the best with respect to the time needed for an entire cycle, the circular chromatic number of a graph is used. In general, every vertex in G has a weight which corresponds to the time for which the corresponding direction is open. This is necessary if the number of cars coming from different directions is not even. In this paper, for simplicity, we give the definition assuming that all the weights are equal to 1.

It is easy to see (Zhu, 2001) that the “circular chromatic number” of a graph is less or equal to its chromatic number:

Proposition 1. $\chi_c(G) \leq \chi(G)$.

It is shown in Zhu (2001) that this infimum is attained and thus we can replace it with the minimum. In what follows an arc $c_p(v)$ will be usually identified (and drawn in Figures) with its centre point. Thus, in the circular colouring of G the distance (along the circle) of two centre points corresponding to vertices connected by an edge must be at least 1 (given the arcs are non overlapping).

Now consider the crossroad in Figure 1. Since there are two lanes in each direction, we shall assume that cars coming from direction 1 and 5 can go simultaneously. By symmetry, the same is true for directions 4 and 9, 7 and 11, 10 and 2. The corresponding graph is in Figure 2.

A vertex v is called “pendant” if it is adjacent to only one vertex (degree 1). Vertices number 3, 6, 9 and 12 are pendants. A pendant vertex v in G can be identified with a vertex of G that has a common neighbor with v, without changing $\chi_c(G)$ and $\chi(G)$. Therefore, we can omit pendants when we study the (circular) chromatic number. As a result, we get the “reduced graph” G_1 depicted in Figure 3.

Proposition 2. The chromatic number of the graph G_1 is 4 ($\chi(G_1)=4$).

Proof: First we prove that $\chi(G_1) \leq 4$, by 4-colouring G_1 with a colouring function c. (see Figure 2).

Let $c(v_1)=c(v_2)=c(v_3)=R$ (R for Red)

$c(v_4)=c(v_5)=c(v_6)=B$ (B for Blue)

$c(v_7)=c(v_8)=c(v_9)=G$ (G for Green)
$c(v_{10})=c(v_{11})=c(v_{12})=Y$ (Y for Yellow)
Therefore: $\chi(G_1) \leq 4$.

Now, we prove that the graph has no 3-colouring (see the symmetric representation of G_1 in Figure 5). Suppose, without loss of generality, that there is a 3-colouring c* using Blue (B), Green (G) and Yellow (Y). We may assume $c^*(v_7)=B$ and $c^*(v_4)=G$. Now, this forces $c^*(v_2)=Y$ (since $c^*(v_2)$ is adjacent to both v_7 and v_4). Similarly, this forces that $c^*(v_5)=G$. Then $c^*(v_{10})=Y$. But then v_8 and v_{11} both have to be B, which is a contradiction, since v_8 and v_{11} are adjacent. Therefore, there is no such 3-colouring c* of G_1.

Therefore: $\chi(G_1) \geq 4$. We deduce that $\chi(G_1)=4$.

Proposition 3. The circular chromatic number of the graph G_1 is 4; $\chi_c(G_1)=4$

Proof: By Propositions 1 and 2 we have that the circular chromatic number is at most 4.

Now, we prove that it is equal to 4. In any circular colouring the arcs $c_p(v)$ and $c_p(w)$ can intersect only if v and w are not adjacent in G_1. Consider the graph G_1' (Figure 4), the complement of the graph G_1, i.e., vertices v and w are adjacent in G_1' if and only if they are not adjacent in G_1. Since there is no triangle (three vertices pairwise connected) in G_1' there are no three vertices in G_1 such that their corresponding arcs have a non-empty intersection. Thus, every point on the circle is contained in at most two arcs. Since there are eight arcs of length one, the circumference of the circle must be at least 4.

This is an example where the circular chromatic number is identical to the chromatic number. However, in the next section, we show a model for which the circular chromatic number is clearly a more efficient method.

5 MODEL II: CLASSIC FOUR WAY ELEVEN LIGHT ROAD JUNCTION

Now, we shall examine the situation with one less direction. Consider the same crossroad as in Figure 1, but omit the possibility of turning left (v_1) as depicted in Figure 6. We get the same graph G_2 which is obtained from G_1 by deleting v_1 from G_1. Again, we can study the reduced graph by omitting the vertices of degree 1. We get the graph G_2 with seven vertices (Figure 7). By symmetry of G_1 the statements about G_2 would be true if we would omit an arbitrary left or straight direction from the original 12-direction crossroad.

Proposition 4. The chromatic number of the graph G_2 is 4; $\chi_c(G_2)=4$

Proof: The proof is in all respects the same as the proof of Proposition 2, since the proof of $\chi(G1)>3$ is independent of the vertex v_1.

Proposition 5. The circular chromatic number of the graph G_2 is 7/2; $\chi_c(G_2)= 7/2$.

Prooof: The 7/2 circular colouring shown in Figure 10 proves that the circular chromatic number is at most 7/2. By the same argument as in the proof of Proposition 3, no three arcs can overlap, and since there are seven arcs, the circular chromatic number is at least 7/2. Hence, $\chi_c(G_2) = 7/2$.

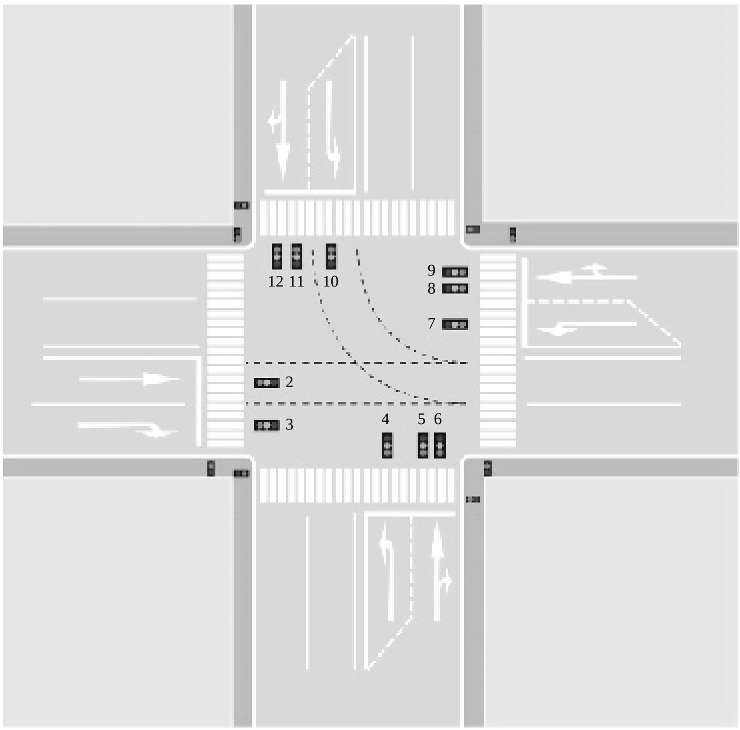

Figure 6: Model II: A classic road junction with eleven vertices.

To see the validity of the 7/2 colouring of G_2 given in Figure 10, it suffices to verify (using Figure 11) that the following two constraints are satisfied:

- Every traffic light, (v_2, v_3, …, and v_{10}) has received at least one full green light period;
- No overlapping green light time is assigned to any incompatible pair.

The fact that the total one traffic period is 7/2 time units is rather straight forward from either of the two figures.

Note also that the traffic lights of Model II that are reduced, v_3, v_6, v_9 and v_{12}, (see Figure 7); any amount of green light interval that does not overlap with v_{11}, v_2, v_5 and v_8, respectively can now be assigned.

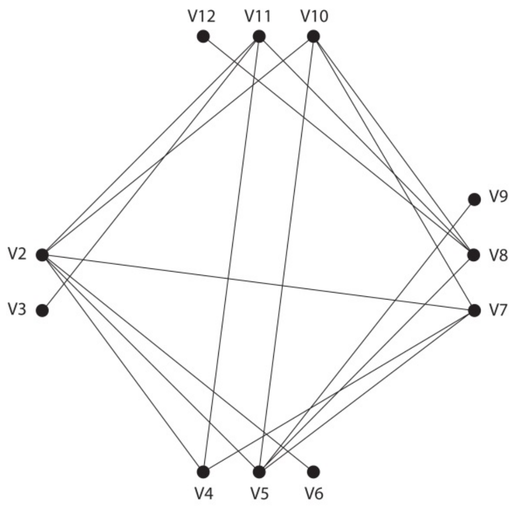

Figure 7: A graph for model II with 11 vertices (11 lights) and edges connecting incompatible vertices.

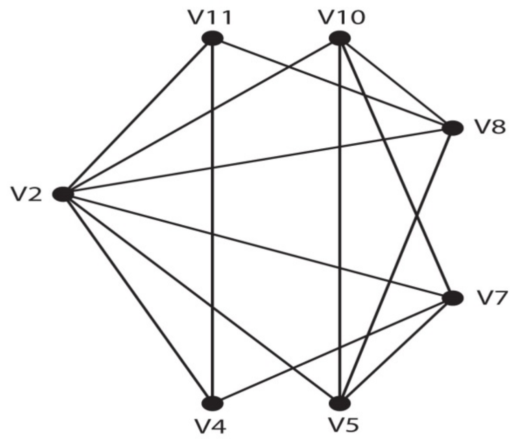

Figure 8: Graph G_2.

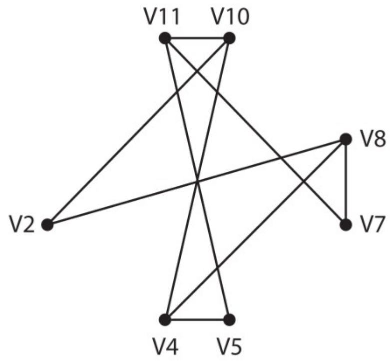

Figure 9: Complement G_2' of G_2.

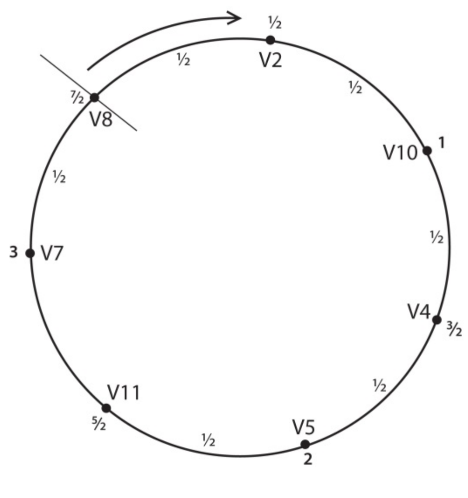

Figure 10: Circular colouring of G_2.

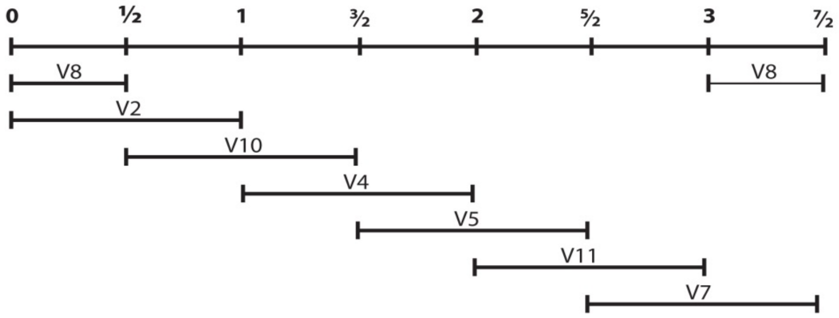

Figure 11: Traffic flow phases after chromatic circular graph.

6 CONCLUSION

In this paper we have chosen the two most common traffic junctions and showed in one of the two cases that the circular colouring method yields a more efficient solution than the usual colour minimization method. To be more specific, we have first reduced the traffic model by removing a redundant traffic light. Interestingly, such a traffic light reduction alone does not result in any traffic period reduction as shown by Proposition 4. On the other hand Proposition 2 also shows that the circular colouring method alone does not necessarily yield a better solution. Thus, it is made apparent in this paper that it is the combination of both methods that translates into more efficient traffic management.

By virtue of simplicity, we have made our point clear without including long and tedious calculations. From a real world point of view, however, it is often necessary to consider additional factors. These factors inevitably lead to a more technical and computational analysis. We discuss here two such important factors and we conclude by remarking how we intend to resolve them.

In the first place, all roads at a traffic junction need not have an equal distribution of traffic load. A given road may be a lot busier than another although they meet at the same junction. As a result assigning equal time length to all traffic lights can lead to some undesirable traffic congestion.

The second factor can be described as follows: We note that we have defined two traffic lights to be either incompatible or compatible. From this point of view, we decided to allow an overlapping green light interval only to compatible lights. However, we did not specify how much of an overlap time that can be allowed. The maximum being one, we have left the minimum overlapping time open to any. On the other hand, when two lights are incompatible, we have only considered the case that they are assigned a disjoint (non-overlapping time) interval. However, in a real world scenario, the situation may not be that simple. For instance, in order to assure the safety of the traffic light system, there may be an additional requirement that two incompatible lights should not only have a non-overlapping green light time, but also that there is a certain time gap between the intervals. That is, one may not be given a green light immediately after the other's green light turns red, but rather should wait a certain length of time before being allowed to proceed via a green light. There may also exist incompatible pairs of lights where such a restriction is not necessary. This leads to the notion of the "degree of incompatibility" between two incompatible lights. We can also analyze the dual problem of "degree of compatibility" problem between two compatible lights.

How do we approach such issues? There are certain generalizations of the circular colouring that are suitable to such a variety of real world problems. For the first factor that we discussed above, a type of circular colouring called "vertex-weighted" circular-colouring seems to be appropriate. The busier a given road is, the more weight we give to the light that corresponds to the busy road. In this manner, we obtain a graph which has labels on its vertices. The labels correspond to the weight that traffic light is given. Then, the vertex-weighted circular colouring assigns a green light time interval to each traffic light proportional to the given weight of the specific vertex. In short, the vertex-weighted circular colouring addresses the problem of an unequal traffic distribution junction problem.

