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GNSS Integrity for Railway Transportation

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ABSTRACT: This article contains an analysis of GNSS (Global Navigation Satellite System) integrity from a viewpoint of railway transportation. The integrity concept of functional EGNOS (European Geostationary Navigation Overlay Service) system is explained in detail and also the integrity mechanism of the future Galileo system is briefly outlined. In order to verify the theoretical conclusions, static measurements by means of EGNOS receiver in a safety mode have been performed. Selected experimental results are discussed.

KEY WORDS: GNSS integrity, railway, EGNOS, DGPS, GPS, Galileo.

1 MOTIVATION

Before a satellite navigation system such as EGNOS or Galileo can be used in railway safety-related applications, it is necessary to perform a risk analysis of the whole railway safety-related system and specify its safety integrity and dependability requirements. It is mandatory to perform the risk analysis according to the railway safety standards (EN 50126, EN 50129, etc.). For this reason, EGNOS dependability attributes as quality measures of one of subsystems must be determined - according to the railway safety concept.

2 DESCRIPTION OF GNSS INTEGRITY AND AVAILABILITY FOR RAILWAY ENVIRONMENT

It is well known that conditions for the application of GNSS in aviation and on railway are very different. This is mainly due to SIS (Signal-In-Space) shadowing by different objects along the railway line or by a landscape profile, and also due to the more demanding requirements for safety and dependability on railway. The total integrity of GNSS positioning can be influenced by errors in a space segment, errors due to SIS propagation effects in the atmosphere, errors due to multipath effects and finally by errors due to potential failures in the user receiver. The error sources with a potential impact on SIS integrity and effects of railway environment are depicted in Fig. 1.

2.1 SIS integrity

This means the integrity of SIS transmitted by satellites. Integrity is a measure of the trust which can be placed in the correctness of the information supplied by the system. Integrity includes the ability of the system to alert the user when the system should not be used for the intended operation. At this time, the system EGNOS has been certified for use in avionic safety critical applications since December 2010 (Safety of Life Service).

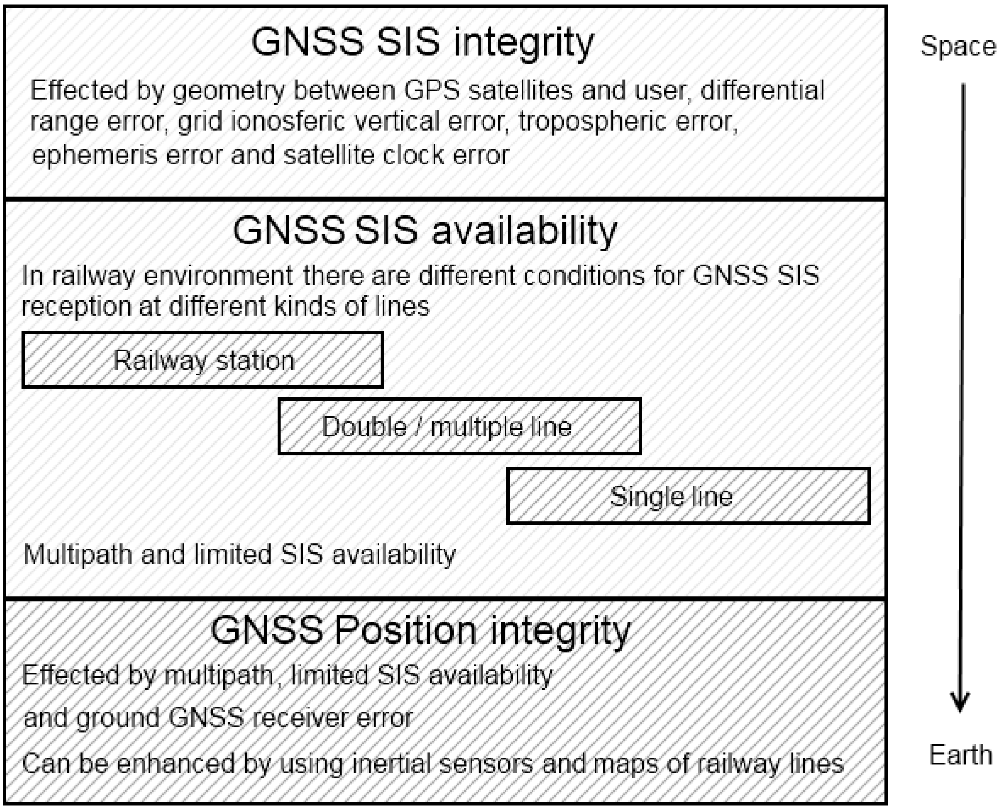

Figure 1: Effects on GNSS integrity and SIS availability.