For the second factor that we discussed above, a type of circular colouring called "edge-weighted" circular-colouring seems to be the appropriate approach. The further apart we want two incompatible lights to have green light intervals, the more weight is given to the edge that is between the corresponding vertices in the graph. In this manner, we obtain a graph which has labels on its edges. The labels correspond to the "degree of incompatibility" between the traffic lights that are represented by the endpoints of the edge. Then, the edge-weighted circular colouring assigns a green light time interval to each traffic light proportional to the given weight of the specific edge.

Each of the edges and vertex-weighted circular-colouring minimizes the colouring number, and so it is presumed to give an optimal solution.

We hope to study and present an extension of the current work in a forthcoming paper, by considering these two types of generalized circular-colourings and exhibit certain models where such methods prove to be more efficient than standard methods.

ACKNOWLEDGEMENT:

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Public Finance and Transport

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ABSTRACT: The common market is considered to be one of the greatest benefits of European integration. The single European transport area with optimal modal split is a basic precondition for a common market in goods and the required high mobility of passengers. To assure smooth traffic flow, with the minimum of traffic accidents, and to be more environmentally friendly and energy efficient necessitates the maximum utilization of all current transport facilities that are available. However this shall not be enough. Regarding the delay in adapting the transport infrastructure to the enormous growth of traffic, it is necessary to increase investments into bottleneck removal and add new links according to new requirements. Some prioritization of investment in transport infrastructure is connected with the broad effort of public authorities to increase growth and employment in order to facilitate solutions to end the current crisis and assure the further development of the economy; the contribution of public funding is considered to be an important incentive for private capital inflow.

KEY WORDS: Spending on transport infrastructure.

1 HIGHEST POSSIBLE QUALITY OF TRANSPORT AS A PRECONDITION FOR AN EFFECTIVE COMMON MARKET

In the mid-seventies the share of transport expenses in the budget of Member States (MS) of the EU was 1.5% of GDP, which was considered for MS to be rather low (EC, 1991). This rate was also adapted by the European non-MS as a recommended dimension within the European Transport Committee of the Economic Council of Europe of UNO as the lowest standard. There were only some exceptions, caused by the military needs within the period of the “cold war”. Nevertheless, to the detriment of the transport sector transport services were provided at a satisfactory level during seventies and eighties. For this reason the amount of transport expenditure within the budget of European Communities has dropped to 0.8% of GDP in 2008, despite a broadening and deepening of the common market (EC, 1991).

The level of transport services has had an adverse influence on the transport market in goods and the worsening of passenger traffic. The main troubles have been found in road transport; the steep growth of road vehicles and their performance were contrary to the slow rate of growth in the capacities of road infrastructure. Therefore it has been impossible to remedy the disproportion partially caused by the poor growth of road capacities for decades.

The first two White papers on the European transport policy of the European Commission 1991 - 2000 and 2001 - 2010 (EC, 1991; EC 2001) were significantly affected by the inability to raise the capacity constraints in the relevant decades, (though the main aim was environmental and energy sustainable development). In the first White paper these ideas were stated in a more general form. In the second White paper a more general approach was stated as the main reason for the lesser success in the implemented provisions and nearly identical principal requirements were made more concrete after being split into about 120 sub-items. In these two documents the European Commission made a great effort to slow down the traffic growth in general, paying special attention to separate the growth of transport and the growth of GDP, reduce traffic volumes (particularly in road transport) by transferring a part of road traffic to rail and water transport (with a subsequent task to transfer only a part of new transport to rail and water).

The second White paper was revisited in the middle of the planned decade 2001-2010 (EC, 2006) after many objections to the possibility of limiting transport too much, especially road traffic, as such an attitude could be dangerous on account of undermining the global competitiveness of the European economy.

As necessary further steps the European Commission proposed within the framework of the new medium-term financial outlook 2014 - 2020 a fourfold increase to the share of funding from the Union budget in comparison with the period 2007 - 2013. Instead of programming the European transport policy for only decades, further development in some basic indicators has been scheduled up to the thirties and, in connection with energy and environmental impact, until the fifties. As an additional source proposals to allow bonds as supplementary funding of major projects of transport infrastructure have again been negotiated. Such bonds when guaranteed on a pan-Union level make for cheaper investment loans.

The latest White paper “Roadmap to a single European Transport Area” (EC, 2011) from the year 2011 which has only 17 pages but details in 5 annexes (Transport matters, Putting sustainability at the heart of transport, Plugging into smart solutions, Reducing barriers to free movement and mainly Investing in the network) is indicatively prolonged to the year 2050, with an intermediate stage 2030 (2030 is the last year of the recently prepared period of TEN-T); many main indicators are proposed in parallel with energy savings, especially as regards the decreasing sources of fossil fuels and emissions from transport.

2 ADDITIONAL EFFECTS OF INVESTMENT IN TRANSPORT INFRASTRUCTURE

Priorities of support for the eligible sustainable development of transport infrastructure could apply a larger necessity to the use of mass passenger transport instead of individual transport, in some cases even with a lower energy efficiency per passenger because of a lower than minimal necessary occupation, if it could save capacities of the transport infrastructure. This applies especially to road transport. Notably at the time of the crisis and lower employment a transfer of passengers from cars to railways and buses could be more acceptable because of lower costs and the prices of public transport services. The strength of such a transfer is then evidently influenced by the taxation of public transport services. Such services have been taxed with decreased rates in all Member States of the European Union; the decisive percentages of taxation are excise duties on fuel that could be partially eliminated by fueling abroad, with lower value added tax (EC 2012a; EC 2012b). The level of decreased rates of value added tax- VAT- differs from 5% to 15%. (Some MS even have had super decreased rates of VAT below 5%). The level of decreased rates as a reduction in comparison with the standard rate differs in EU MS from 5% to 15%. (The standard rate, with only some exceptions, is higher than 20%, but the only EU state in 2011 with a standard rate of 23% has been Denmark).

The growth of taxation and cuts in state budget expenditure, despite relatively healthy public finance, led to the stagnation and later recession of the Czech economy.

It is possible to demonstrate it using data describing the growth and the level of government expenditure in the period 2009-2012 in the EU (Eurostat, 2013).

Table 1: Government deficit and debt.

	Government deficit				Government debt			
	2009	2010	2011	2012	2009	2010	2011	2012
EA17	-6.4	-6.2	-4.2	-3.7	80.0	85.4	87.3	90.6
EU27	-6.9	-6.5	-4.4	-4.0	74.6	80.0	82.5	85.3
BE	-5.6	-3.8	-3.7	-3.9	95.7	95.5	97.8	99.6
BG	-4.3	-3.1	-2.0	-0.8	14.6	16.2	16.3	18.5
CZ	-5.8	-4.8	-3.3	-4.4	34.2	37.8	40.8	45.8
DK	-2.7	-2.5	-1.8	-4.0	40,7	42,7	46,4	45,8
DE	-3.1	-4.1	-0.8	0.2	74.5	82.4	80.4	81.9
EE	-2.0	0.2	1.2	-0.3	7.2	6.7	6.2	10.1
IE	-13.9	-30.8	-13.4	-7.6	64.8	92.1	106.4	117.6
GR	-15.6	-10.7	-9.5	-10.0	129.7	148.3	170.3	156.9
ES	-11.2	-9.7	-9.4	-10.6	53.9	61.5	69.3	84.2
FR	-7.5	-7.1	-5.3	-4.8	79.2	82.4	85.8	90.2
IT	-5.5	-4.5	-3.8	-3.0	116.4	119.3	120.8	127.0
CY	-6.1	-5.3	-6.3	-6.3	58.5	61.3	71.1	85.8
LT	-9.8	-8.1	-3.6	-1.2	36.9	44.4	41.9	40.7
LV	-9.4	-7.2	-5.5	-3.2	29.3	37.9	38.5	40.7
LU	-0.8	-0.9	-0.2	-0.8	15.3	19.2	18.3	20.8
HU	-4.6	-4.3	4.3	-1.9	79.8	81.8	81.4	79.2
MT	-3.7	-3.6	-2.8	-3.3	66.4	67.4	70.3	72.1
NL	-5.6	-5.1	-4.5	-4.1	60.8	63.1	65.5	71.2
AT	-4.1	-4.5	-2.5	-2.5	69.2	72.0	72.5	73.4
PL	-7.4	-7.9	-5.0	-3.9	50.9	54.8	56.2	55.6
PT	-10.2	-9.8	-4.4	-6.4	83.7	94.0	108.3	123.6
RO	-9.0	-6.8	-5.6	-2.9	23.6	30.5	34.7	37.8
SI	-6.2	-5.9	-6.4	-4.0	35.0	38.6	46.9	54.1
SK	-8.0	-7.7	-5.1	-4.3	35.6	41.0	43.3	52.1
FI	-2.5	-2.5	-0.8	-1.9	43.5	48.6	49.0	53.0
ŠE	-0.7	0.3	0.2	-0.5	42.6	39.4	38.4	38.2
UK	-11.5	-10.2	-7.8	-6.3	67.8	79.4	85.5	90.0
CZ order	14	13	11	20	8	8	9	12
Innovation	15	17	17	17				

In the last line of the table it is possible to find the effects of cuts for future development described by innovation capacity. The European Commission has prepared a yearly Innovation Union Scoreboard (EC, 2009, 2010, 2011, 2012). The innovation performance of the MS is divided into 4 groups:

- Innovation leaders: Denmark, Finland, Germany, Sweden ("well above the EU27");
- Innovation followers: Austria, Belgium, Cyprus, Estonia, France, Ireland, Luxembourg, the Netherlands, Slovenia,UK ("near to EU27");
- Moderate innovators: the Czech Republic, Greece, Hungary, Italy, Malta, Poland, Portugal, Slovakia ("below that of the EU27");
- Modest innovators: Bulgaria, Latvia, Lithuania, Romania ("well below that of the EU27").

The Czech Republic has been, from the beginning, in the 3rd group. But the groups of states in each group are relatively wide. A more detailed view is possible from the year by year overall global chart 2009-2012. The figures show the performance results for 27 EU and indicates a steady and slow decline in the Czech Republic. The chart for 2009 was formally modified in the following years (Mourre et al., 2013).

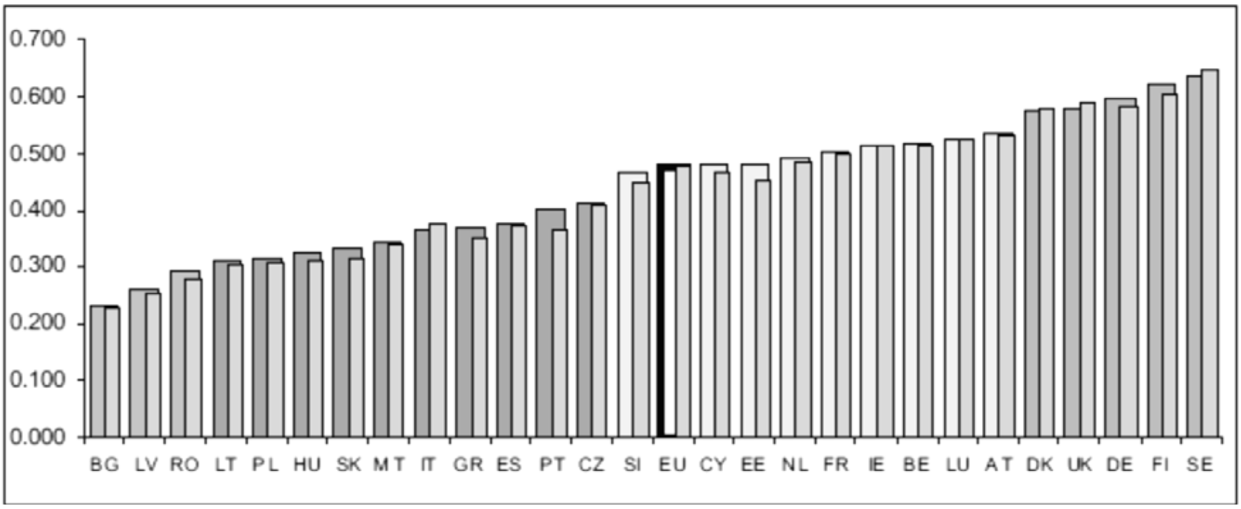

Figure 1: Charts of innovation level in 2009
(In 2010 there was a change in the methodology).