2.2 SIS availability

SIS availability is affected by different conditions along the railway lines. This part can be divided into three basic subparts:

- single line,
- double or multiple line,
- railway station (many rails).

The conditions for GNSS signal reception are different in each of these cases. The position can be determined only in a 1D domain at a single line. This leads to the use of simpler algorithms for integrity verification. At a single line there are often worse conditions for GNSS signal reception, due to bridges, nearby buildings, trees and forests along the line. The position is determined in a 2D domain to distinguish on which of the two or more parallel lines the train is situated in case of a double or multiple line. There will be significantly better conditions for GNSS signal reception. In the case of a railway station, where there are usually many parallel lines, there are frequently the best conditions for GNSS signal reception. On the other hand, it will be hardest to decide on which of the many parallel lines the train is situated. During the GNSS signal reception on earth ground there is also disturbing by multipath.

2.3 Position integrity

Position integrity is a measure of the trust which can be placed in the correctness of the estimated position. Position integrity is effected by SIS availability and multipath. Position integrity can be improved by adding inertial sensors (INS) such as an odometer, accelerometer, gyroscope and microwave Doppler speedometer. Data from INS can be fused by a Kalman filter and projected to the map of railway lines. It is thereby possible to check the position integrity by means of using maps. The mathematical equations which can be used were presented in [7]. Also autonomous integrity monitoring can be used to increase position integrity; this means that the system compares the estimated positional error (represented by horizontal standard deviation estimated by the receiver) with the current level of the horizontal protection level (HPL) which will be explained further.

3 CURRENT EGNOS INTEGRITY CONCEPT

The EGNOS integrity concept is described in standard DO-229D. The EGNOS system has three satellites which provide information about system integrity. The EGNOS system signal is available throughout the whole of the European territory. The EGNOS signal is partially available even in Asia and Africa, as is depicted in figure 2. The dots in the graph represent ionospheric grid points (points where ionospheric corrections are available). The dots which are marked by red circles represent the territory where signal is theoretically available. This graph was generated by Pegasus software, which is being developed by Eurocontrol for EGNOS and Galileo validation tests.

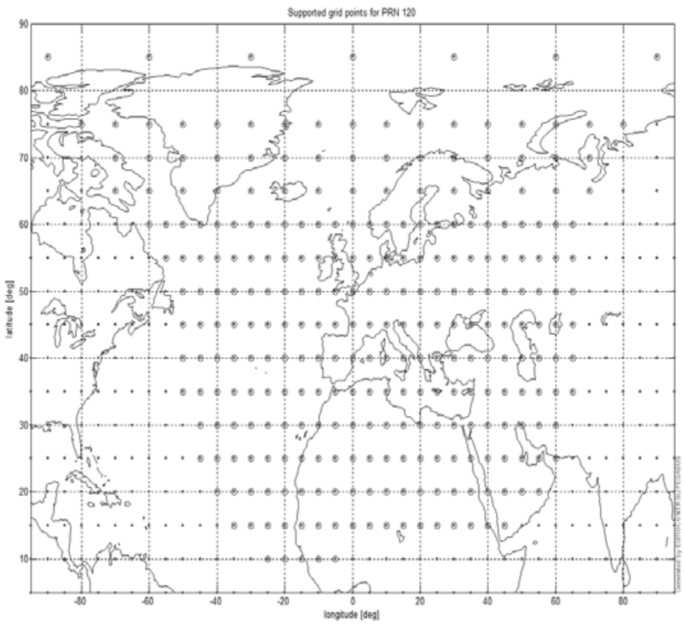

Figure2: Territory where EGNOS SIS is available.