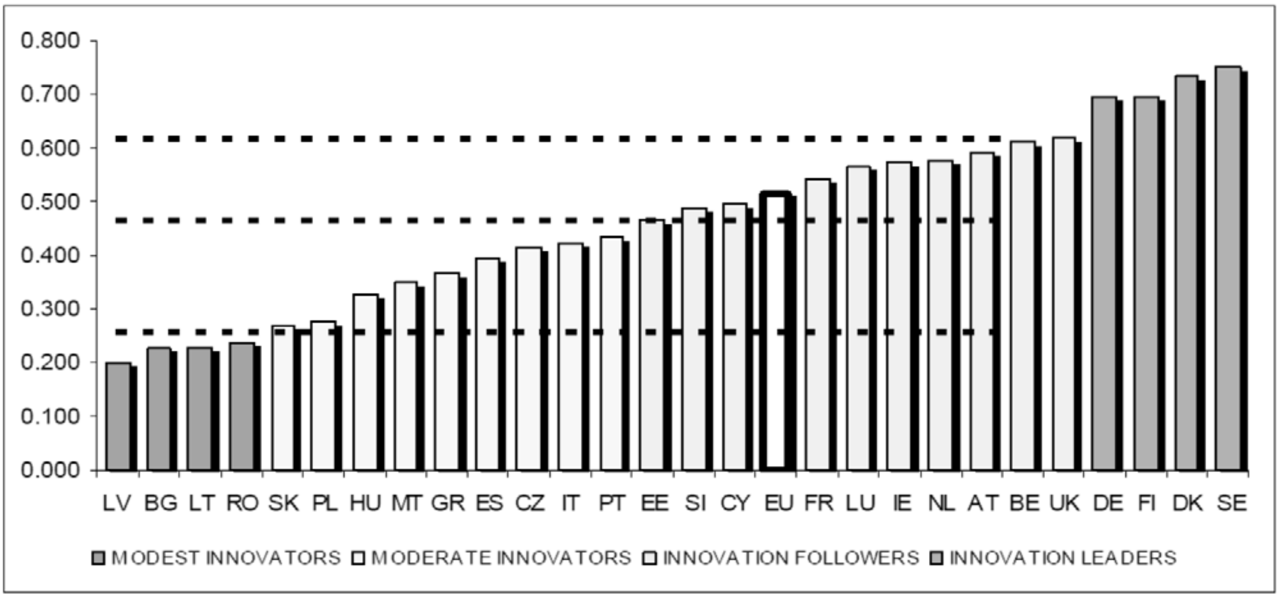

Figure 2: Charts of innovation level in 2010.

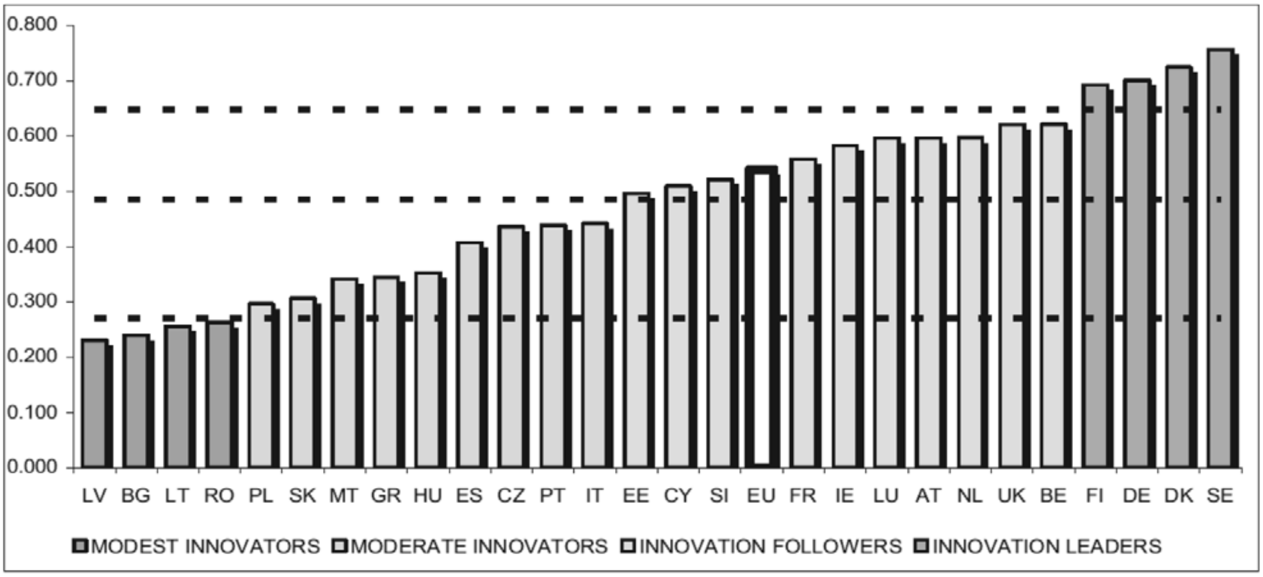

Figure 3: Charts of innovation level in 2011.

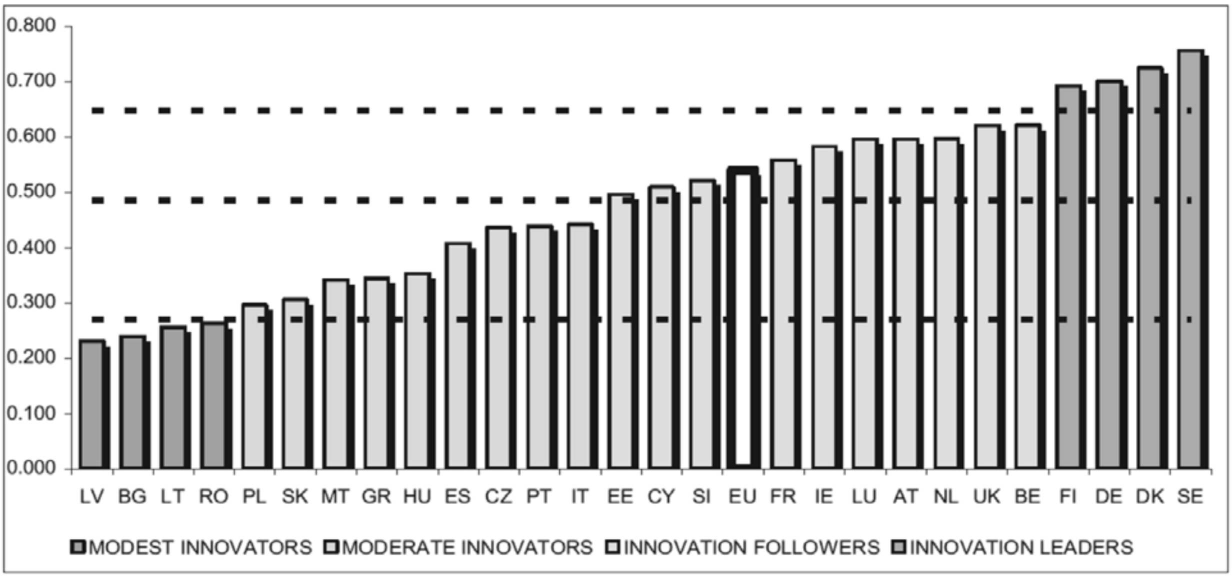

Figure 4: Charts of innovation level in 2012.

3 UTILIZATION OF INVESTMENT IN TRANSPORT INFRASTRUCTURE AS A WAY OUT OF THE CRISIS TO FURTHER DEVELOPMENT OF A COMMON MARKET AND THE GROWTH OF ECONOMY

If we take as a basis for further consideration the data from the speeches of the vice-president of the European Commission, Siim Kallas, a new investment in transport infrastructure co-financed by the EU Union-wide and averaging € 1 bill. could create 18 000 new jobs (Kallas, 2012). In addition it could draw a fivefold amount of private capital after the obligatory co-financing of the MS.

After converting these figures from € to CZK (1€=25 CZK) and the purchasing power parity in the Czech Republic (about 75% of EU average), it can be estimated that CZK 1 bill. enables the creation of 1000 new jobs (CZK 25 bill. x 0.75) If the estimated state spending on unemployment in the construction sector is at least CZK 100000 yearly per unemployed in the Czech Republic, the CZK 1 bill. decreased spending by the state on unemployment is at least CZK 100 million. Additionally, there is a naturally important leverage effect on the input of a four to fivefold inflow of private finance.

It is interesting to compare generally the efficiency of transport (and other development) investments as a tool for further income into the state budget using the higher volume of taxed services or necessary expenditure used in the state budget to produce or save value added tax.

It should be emphasized that the reduction of budgetary resources for investment plays a decisive role in the operation of programs with projects co-financed by the EU by up to 85% of the eligible costs of investment.

For the Czech Republic quotas have been allocated or have been supposed in the middle-term financial outlooks for:

- May 2004-2006 nearly CZK 420 bill., with drawing 98.1%;
- 2007-2013 about CZK 680 and till now assumed;
- 2014-2020 less than CZK 500 bill.

Quotas for middle-term financial allocation are possible extend by another two years in the case that the projects have started in the last year of the allocation period.

Quotas for the Czech Republic and other MS have been decreased for the period 2014-2020 because some MS want to decrease expentitures and through that their contribution to their own sources of the EU. This was also influenced by a lower than expected level of drawing of co-financing however.

Until now the transport sector in the Czech Republic has had slightly less than one quarter of the total allocated quatas. On account of the crucial importance of transport for the common market the Facility Connecting Europe was newly established with co-financing from the EU as in the case of operational programs. It has been designed for all 10 new MS, without national quotas, with the only selection criteria the quality of the submitted projects.

Respecting the initial orientation of EU co-financing as an additional and not replacement source, it would be an impressive amount of money.

4 SAVINGS IN PUBLIC EXPENDITURE BUDGETS

The yearly report of the European Commission DG Taxation and customs union: “Taxation trends in the EU – Data for the Member States, Iceland and Norway” 2012 has described in detail the development of all types of taxes and their revenues as a share of GDP up to the period 2000-2011 (EC, 2012a). In table I-1.1 of the report “Tax revenue sensitivity – percent change in tax revenues (as a ratio to GDP) in reaction to a 1% change in the output gap” are sensitivities for all MS in the range 0.26 to 0.48; for the Czech Republic it is 0.36.

This means that a 1% GDP output gap shall reflect the increase of overall tax burden of 1% GDP x 0.36. Nonetheless at least the same sensitivity is in the ratio output gap-tax revenues. The share of taxes in GDP was in 2009 34.5% - 34.8% of GDP – lower than GDP 2011. After the conversion of GDP and the GDP tax ratio for 2011, the tax ration grew by 1%. With the growth of expenditures to unemployment the effect of tax increase and cuts in budgetary expenditures was negative. With the removal of losses through tax evasion caused by the relocation of about 13000 headquarters of Czech business entities abroad, which can be limited, and with the Czech Republic joining the taxation of financial transactions, the results from continuous growth of economy and employment would highly overweight the effects from increased taxes and cuts in budgetary expenditures.

One of the occasionally discussed issues is the effectiveness of some public expenditures. It is effective if the expenditure covers the necessary costs of measures oriented towards either the growth of value added tax (e.g. investments in well prepared projects), or at least protect the fair operation of the market, protect the law, produce public services at an adequate level of quality. (See attempt in “Charter of citizens of the United Kingdom” during the governments of Mrs. Thatcher and Mr. Major, with the idea that the quality of public services should give adequate value for money).

5 CHANGES IN THE METHODOLOGY FOR THE CALCULATION OF SENSITIVITY

Up to the year 2011 the original methodology OECD was used, accepted and agreed with the European Commission in 2005; it was used both for the forecasting of cyclically-adjusted budget balances and even for the parameters of the preventive arm and repressive arm of the Stability and Growth Pact. For the year 2012 amended methodology (Mourre et al., 2013) was used with updated data and slight modifications (Kallas, 2012). The cyclically-adjusted predominant part of budget items has been really dependent on cycles; a much smaller part, mainly connected with public administration, may not be directly linked to economic cycles. So the original calculated sensitivity is reduced by subtracting the items and identified as semi-elastic. The difference for the Czech Republic is 1% GDP. For the cyclically-adjusted revenue of the state budget for 2012 there is a sensitivity of 0.409, as semi-elasticity 0.399.

It seems to be most important single point: the only way to start the growth of economy and employment within the milieu of global economy is efficient investment. Cursory assessment leads to the conclusion that the same relations are valid in all MS. The Czech Republic has been, despite growing government debts, in the first third of MS. Conversely it is a pity that the Czech Republic is, at the same time, in the last third in the EU in the slow rates of growth of economy and innovation.

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Design Methodology of a Fuzzy Control System in PTV VISSIM

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ABSTRACT: Fuzzy logic has been a popular tool for addressing advanced control tasks lately. This is true even in transportation, where it has been used for tasks such as ramp metering, control of traffic lights, as well as, for example, within highway management. Before application on a real street, however, such a control algorithm has to be evaluated and tested. In recent years, a so called microsimulation approach has been accepted as a useful tool for such tasks. In this paper, we demonstrate that PTV VISSIM can also be used for the evaluation of advanced control algorithms, even without the use of API. In this way, even without a knowledge of classic programming languages such as C ++ or Java, any fuzzy control algorithm can be implemented directly in the microsimulation tool and its effect on traffic directly evaluated. The ability to do this can be an important decision criterion when selecting a microsimulation tool, as was the case for example in the early stages in project SIRID (TA CR ALFA 2012 - Technology Agency of the Czech Republic). The presented approach within this paper is demonstrated on a real world problem of a single intersection control.

KEY WORDS: Microsimulation, PTV VISSIM, VisVAP, fuzzy logic, traffic control.

1 INTRODUCTION

1.1 Microsimulation models to evaluate traffic control strategies

Microsimulation models can measure different parameters of interest (such as delay time, travel time, average speed and others) on the basis of individual vehicles. Often, the decision to use one particular model is based on the experience of the development team and availability of a particular tool in the given organisation. In this paper, we selected the PTV VISSIM (PTV, 2011) software to help us in the project because of its usage at the Faculty of Transportation Sciences (Czech Technical University). For traffic control system design and development, the VAP language (Vehicle Actuated Programming) was used. Vehicle Actuated Programming VAP (PTV, 2012) is a simple programming language embedded as an add-on module to VISSIM. With the VAP you can create a phase or stage based and traffic actuated signal controls. The general programming elements in VAP are similar to those of common programming languages such as "If-then-else-end" used for a conditional statement and ":=" used for an assignment of values to variables. In order to make programming easier, PTV implemented a graphical user interface to design and edit VAP–based control directly and in a user friendly way. This interface is called Visualisation VAP

(VisVAP) (PTV, 2006) and can be used, for example, for intersection control design, speed harmonisation, ramp metering and others. Using the VisVAP provides many advantages for the development of control system: intuitive and easy creation of control strategies using flowcharts, without deep programming knowledge, and the possibility of rapid changes of proposed control strategy for example for optimizing the control algorithm. Control strategy can be designed for any traffic system. Knowledge of the GUI ViVAP, bases of algorithms and the creation of flow charts is a sufficient condition for using the software VISVAP which is met by most of the experts in transportation planning. In this paper, the authors guide through the entire process of creating a fuzzy control system for a single intersection (even though the approach is the same for other applications) and implementing it using VisVAP. The results of a case study demonstrating its results are also included.

1.2 Fuzzy logic

A fuzzy set is a set without crisp boundaries. The transition between "to belong to a set" and "not to belong to a set" is gradual. Mathematically, we can define a fuzzy set A in X as a set of ordered pairs:

$$A = \{x, \mu_A(x) | x \in X\} \tag{1}$$

Where $\mu_A(x)$ is called the membership function (MF) for the fuzzy set A. The *MF* maps each element of *X* to a membership value between 0 and 1. After fuzzy logic is introduced, the control algorithm can be expressed using simple rules and human language. This additionally improves robustness of the control algorithms. For a better overview of fuzzy logic and its advantages please refer to (Babuška, 1998). It has to be noted that fuzzy logic was already introduced for traffic control in the 1970s (Pappis & Mamdami, 1977).

2 THE CASE STUDY

In order to demonstrate the approach, a fuzzy model, also known as the fuzzy inference system (FIS) is used on a real 4-leg intersection located in a town called Chrudim (Czech Republic). Nowadays the intersection uses a fixed-time control with two phases and an overall cycle time of 46s. The traffic volumes and origin-destination traffic data were collected as part of a traffic census in June 2011 within the project (Kocourek et al., 2011). In this paper, an alternative control algorithm will be proposed and compared to the existing one. On this intersection it was observed that there is an average total of 15.73 [sec/vehicle], average standstill 6.68 [sec/vehicle] and an average number of stops 0.70 [stop/vehicle]. Our objective is clearly to improve these values. The results are provided in the final chapter of this paper.

3 FUZZY INFERENCE SYSTEM (FIS)

This section describes the design of a fuzzy control system, also called - fuzzy inference system (FIS) for a level intersection. An overview of a fuzzy signal control system within the scope of intersection control systems is illustrated in Figure 1. The names of input and output variables are denoted here, but described in the following parts of this paper. In the upper part of the picture a micro-simulation model in VISSIM application is depicted. The bottom part depicts the signal control system. The Signal controller needs vehicular detectors to provide accurate information of the prevailing traffic conditions in real-time. This information (VPT, VAG) is used as input data for the Fuzzy control system. The process of signal control calculates (gives) an output variable (GTD) which is transmitted to the signal heads.

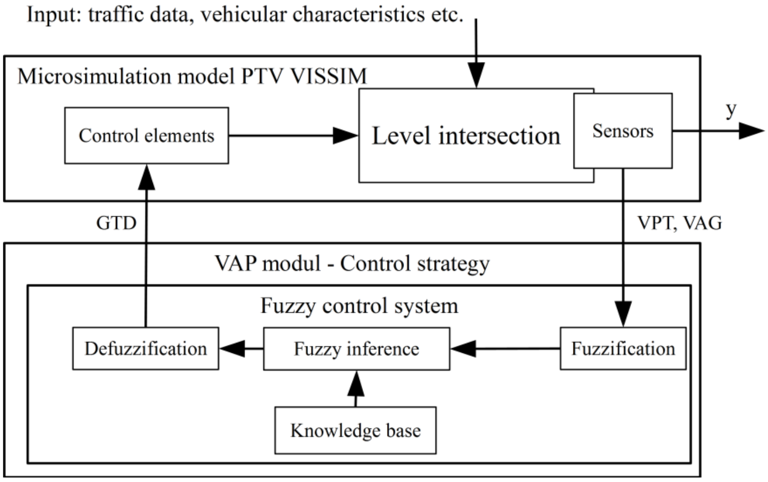


Figure 1: Fuzzy signal controller and its relation to the model. The input variables VPT, VAG, and the output variable GTD are described in the next chapters.

3.1 Fuzzy inference system – input variables

The proposed FIS uses two input variables: The number of vehicles per one minute which passed through the traffic detector VPT, [veh/min] - upstream count detector. The traffic detectors are located before each individual intersection lane. The number of vehicles after the green signal VAG [veh]. The same membership functions (i.e. VPT, VAG) - small, medium, and large, are used for both input variables and provided for clarity in Figure 2 a) and b). The parameters of the membership functions were set based on existing expert knowledge and literature review (Koukol, 2012). The input data are obtained from detectors of the microsimulation model in real-time.

3.2 Fuzzy inference system – output variable

Our FIS has one output variable - the green time for each signal group, GTD [s]. It has three linguistic variables: small, medium, large, as depicted in Figure 2 c) and similarly to the membership functions on the input variables were designed using expert knowledge.

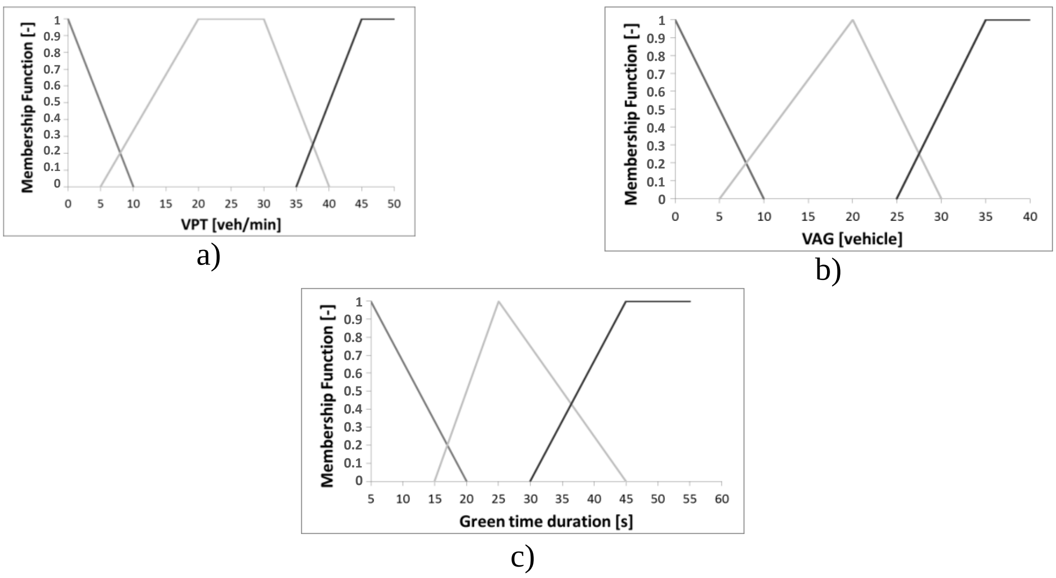


Figure 2: a) Input Fuzzy Variable VPT, b) Input Fuzzy Variable VAG, c) Fuzzy controller output membership functions for GTD.

3.3 Fuzzy knowledge base

The rule base together with the data base containing the different inference mechanisms is commonly known as the fuzzy knowledge base. The information on fuzzy sets of all variables used in the system is found in the database. The rule base contains all rules of the fuzzy inference system. The knowledge base and measured values of independent variables are used for an approximate deduction. An output fuzzy set is a result of such a deduction. The task of the further depicted inference mechanism is the evaluation of all rules and the subsequent merging of the results into one fuzzy set. We have set a two-dimensional functional dependence of linguistic variables VPT, VAG. That means the interference rules make up pairs which belong to the set $A \times B$. The set $A \times B$ is determined by a Cartesian product in our example.

$$P = \{(x, y)/x \in A, y \in B\} \tag{2}$$

For the number of rules, P, applies that $P = m \times n$, where n and m denote the number of fuzzy set terms for each variable. This equation implies that the number of fuzzy rules increases significantly with the number of fuzzy set terms as well as number of input variables. In our case, since we have two variables, each of them with three membership functions, there are overall 9 fuzzy rules. Each fuzzy rule consists of two parts; an antecedent (between the IF and THEN) and a consequent (following THEN). The fuzzy rules are provided in the following table, where one lane corresponds to one fuzzy rule.

Table 1: Table of all the fuzzy rules.

IF	VPT SMALL	AND	VAG Small	THEN	GDT Short
IF	VPT SMALL	AND	VAG Medium	THEN	GDT Short
IF	VPT SMALL	AND	VAG Large	THEN	GDT Medium
IF	VPT Medium	AND	VAG Small	THEN	GDT Short
IF	VPT Medium	AND	VAG Medium	THEN	GDT Medium
IF	VPT Medium	AND	VAG Large	THEN	GDT Long
IF	VPT Large	AND	VAG Small	THEN	GDT Medium
IF	VPT Large	AND	VAG Medium	THEN	GDT Long
IF	VPT Large	AND	VAG Large	THEN	GDT Long

The next important decision affecting the performance of the model is the setting of the inference engine. Several different settings were tested. As the result, the following setting is used in this paper:

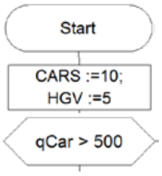
And Method:	Min
Or Method:	Max
Implication:	Min
Aggregation:	Max
Deffuzification:	Centre of gravity

The crisp output value (i.e. the control signal) is determined as the coordinate of the centre of gravity (Jura, 2003), and computed according to equation (3).

$$y^* = \frac{\sum_{j=1}^{m} y_j * \mu_B(y_j)}{\sum_{j=1}^{m} \mu_B(y_j)} \tag{3}$$

4 IMPLEMENTING CONTROL SYSTEMS USING VISVAP

VisVAP is a Graphical User Interface which broadens the possibilities of VAP language use for design of traffic control systems. VisVAP application can be defined as “a tool” for a comfortable design and editing of a program for traffic control system. Any VisVAP flow chart of the fuzzy control system consists of the following few basis elements (PTV, 2006). Please note that we are not providing all of the available elements, but only those needed for the design of a fuzzy control system.



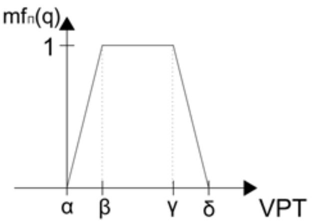
Terminus	Defines the start and the end of the program logic.
Statement	Used for commands and assignments
Condition	Used for logical conditions.

4.1 Fuzzy control algorithm in VisVAP

In this section, we focus on the implementation of a FIS using VisVAP. It has the following major steps. First the input and output membership functions must be parameterised in VisVAP and then we will proceed to the description of the fuzzy strategy of control in the VisVAP application. Because of the complexity and length of the algorithm, the procedure is presented for one rule of Table 1 only.

4.1.1 Input and output membership functions and their parameterization using VisVAP

At first, crisp values must be transformed into linguistic terms (fuzzy sets), also called fuzzification. This is one of the most important steps in our approach and is described in this section in great detail. The proposed system uses triangular and trapezoidal types of membership functions. This decision was based on the computational efficiency of the proposed shapes and an easier parameterization. The proposed approach can however deal with any shape of the membership function (for example Gaussian), only since the software VisVAP cannot deal with exponential or logarithmic mathematical functions directly, such shapes must be approximated in terms of equivalent polynomial forms (Koukol, 2013). The following Figure 3 demonstrates parameterisation of a trapezoidal membership function. All parameters α, β, γ and δ, that are referred to in the flow chart and in expressions must be defined in the parameters table (VisVAP).



$$\Pi(q,\alpha,\beta,\gamma,\delta) = \begin{cases} 0 & q < \alpha \\ (q-\alpha)/(\beta-\alpha) & \alpha \le q \le \beta \\ 1 & \beta \le q \le \gamma \\ (\delta-q)/(\gamma-\delta) & \gamma \le q \le \delta \\ 0 & q > \delta \end{cases}$$

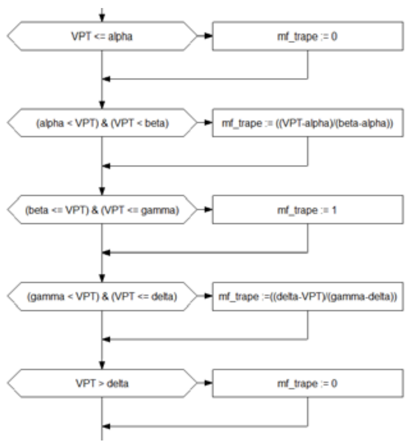


Figure 3: The trapezoidal function and its parameterization (left) VisVAP flow chart of the trapezoidal function (right).

The following flow chart (Figure 3) is an excerpt from VisVAP, demonstrating the corresponding implementation within VAP of calculating the membership function for the trapezoidal function. We used only two elements, the Condition and the Statement. The variable VPT denotes the volume of the vehicles.

4.1.2 Fuzzification, inference engine and defuzzification in VisVAP

In this section, the steps used in the FIS are described (Jura, 2003). As an example, we quote just the first rule line from Table 1. The important steps for designing (identification) of fuzzy systems are described in this Chapter. The following steps aim to focus on the particular issues described above and provide a description on how to implement them using VisVAP. Please note that their meaning is provided above. An example of implementing these steps is provided in Figure 4 a) – e).

Computing a degree of membership
First, the degree of membership is calculated for input value VPT. Given the inputs (crisp values) we obtain their membership values. This process is called 'input fuzzification' Figure 2 a). In the next step, the degree of membership is calculated for the input value VAG Figure 2 b).

Implement the rule evaluation and the rule consequent
After that the weight for a rule antecedent is computed. The minimum of all rules' degree of membership is applied in our model. The implementation in VisVAP is demonstrated in Figure 2 c). The resulting value is considered to be a weight of the rule (also called firing strength) and is applied to the consequent membership function MF_GTD_MAIN Figure 2 c).

Implement the defuzzification
The process of transforming a fuzzy set into a specific numeric value (GTD_MAIN) is called defuzzication, where the membership function of the output set is determined (given) by the union of cut-off membership functions (applies for Mamdani's type of FIS). For this, a new (auxiliary) point x_1 Figure 2 d) is calculated. We use the centroid (see equation 3), which returns the center of the area under the fuzzy set obtained in the previous step. This method is the most common choice in applications for its simple structure of min/max operations. The calculations are shown below in Figure 2 e).

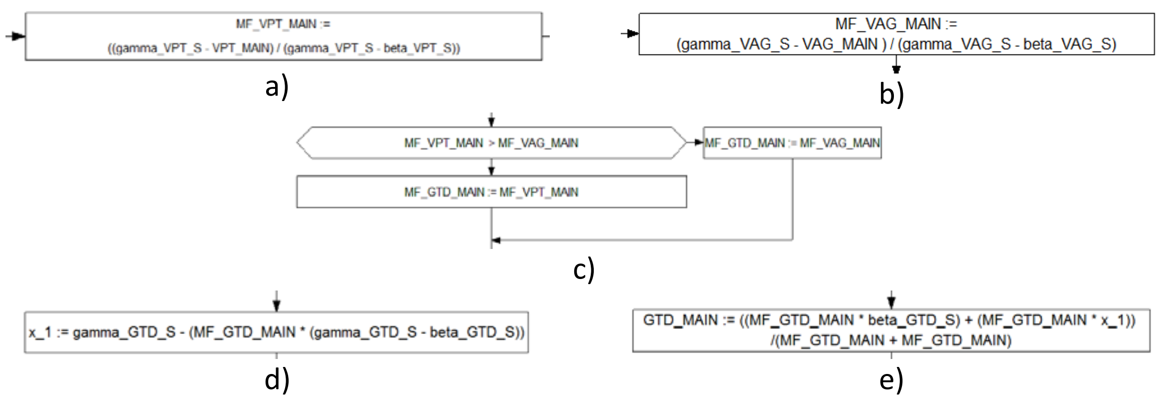


Figure 4: Fuzzification, Inference engine and defuzzification in VisVAP.

Integration of the main and secondary communication of the fuzzy engine into the control program core is the final step. Basically it is nothing more than a basic system which can be expanded or easily modified. Furthermore, it is possible to apply various methods of fuzzification and defuzzication with discrete expression.

5 RESULTS OF CASE STUDY

The approach introduced in this paper has been proved in the model of an intersection described above. The model of a given 4-way intersection with traffic lights was calibrated according to the characteristics: volume, traffic flow composition, vehicle direction, speed of vehicles (curve, section) and time gaps. To determine the quality of SSZ control, a 200m measured section was created for each traffic line in a micro-simulation model. The beginning of the observed section was placed about 190m in front of the stop line and the end was situated on the outbound (exit) arm of the intersection. The data was collected in six different measurements for two different traffic control system (average value was calculated): a fixed time control (FT) and a control with fuzzy inferential system (FIS). The measurement took place from 6AM to 8AM and the following traffic characteristics were assessed: the average total delay of vehicles in the observed section (sec/min), the average number of vehicle stops in the observed section (stops/min). The verification was done in two steps. In the first step the intersection with the fixed time (FT) was tested and in the second step the fuzzy inference system (FIS) was tested. The aggregated values from all intersection approaches are represented in the Table 2.

Table 2: Average total delay and average number of stops of the fixed time controller and the proposed FIS.

	Delay (sec/min)	Stops (stops/min)
Fixed time (FT)	15.73	0.70
Fuzzy inference system (FIS)	9.72	0.46
Improvement	35.59%	32.55%

The results presented above have proven the benefit of the fuzzy inference system in decreasing the average total delay time. This is certainly a significant improvement, considering the simplicity of the proposed model and the fact that the fixed time control is really in use on the intersection of concern.

6 CONCLUSIONS AND NEXT STEPS

In this paper an approach for implementing a fuzzy control system directly within a microsimulation tool VISSIM was presented. It provides a detailed overview so that everybody can evaluate control strategies without a detailed knowledge of programming languages or the need to purchase an additional API. Simplification of such evaluation is really an important issue nowadays, so we believe that the described implementation approach can be very useful and can bring more advanced control strategies into use. This article has clearly shown the potential of the VisVAP software in the design of an advanced control system. The designed system can be applied, for example, to a level intersection with traffic lights, urban traffic control system, road line traffic control (speed harmonisation), ramp-metering or dynamic traffic assignment. Next, this approach will be used in a larger project, in which different highway management strategies (including road line traffic control) will be compared in a microsimulation tool. This is, for example, true for project SIRID. Here an advanced algorithm for speed harmonisation on a highway will be developed as an improvement of the existing solution based on simple decision trees. Such a new algorithm will be evaluated with the use of a microsimulation model as a part of this project.

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Alexithymia and the Perception of Stress of Public Transport Drivers

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ABSTRACT: The objective of the research was description of the factors of psychological stress of Czech drivers in association with an occurrence of alexithymia and with the number of accidents. Psychological stress, occurrence of alexithymia and the number of accidents were indicated in a questionnaire. The sample consisted of 611 public transport drivers from the Czech Republic. Alexithymia was assessed by a 20-item Toronto Alexithymia Scale questionnaire. The level of stress was assessed by a questionnaire Stress of Public Transport Drivers. The occurrence of psycho-pathological symptoms was assessed by The Symptom Checklist-90. The drivers have shown only a low level of stress which did not differ by the vehicle type. Alexithymia occurred with 1/3 of the drivers. The association of alexithymia and the perceived stress was confirmed; the association of alexithymia and stress and the number of accidents was not confirmed. Contrary to the expectation, the drivers showed a low level of stress. The interaction with passengers was revealed as the most significant stressor. In accordance with our expectation and prior studies, alexithymia highly correlated with the problems in the relationship with other people.

KEY WORDS: Alexithymia, work stress, public transport drivers.

1 INTRODUCTION

According to the national statistics, more than 20% of all sick leaves are caused by the illnesses of the muscular system. Following the illnesses of the respiration system, they are the second most frequent cause of sick leave (Zdravotnická statistika, 2011). The occupation of a driver is essentially demanding in terms of psychological and physical resistance of the individuals (see Rydstedt et al., 1998; Kompier & Martino, 1995). The stress has an impact on the decision making process and, therefore, on the performance of a driver. Thus it might be one of the significant causes of traffic accidents. If a driver manages to cope with the task of driving a vehicle in heavy traffic under the stress, the stress often manifests elsewhere, and in the form of physical or psychological complications. Moreover, if the driver has certain personality traits which cause a limited capacity to cope with the excessive stress and a limited amount of adequate decision-making – as alexithymia is – the risk of negative impacts on the job increases. As a covering factor in the studies dealing with this topic the so called control theory is confirmed (Klein, 1991), which shows that the occupation of public transport (PT) drivers is demanding, especially in terms of great responsibility, but with a little control over the situation; the drivers do not have a large impact on the results of their work (Searle & Bright, 2003; Evans & Carrère, 1991).

The studies of the population of professional drivers have confirmed the hypotheses that there is a direct association of physical difficulties with the deficits in the emotional awareness (Mehling & Krause, 2005; Alperovitch-Najenson et al., 2010). Alexithymia is considered a personality trait, or a specific affective and cognitive style. The term alexithymia was introduced in the second half of the previous century by Sifneos (1972), who observed the typical characteristics in his patients with psychosomatic illnesses. Basically, it means that these people cannot recognize their own emotions or the emotions experienced by other people. Sifneos (1972; 1996) defined alexithymia with the following characteristics:

- Individuals describe how they feel through their body symptoms, they are not able to associate their feelings with any images or ideas;
- They concentrate on the description of the situations in which they get such a feeling;
- They are not able to specify closely or explain what a particular feeling means;
- They seem to be less capable in communication, with a limited vocabulary.

The findings which we consider important concern the association of alexithymia and various kinds of somatic or psychosomatic illnesses. Alexithymia considerably increases the vulnerability towards illnesses (not only psychosomatic), and it is one of the important factors which influence the efficacy of the treatment intervention. Lumley et al. (1996; 2010) claim that alexithymia is effective at three levels: physiologic, biologic, and cognitive. It is confirmed that the physiological level of alexithymia impact on the health is through a level of cortisol in blood of the alexithymic patients (their body is therefore constantly in a stress mode). The biological level of impact goes through unhealthy behaviour in the form of various addictions (cigarettes, alcohol, and drugs), compulsive behaviour, unhealthy life style, eating disorders which are reactions to the incapability to manage the stress in an adaptive way. The cognitive level leads through the perception of unspecific bodily sensations as the symptoms of illness, and thus increased sensitivity to these symptoms, and thus also to the somatoform disorders.

According to the research (Mehling & Krause, 2005; Singh et al., 2011), alexithymia has an impact on the ability to cope with stress adequately; and in our opinion, this deficit may show the problems connected with driving a motor vehicle; this fact may be more applicable to PT drivers. The occupation of PT driver is stressful; in terms of traffic: higher demands on concentration and the speed of decision making; as well as in terms of permanent interaction with passengers. With regard to the ability of alexithymic patients to cope with stress, we suppose that it transforms into psychosomatic difficulties. Therefore, these drivers should be offered training and education how to cope with emotions. According to the current knowledge of alexithymia as a personal trait which is associated with personal traits as behaviour of type A and hostility, it might be related also to the number of accidents.

1.1 Objective and hypothesis

The objective of this research is to describe the factors of psychological stress of Czech drivers and to find out the association of alexithymia with the perception of this psychological stress (distress); and moreover the number of accidents of the PT drivers. A further step is to apply the findings in a suggestion of specific programmes which will be focused on a real help to reduce the psychological stress of individuals.

2 METHODS

2.1 Description of population

The total number of participants is 611 drivers from four transportation companies in the Czech Republic, namely in the towns: Brno, Ostrava, Liberec, and Plzeň. The representative sample consists of tram, bus, and trolley bus drivers. The sociodemographic characteristics of the sample are shown in Table 1.

The data was collected in the years 2012 and 2013. The motivation to take part in the research was a financial reward of 400 Czech Crowns. Each participant received a folder which contained a letter of instructions about anonymity and ethical properties of the data collection, and the battery of questionnaires. The battery consisted of the questionnaire concerning socio-demographic indicators of age, sex, marital status, driving practice and the number of driven kilometres, the number of accidents, and of the questionnaires shown below.

The study population consisted mainly of males (89%), the majority of respondents had a degree (88.1%). Accidents in the last year were reported by 27.3% respondents. The cohort consisted of bus drivers, tram drivers and trolleybus drivers.

Table 1: Characteristics of study participants (n=611).

		Mean (S.D.) or %
Age		46 (10.3)
Sex		
	Female	10%
	Male	89%
Education		
	Primary school	4.1%
	Graduation	88.1%
	University	5.7%
Marital status		
	Single	17.8%
	Married	54.1%
	Divorced	24.2%
	Widowed	2.5%
Accidents		27.3%
SMHD (stress)		67.468 (31.029)
	Tramway	73.016 (29.693)
	Bus	63.923 (30.809)
	Trolleybus	68.268 (32.628)
TAS (alexithymia)		31.8%

2.2 Questionnaires

Stress of PT drivers (SMHD)

In order to assess the subjective perception of stressful situations when doing the job of PT driver, a questionnaire was designed. The questionnaire consists of 54 statements which are assessed by a proband on the scale 0 (it does not bother/stress me) to 4 (it bothers/stresses me a lot).

In terms of the psychometric qualities, the questionnaire has shown to be reliable. The reliability was inspected by the inner consistency; hence the Cronbach´s alpha was 0.955.

Toronto Alexithymia Scale (TAS-20)
The questionnaire used the Czech version of the Toronto Alexithymia Scale (Hošková-Mayerová & Mokrá, 2010). The scale consists of three subscales: a) difficulty identifying emotions (TAS_DIF) (items: 1, 3, 6, 7, 9, 13, 14); b) difficulty describing emotions (TAS_DDF) (items: 2, 4, 11, 12, 17) and c) external-oriented thinking (TAS_EOT) (items: 5, 8, 10, 15, 16, 18, 19, 20). The items 4, 5, 10, 18 and 19 are negatively coded. The respondents are asked to express their agreement with the given statements (1… I definitely do not agree to 5… I absolutely agree). The total score is between 20 to 100 points. The authors divided the scale by two limiting values: 51 and 61. The score 51 and less correspond to the individuals without alexithymia traits, the score 61 and more correspond to the individuals with alexithymia traits. The interval {51; 61} refers to "possible alexithymia". Some studies (e.g. Taylor et al., 1997; 2008; Guttman & Laporte, 2002) may work with the respondents of this score.

Symptom Checklist (SCL)
SCL consists of 90 items assessed by a five-point scale from 0… absolutely not to 4… very much. SCL measures nine primary dimensions of anxiety: somatization, obsession and compulsion, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, psychoticism. Total score is between 0-360. The respondents scoring 224 and more are in a serious danger of psychopathology (Preuper et al., 2007).

3 RESULTS

The statistical analysis was made using the IBM SPSS Statistics 19. The descriptive statistics are presented in Tab. 1. To detect the links between alexithymia, level of stress and accidents, the correlation analysis (Pearson correlation coefficient) and t-test for independent samples were used.

The distribution of alexithymia is 6.8% in the sample of drivers (score in TAS-20 more than 61 points), with respect to the fact that this group counts only 19 drivers out of the total number of respondents, thus corresponding with the recommendations of authors of the scale. The drivers with possible alexithymia scoring between 51 and 60 were also included in the increase of the number of respondents for the statistical analysis; thus the rate of alexithymia in the sample rose to 31.8%.

The level of stress is relatively low. Most respondents scored the value 1 or 2 in the SMHD questionnaire, which indicates moderate level of stress. The mean level of stress in the sample is 67.468 with standard deviation of (S.D.) 31.029. The highest value of stress were found for tram drivers 73.016 with S.D. 29.693, then followed by the trolleybus drivers 68.268 (S.D. 32.628), the smallest value of stress had bus drivers 63.923 (S.D. 30.809).

The association of the level of stress with alexithymic traits is significant, nevertheless, relatively weak (0.249). We found significant differences by comparing the groups of stressed and not stressed respondents (by SMHD score) according to the alexithymia characteristics (see Table 3). The respondents with more emotional trouble, who have alexithymic characteristics, e.g. difficulty identifying and describing feelings, are more stressed than the respondents who have good emotional awareness and vice versa (based on t-test for independent samples).

As shown in Table 2, there is a significant association between alexithymic traits and all the subtests of Syndrom checklist (SCL-90). There seems to be a stronger significant association with interpersonal sensitivity (0.424) and hostility (0.404).

The correlation analysis did not confirm the association between alexithymia, level of stress and the number of accidents.

Table 2: Alexithymia, level of stress and number of accidents.

	TAS sum
SCL	
Somatization	0.233*
Obsession and compulsion	0.319*
Interpersonal sensitivity	0.424*
Depression	0.373*
Anxiety	0.382*
Hostility	0.404*
Phobic anxiety	0.359*
Paranoid ideation	0.326*
Psychoticism	0.359*
SMHD	0.249*
Accidents	- 0.051

* Significant effects at p-value ≤ 0.05 are indicated for all variables.

Table 3: Emotional difficulties and level of stress.

Emotional difficulties	**Level of stress****	**Mean**
Difficulty identifying feelings (DIF) *	1	11.76
	2	13.55
Difficulty describing feelings (DDF) *	1	11
	2	13
Externally oriented thinking (EOT)	1	21.44
	2	31.96
TAS sum*	1	44.31
	2	48.63

* Significant effects at p-value ≤ 0.001.

** 1 = not stressed; 2 = stressed

4 DISCUSSION

The research aimed to verify the association of alexithymia and the level of stress of PT drivers. Based on the studies, the research focused on the association of alexithymia and the level of stress and the number of accidents of the drivers.

Contrary to our expectations, the analysis showed that public transport drivers are not under major work stress. The general level of stress in the studied cohort is relatively low. The respondents perceive the work related stress as little to moderate. This finding might be related to the inability of PT drivers to adequately assess the situation and adequately evaluate their condition. Another possible reason is a self-defence mechanism of denial which helps the drivers to cope with everyday stress. On the other hand, the PT drivers should be selected so that they are able to cope with the higher level of stress. Therefore, it is possible that in our selected cohort the stressors do not constitute high, above the limit, stress. The low association with psychosomatic difficulties supports this fact.

The study did not confirm our expectation about the association of alexithymia, the level of stress and the number of accidents. It does not show that alexithymia or distress would be significant factors in the occurrence of accidents. The finding might be influenced by the methodology of data collection. The number of accidents was assessed by a subjective interview with the respondents when we asked them how many accidents they caused and did not cause last year. We may assume that the respondents were afraid to say this information.

As expected, the study confirmed the association of alexithymia and the level of stress of professional drivers. The results show that for drivers who are more stressed it is difficult to be aware of their emotions and work with them correctly. It can be especially dangerous in situations where it is necessary to recognize the emotional reactions and behaviour of others (e.g. road users) and predict their future behaviour. It shows that drivers who are not able to recognize emotions in themselves have a problem to recognize emotions of other people. The result refers to psychosomatic problems of individuals with higher level of alexithymia in relation to higher level of stress (Lumley et al., 1996; Taylor et al., 2008).

If we focus more deeply on drivers' personality, there seems to be a considerable association of alexithymia and hypersensitivity, defined as hypersensitivity to the interpersonal relations, easily hurt feelings. The finding is in accord with other studies that explored the relation to the social environment, i.e. to people (Spitzer et al., 2005). Thus the conclusion that alexithymic people, in our case PT drivers, have more interpersonal problems, and in social contact they are not assertive are confirmed. In contrast to our expectation, the research did not show significant association of alexithymia with somatic problems and depression. There is a small correlation, but with regard to the prior studies (Lumley et al., 1996; Honkalampi et al., 2000) it was expected a much higher one. A significant association was found between alexithymia and psycho-pathologic symptoms assessed by the Syndrome Checklist; they are the scales of interpersonal sensitivity, hostility and anxiety; these relations are obvious as they describe alexithymic patients as they are: hypersensitivity to their emotional reactions and to the interaction with people in which there is incorporated emotional reaction to the reactions of others (in SCL interpersonal hypersensitivity), emotional behaviour is associated with fear and anxiety on the one hand (in SLC anxiety); and on the other hand, presumably as a defensive mechanism against anxiety. In terms of emotional awareness it would be appropriate to focus on the area of interpersonal relationships, which is a significant predictor of stress and alexithymia.

5 CONCLUSION

The authors worked with a sample of 611 PT drivers from four transport companies in the Czech Republic. The main objective of the research was to identify the basic factors of psychological stress of PT drivers, and to find out the level of impact or association of alexithymia and the perceived stress, and the number of accidents. The objective of the study was partially confirmed. The work with emotions is also important for the occupation of driver because of everyday contact with emotions, and thus the impossibility to avoid this interaction, i.e. the stressor. The work with drivers should be particularly focused on the area of emotions, more specifically on better identification and necessity of adequate reactions to emotions as well as to emotions of other road users.

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Crash Tests of Vehicles – Selected Experiments and Analysis

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ABSTRACT: The university research projects systematically deal with traffic safety, especially passive safety. Several experiments were carried out with the purpose to increase the knowledge in the automotive safety field, to obtain in-deep information from non-standard processes and data for validation of mathematical simulations and to extend the results and knowledge databases.

KEY WORDS: Passive safety of vehicles, crash test, deformation, injury, experiment.

1 INTRODUCTION

Research of passive safety of all categories of vehicles covers many areas. The partial results from different areas are subsequently synthesized and implemented into vehicle design. The current knowledge of M1 category vehicles is so advanced, that legislatively defined method of verifying barrier testing - the frontal crash test – has been enacted. The conditions under which given test is carried out are firmly established and form the basis for evaluation criteria of vehicle passive safety. Under this method, the test cars are evaluated according to 1975 - ECE Regulation No 33 and 1995 - ECE Regulation No 94. The experimental evaluation is based on biomechanical criteria which determine the severity of possible injuries to human body, represented by dummies.

Since the approval tests are carried out on new vehicles, knowledge databases utilizing information obtained from simulated accidents carried out under non-standard conditions (not identical with legislation, where age of the vehicle influences its parameters) are growing in importance. Monitoring of vehicle structural integrity is an important part of passive safety research, and in case of M1 category vehicles, it is mainly about the strength of integral body and deformation zones. One of the possible ways to assess them is to detect tension at the exposed vehicle body parts. The obtained values can be used to compare the statistics as well as serve as input values in a computer simulation (Kramer, 2008).

In recent years, several experiments of passenger car collisions with a fixed barrier have been carried out under non-standard conditions. The preparation, process and results of these experiments are the subject of this article.

2 HEAD-ON COLLISION OF A PASSENGER CAR ŠKODA FABIA 1.2 HTP WITH A BARRIER

Crash test of a passenger car into fixed barrier was carried out to investigate the restitution parameters of crush zones (Scuderi, 2006).

Further objectives of this experiment were to determine the probability of injuries to driver's head and to find out total instantaneous deformation of the vehicle and consecutive technical condition of the vehicle after the collision.

The vehicle was equipped with the crash test dummy Hybrid II (at driver's position). The dummy was restrained by the three-point safety belt and equipped with a three-axis accelerometer, placed into the head of the dummy. The engine was running at an idle speed. The vehicle was equipped with 8 strain gauge tension sensors and one longitudinal acceleration sensor, as shown at Figure 1. The driving position was equipped with a front airbag, whereas passenger airbag was not installed in this vehicle.

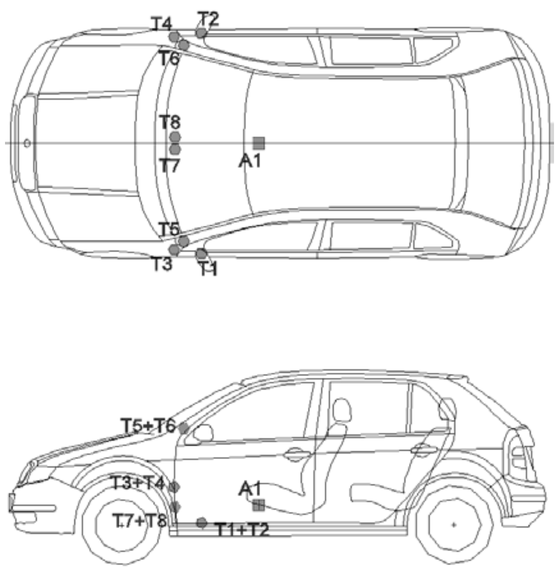

Figure 1: Position of strain gauges T1 - T8 and accelerometer A1 on the vehicle body.

The testing car was accelerated by a special device into a fixed rigid barrier. The weight of the barrier, determined by calculation, amounted to 25 t. The weight of the object was 1060 kg + 72.5 kg = 1132.5 kg. The velocity of the object at the moment of impact was 50.77 $km \cdot h^{-1}$ and its kinetic energy was 112.62 kJ.

After the impact, the following head injury criterion for the crash test dummy Hybrid II was established: HPC_{36} = 302.94; T_1 = 164.4 ms, T_2 = 197.8 ms (Figure 2).

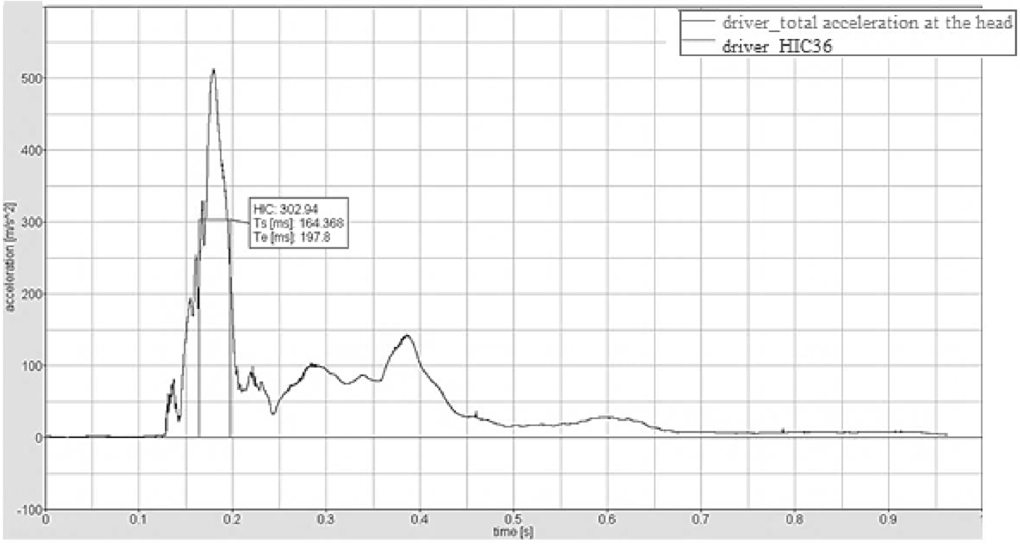

Figure 2: Progress of total acceleration (SAE 1000) at the head of the driver's dummy and injury criteria HIC.

Total instantaneous vehicle deformation was 0.447 m. Values were obtained from a camera recording with estimated accuracy of ± 5%.

2.1 Condition of the vehicle after collision (visual findings)

Fluid leaks: coolant leaked, leakage of a small amount of fuel from damaged fuel line to injection units. Brake fluid, engine and gear oil without leaking.

Wheelbase: unchanged - as measured by total station, a deviation of ± 2 mm from original state.

Wheels: tires undamaged – inflated, discs (metal) undamaged.

Passenger space: airbag on the driver's position was activated. Belt pre-tensioners were activated, it was possible to unwind driver's belt, whereas passenger's belt was blocked. The steering wheel remained without visible deformation; displacement of the steering column has not been documented as the steering wheel did not move towards the interior. The position of seats remained unchanged. There was also a visible deformation of the dashboard, specifically in the area of the glove compartment in front of the passenger, where the switch box is towards driver's knees. Asymmetric gaps occurred in plastic parts of the dashboard. Foot pedals remained non-deformed and functional.

Vehicle body: deformation and damage to the hood, headlights and winkers, bumper, bumper beam, left and right front fender, including arches. There was also an occurrence of recesses at the sill of B-pillar connection and cracks in the lower corners of the windshield. Steering remained functional, but the wheel turning angle was limited.

Engine Compartment: left and right longitudinal beams were deformed in the front. The engine moved backwards and the flexible engine mounts on the right side were damaged. Gearbox suspension was deformed on the left side. Damage of radiator including fan, destruction of plastic parts and injection system suction of engine unit were identified. The engine control unit was released from its holder.

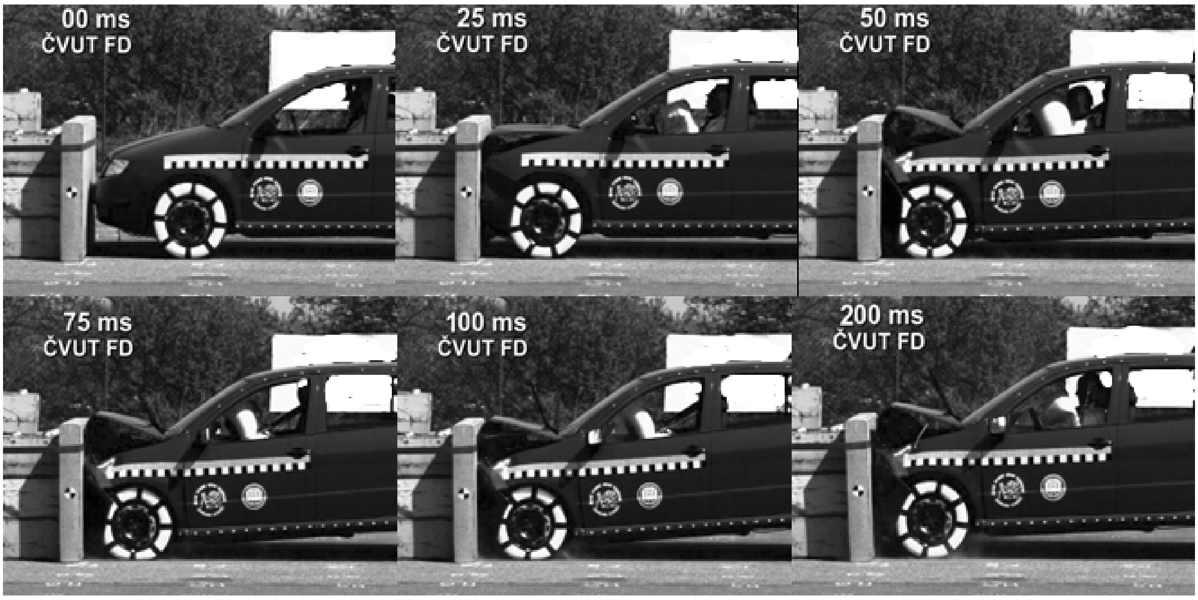

Figure 3: Frontal impact of Škoda Fabia to rigid barrier.

2.2 Partial conclusion

After the evaluation of the test, very good safety at the front seats was found. The space for survival remained unchanged. The calculated head injury criterion was far below the threshold limit of 1000. Probable severity of the injury was at the level of AIS 1 – 2, which means skin scrapes, nose fracture, mild concussion (Viano & Olsen, 2001).

Body strength of Škoda Fabia assessed by deformation in a head-on collision is statistically comparable to cars of a similar concept. The obtained data provided necessary background for restitution analysis using standard mathematical methods.

3 HEAD-ON COLLISION OF A PASSENGER CAR ŠKODA 120 AND NISSAN MAXIMA WITH A BARRIER

During the experiment, there were two separate frontal impacts of moving M_1 category vehicles with an overlap of 40% to unmovable rigid barrier. The vehicles differed in the following properties: weight, body condition, degree of corrosion, structure and concepts. The purpose of the tests was to assess the strength of the vehicle body, while establishing dummy acceleration and prediction of injury was not considered.

Both vehicles were equipped with crash test dummies Manikin, both on the driver and passenger seat. The vehicle Škoda 120, manufactured in 1988, was equipped with three-point seat belts and head restraints. The Nissan Maxima vehicle, manufactured in 1993, was also equipped with three-point seat belts and head restraints and, moreover, a driver side airbag. The corrosion degree of both vehicles corresponded with time of operation under standard conditions.

The same accelerator device and barrier were used as in the previous impact test. The weight of Škoda 120 vehicle with a crew was 875 kg + 72.5 kg + 72.5 kg = 1020 kg, impact velocity 48 km·h^{-1} and the degree of vehicle / barrier overlap was 30 %. The weight of the Nissan Maxima vehicle with a crew was fixed at 1400 kg + 72.5 kg + 72.5 kg = 1545 kg, impact velocity was 43 km·h^{-1} and the degree of vehicle / barrier overlap was 40%.

3.1 Condition of Škoda 120 vehicle after collision

Due to the impact, the front of the car was deformed by 949 mm.

Fluid leaks: Coolant leak from damaged radiator and pipes. Other fluids such as fuel, brake fluid, engine and transmission oil remained without leakage.

Wheelbase: a major shift of front axle - deformation of housing in the vehicle body.

Wheels: tires undamaged - inflated, metal discs undamaged.

Passenger space: blocked unwinding of the seat belt coils and deformed seat belt anchorage points in the body. Large-scale deformation of the left wheel arch and the space for driver's feet (broken by floor). Deformed steering wheel rim as a result of contact with the dummy. Due to the deformation of the partition between the passenger space and the boot (in front) the dashboard frame shifted and subsequently its individual components were twisted. The plastic cover of heating in the space of front passenger's knee was torn after the contact with the dummy. There was also a significant shift in the anchorage of control pedals, pedals themselves were deformed.

Vehicle body: the following parts of the vehicle were deformed and damaged after the impact: the front boot and its suspension, headlights and indicators, front face, bumper, bumper beam, left and right front fender including arches, cracked windshield (partially withdrawn from the frame), left front doors, including rear-view mirror, left sill, breaking of the roof in line of the right A-pillar and left B-pillar, a significant shift of the partition wall between the passenger space and the front boot, change in position and the angle of the grip of the left A-pillar and roof, deformation of front axle, deformation of floor beneath the driver.

Engine Compartment (rear engine): remained without damage.

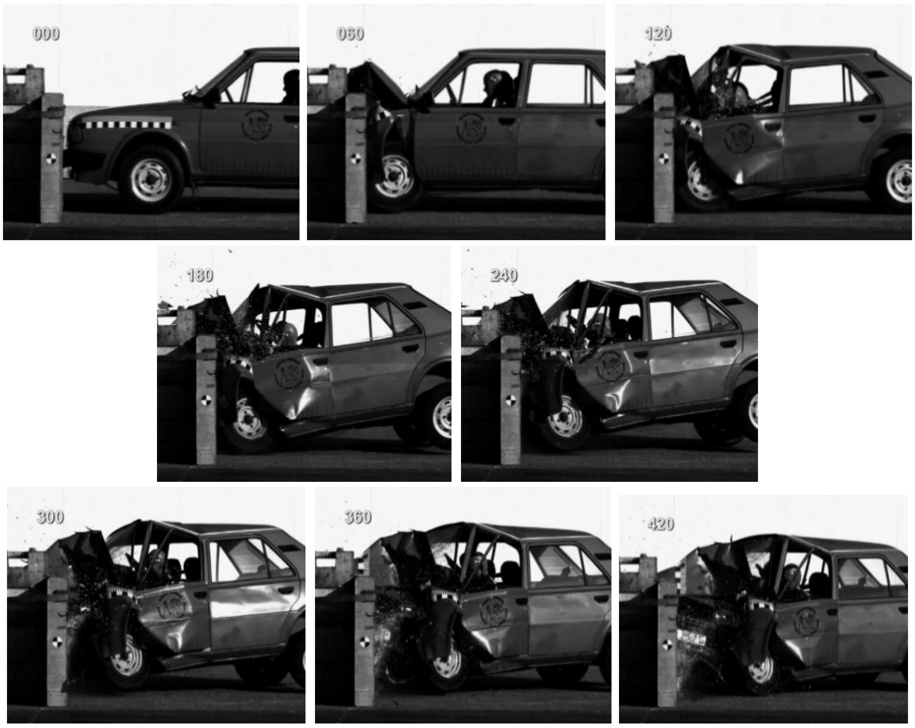

Figure 4: Frontal impact of Škoda 120 with rigid barrier during collision.

3.2 Condition of Nissan Maxima after collision

Figure 5: Frontal impact of Nissan Maxima to rigid barrier after collision.

The front part has been deformed by the impact of 400 mm.

Fluid leaks: Coolant leak from damaged radiator and pipelines. Transmission oil leak. Fuel, brake fluid and engine oil did not leak.

Wheelbase: the right side remained without deformation, the left side was reduced by 25 mm.

Wheels: tires undamaged - inflated, alloy wheels undamaged.

Passenger space: activated seat belt pre-tensioners, locked unwinding of seat belt recoils, activated airbag on the driver's side. The vehicle body of the passenger's space not deformed. Deformation of the cover of the glove compartment on the passenger side, and air vents at the right A-pillar on the dashboard released. The position of pedals remained unchanged and pedals were fully functional.

Vehicle body: the following parts of the vehicle were deformed or damaged after the impact: front bonnet and its suspension, headlights and indicators, left fog light, front face, bumper, bumper reinforcement, front left fender including arches. Further damage was visible at the left front wheel suspension, deformation (indentation) in connection with sheet metal roofs left B-pillar. Steering remained functional.

Engine space: deformed left longitudinal beam and the left wheel arch. Damaged radiator including ventilator. Brake booster, operating cylinder or custom brake line were not damaged.

3.3 Partial conclusion

The objective of the experiment was to evaluate the safety level of tested vehicles. Škoda 120, which was approved according to ECE Regulation 12, does not provide sufficient level of passive safety. The car components collapsed and the survival space during the test was unstable. In addition, the vehicle was not equipped with modern passive safety features such as airbags and seat belt pre-tensioners. The test with Nissan Maxima showed significantly better results than the crash test with Škoda 120. This vehicle was approved by U.S. homologation methodology, which was much stricter than ECE 12. In addition, Nissan Maxima was equipped with effective passive safety components.

Figure 6: Technical condition of vehicle Škoda 120 (left) and Nissan Maxima (right) after collision.

4 HEAD-ON COLLISION OF A PASSENGER CAR RENAULT 5 GTD WITH A BARRIER

A full dynamic passive safety test of a Renault 5 passenger car crash into a fixed barrier was performed to investigate the deformation properties of the given car and dynamics of adult and child dummies. The experiment was carried out on the same test track as the previous tests. It was M_1 category vehicle frontal collision with a 40% overlap to the rigid barrier. The test was supposed to investigate the durability of a body of more than 20-year-old Renault 5 GTD, as well as examine the safety of a crew, which was represented by a dummy Manikin (for the driver) and a P3 dummy (at the rear left side behind the driver), fixed in a child restraint system.

The weight of the vehicle with the crew was 830 kg + 87 kg + 15 kg + 6.6 kg = 938.6 kg, impact velocity was 52.2 km·h^{-1} and the kinetic energy of the object was 98.7 kJ. The same barriers and accelerating equipment were used as in the previous tests.

After the impact, head injury criterion for the dummy Manikin was found at HPC_{15} = 100; HPC_{36} = 136 (Figure 7). Because the driver's dummy Manikin was equipped with a simple uniaxial accelerometer, the head injury criterion is given for reference purposes and only for basic orientation, without any further evaluation of the severity of possible injuries.

The head injury criterion of the dummy P3 in child restraint system was HPC_{15} = 492, HPC_{36} = 612 (Figure 8). It correlates with certain head injury and possible cervical spine damage, which was not observed (Dobbertin et al., 2013).

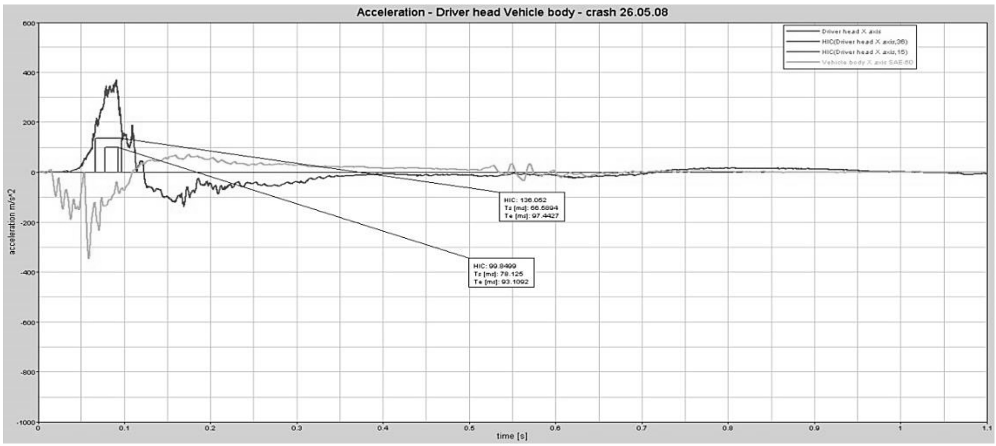

Figure 7: Progress of acceleration (SAE 1000) at the head of the driver's dummy in x direction (dark), head injury criterion HIC and acceleration of the body (SAE 1000) in x direction (light).

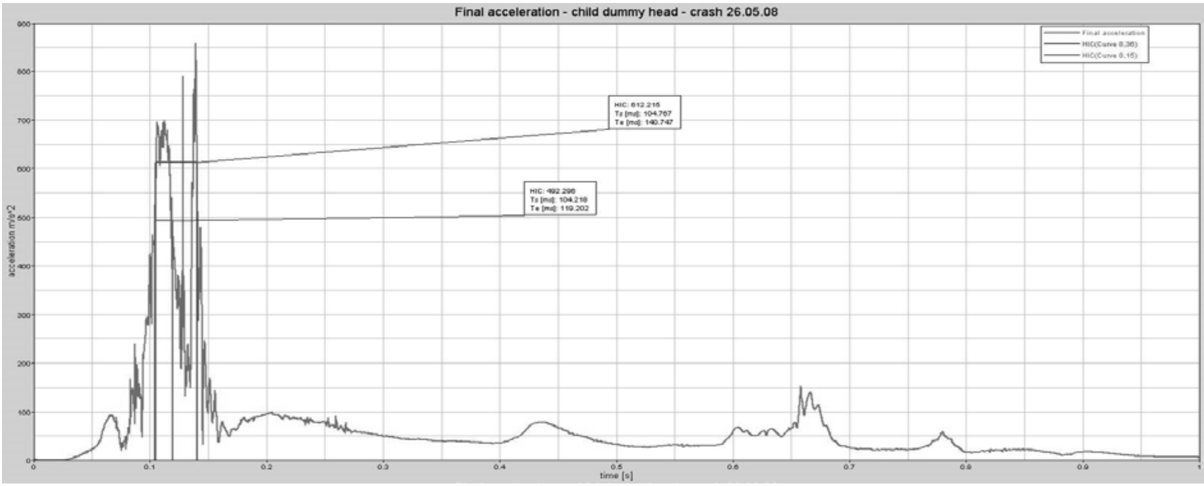

Figure 8: Progress of total acceleration (SAE 1000) in the head of child dummy and head injury criterion HIC.

4.1 Condition of vehicle after collision (visual findings)

Figure 9: Progress of total acceleration (SAE 1000) in the head of child dummy and head injury criterion HIC.

Fluid leaks: most of the fluids were removed before the test, so, during the test, there was a leak only from oil tanks.

Passenger space: driver's seat belt could be unwind from the coil after collision, both seat belts could be freed of anchor buckles without tools. Seat belts of the child restraint system were fully functional. The records from high-speed camera show vertical and horizontal movements of the steering wheel towards driver and the collision of the rim with the head of the driver's dummy. There was also an overall deformation of the dashboard. The control pedals were also deformed and the floor with a wheel arch on the driver's side was deformed towards the driver's foot space.

Body deformation and damage: bonnet, headlights and indicators, front face, bumper, bumper beam, left and right front fender including arches, sills deformation, "B" pillars, front left door and breaking of the roof.

Engine compartment: deformed longitudinal beams (left and right). The engine was pushed back as a result of the damaged elastic engine mount. Furthermore, there was a deformed suspension of the gearbox on the left side and a damaged radiator including ventilator. The vehicle was inoperable after the impact.

4.2 Partial conclusion

The findings from the experiment above allow to reach a conclusion that the protection of the Renault 5 vehicle's crew in a frontal offset crash into a barrier under given conditions is relatively sufficient when taking into account the age of the vehicle. However, questions remain about the real degree of the child injury. The test results of the child restraint systems fixed by conventional seat belts are usually worse than the test results of child restraint systems which are fixed by ISOFIX system.

5 RESULTS AND DISCUSSION

This paper summarizes the experience and knowledge of passive safety of vehicles based on analyses of crash tests carried out the in the past within student projects. The results of the described unique experiments contain a description of passenger cars impacts with a rigid barrier. Specific features are derived from the fact that vehicles of certain age with several years of regular operation were used in realistically simulated real conditions of possible traffic accident scenarios. The majority of standard tests are performed with new vehicles as a part of the homologation process before commissioning. The aim of the described tests was focused on the monitoring of the maximum deceleration of the crash test dummy parts and on the deformation and damage of the car body. Thus, results can be used for the prediction of probable injuries to vehicles crews and for evaluation of technical conditions of damaged vehicles. The basic results prove the fundamental role of legislation in passive safety. Well maintained older vehicles can provide the occupants with sufficient protection level. The realized projects and acquired data are used as important material for student projects and dissertations.

ACKNOWLEDGMENT

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ECE Regulation No 94 Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a frontal collision.

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Technical Note on Methods for Optimal Trajectory Synthesis

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In the existing racing world, race results, or even whole championships, are decided by details in racing packages - race car design specifications, race strategies, optimum car set-ups or drivers' capabilities to adapt to a certain track.

Two main approaches can be applied applied when searching for the weakest points in the racing package:

- Physical experiments (data acquisition systems, wind tunnel measurements);
- Computer aided engineering (e.g., FEM, CFD simulation and optimisation).

Since the computational power was increasing in last decades of the 20th century, engineers' effort was moving from mere experiments to a rational balance between computer aided engineering and the physical experiments. Computer model gives cost effective and easy to interpret results, but cannot reflect the reality completely. It can help to understand the real case, but only the real experiment can verify the results of computer modelling; and, vice versa, the theoretical computation is often used to verify the experimental data.

Hence an optimal trajectory synthesis is defined. The optimal trajectory synthesis (together with optimal velocity profile generation) is a method commonly used in professional racing. It helps to discover the latest tune-up possibilities of the racing package performance. Specifically, the optimal trajectory and the optimal velocity profile are tools to analyse the driver's ability of keeping the race car on its limit. A correlation between the optimal trajectory synthesis and the experimental data obtained from race car telemetry is able to disclose driver's style limits and create recommendations for improvement.

1 STUDY OF APPROACHES

The optimal trajectory synthesis task can be found in different fields - both academic and industrial - and in different branches, e.g. military, aerospace or in robotics. The current study of approaches is focused on dealing with optimal trajectory synthesis issues and necessary methods for vehicles, in both academic field and automotive industry.

1.1 Spline Trajectory and Genetic Algorithms

In Optimization of the Driving Line on a Race Track, Mühlmeier and Müller (2002) present the optimal trajectory synthesis for a Le Mans prototype race car. The vehicle is considered as a single mass point. The dynamic model is based on simple approaches in terms of vehicle traction, vehicle power and aerodynamics. The trajectory is determined using cubic spline curves. The lap time as a cost function is calculated integrating the equation of motion along the trajectory. The optimal velocity profile is based on the iterative determination of the brake points. The optimisation algorithm iteration step consists of changeable cubic spline controlling points P_i and uses the genetic algorithms to generate new population of drive lines. The resulting drive line is in Figure 1. Authors conclude that the optimal drive line significantly depends on the track and the vehicle properties.

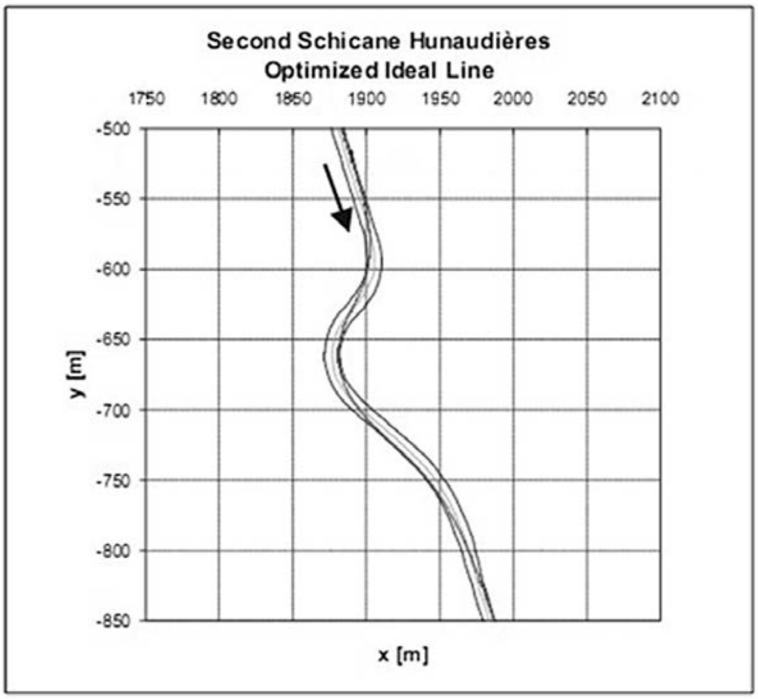

Figure 1: Optimized Ideal Line.

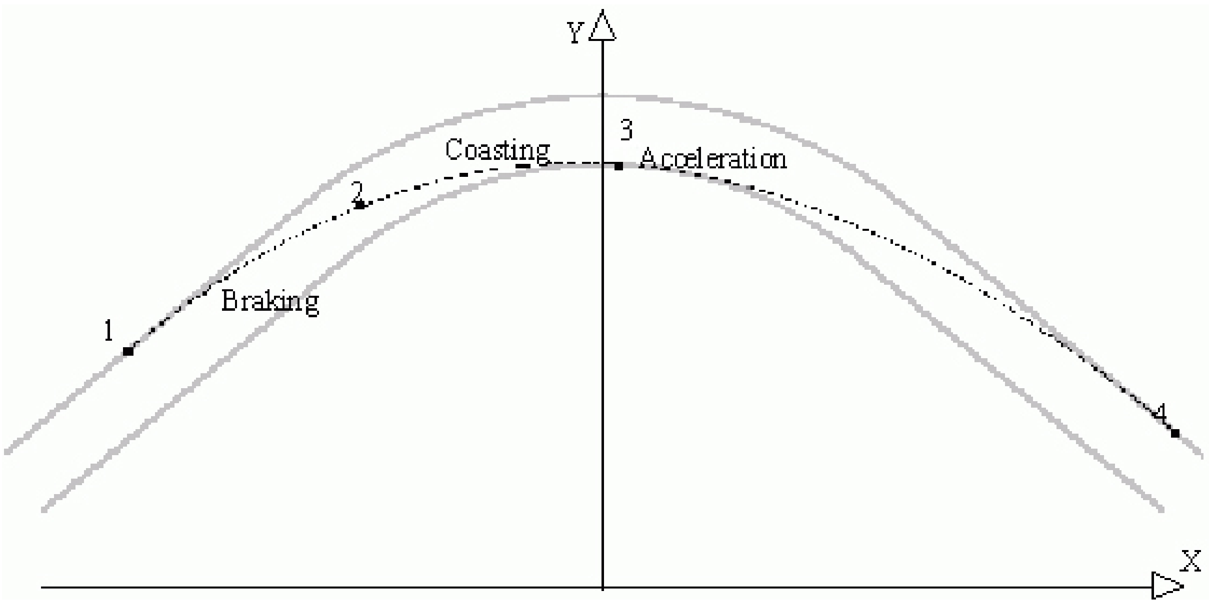

Figure 2: Spline curve trajectory control points (Cambiaghi et al., 1996).

The authors Cambiaghi, D., Gadola, M., Manzo, L., Vetturi, D. (1996) use a similar approach as before, together with the verification of a lap time simulation. The vehicle model is simplified and consists of a non-linear tyre model. The optimisation task includes the determination of 4 important points on the vehicle trajectory described by the cubic spline curve, see Figure 2: turn in point (1), brake release point (2), throttle application point (3) and corner exit (4). The genetic algorithms are used as the optimisation method again.

1.2 Semi-analytical Method for Velocity Profile Generation

In Profile Generation for Given Acceleration Limits, Velenis and Tsiotras (2005) propose a_t semi-analytical method for the optimal velocity profile generation on a given trajectory for a half-car model case. The vehicle is treated as a single mass point with given acceleration capacity, longitudinal force f^{max} and lateral force f_n^{max}, see Figure 3.

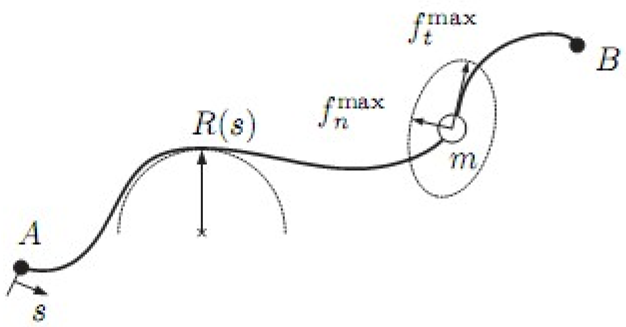

Figure 3: Trajectory for optimal velocity profile generation (Velenis & Tsiotras, 2005).

The optimal velocity profile is searched for on a curve described by partially linear radius function R= R (s), see left part of Figure 4. The search for optimal trajectory starts in finding local minima of the curve radius. In such points, critical velocity vcrit (maximum achievable velocity) is computed. Then the velocity characteristics composed of maximum available braking (before radius local minimum) and maximal available acceleration (after radius local minimum) are designed for each linear part of the curve radius. The minimum of these characteristics in each radius segment determines the optimal velocity profile, see the right part of Figure 4.

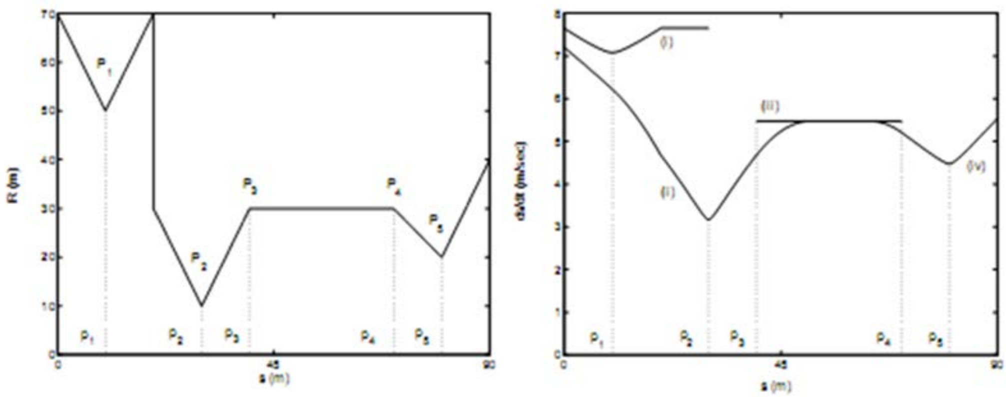

Figure 4: Curvature function (Velenis & Tsiotras, 2005).

2 CONCLUSION

The methods mentioned above show different attitudes to the optimal trajectory synthesis. The basic difference is in the definition: whether the problem is solved indirectly applying the optimisation techniques or directly using the optimal control.

The optimisation approaches evaluate the optimal velocity profile on a given track in each optimisation loop. The advantage of this approach is in the simple description of the mechanical model and therefore the generation of the optimal velocity profile is not exigent of computational power. On the other hand, the optimisation of the trajectory requires high computational power for searching in the set of the allowed curves. The approach described in “A Tool for Lap Time Simulation” is very close to the real driver behaviour when choosing the path and the velocity profile. The optimal control approach is rather different. It deals with the issue in a sophisticated way - it computes the velocity profile directly as a result of an applied optimal control theory approach. The optimal control allows to implement a more precise vehicle model.

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