Within the Safety of Life Service there are two navigation modes and their related maximal dangerous missed detection failure rates λ in a fault-free case are as follows:

- Precision Approach (PA): $\lambda_{PA} = 1 \cdot 10^{-7} / 150\ s$ (planes approach)
- Non-Precision Approach (NPA): $\lambda_{NPA} = 0.5 \cdot 10^{-7} / 1\ hour$ (during the plane flight)

In both these modes a safety-related ground receiver computes the horizontal and vertical protection levels (HPL, VPL) from the data obtained in each epoch. For computing protection levels the system uses only data from satellites which are considered to be healthy (fault-free case). The current level of HPL indicates the area (a circle around the current user position) in which the above-mentioned failure rates are fulfilled. From the point of view of railway transportation HPL is important, because we predetermine the position in the horizontal plane [1, 2].

The essential input quantities for HPL computation are: geometry between GPS satellites and the user (elevation El_i and azimuth Az_i of the i^{th} observed satellite), user differential range error (variance $\sigma^2_{i,flt}$), grid ionospheric vertical error (variance $\sigma^2_{i,UIRE}$), tropospheric error (variance $\sigma^2_{i,tropo}$), and the error of airborne receiver (variance $\sigma^2_{i,air}$). The accuracy of these parameters can be reduced by an ephemeris error (the difference between the expected and actual orbital position of a GPS satellite) and a satellite clock error.

HPL equations:

$$HPL = \begin{cases} K_{H,NPA} \cdot d_{major} \\ K_{H,PA} \cdot d_{major} \end{cases}$$

d_{major} is the semi-major axis of error ellipse and is calculated as:

$$d_{major} = \sqrt{\frac{d^2_{east} + d^2_{north}}{2} + \sqrt{\left(\frac{d^2_{east} - d^2_{north}}{2}\right) + d^2_{EN}}}$$

from projection matrix S:

$$S = \begin{bmatrix} d^2_{east} & d_{EN} & d_{EU} & d_{ET} \\ d_{EN} & d^2_{north} & d_{NU} & d_{NT} \\ d_{EU} & d_{NU} & d^2_{U} & d_{UT} \\ d_{ET} & d_{NT} & d_{UT} & d^2_{T} \end{bmatrix} = \left(G^T \cdot W \cdot G\right)^{-1}$$

where:

$d_{east}^2 = \sum_{i=1}^{N} s_{east,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the east axis

$d_{north}^2 = \sum_{i=1}^{N} s_{north,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the north axis

$d_{EN} = \sum_{i=1}^{N} s_{east,i} s_{north,i} \sigma_i^2$ = covariance of model distribution in the east and north axis

$d_U^2 = \sum_{i=1}^{N} s_{u,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the vertical axis

and i^{th} row of the geometry matrix G is defined with elevation El and the azimuth Az of the i^{th} observed satellite as:

$$G_i = \left[-\cos El_i \cdot \sin Az_i \ -\cos El_i \cdot \cos Az_i \ -\sin El_i \ 1\right]$$

Matrix W is modeled under the assumption of uncorrelated measurements characterized by the variance for the observed satellite as follows:

$$\sigma_i^2 = \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,air}^2 + \sigma_{i,tropo}^2$$

A more detailed view on the computation of integrity parameters is available in self standard DO-229D [1].

The key thing is the derivation of constant $K_{H,NPA}$, it was originally chosen to be consistent with certain assumptions on the distribution of position error and on correlation time error. It is related to the probability of missed detection (Pmd) of misleading information (MI), where MI means that horizontal position error (HPE) is larger than HPL.

$$Pmd_{HPL} = \frac{10^{-X}}{n} = \frac{\lambda_{NPA}}{n}$$

Where 10^{-x} is the integrity requirement for this operation (in our case failure rate λ_{NPA}), and n is the number of independent samples per operation.

The number of independent samples per time unit in EGNOS, based on ionospheric corrections, 360 s was adopted as a reasonable assumption to ensure independence [5].

$$Pmd_{HPL} = \lambda_{NPA} \frac{360}{3600} = \frac{\lambda_{NPA}}{10} = \frac{0.5 \cdot 10^{-7}}{10} \approx 5 \cdot 10^{-9} \text{ per sample}$$

K factor scales the variance to a level compatible with the integrity requirement. In the case of HPL, since the protection has to be bi-dimensional, K is determined from a Rayleigh distribution.

Factor K is directly calculated from the knowledge of the cumulative distribution function (cdf) of the relevant statistical law:

$$K_{H\ NPA} = Rayleigh\ cdf^{-1}\left(1 - Pmd_{HPL}\right) = Rayleigh\ cdf^{-1}\left(1 - 5 \cdot 10^{-9}\right) = 6.18$$

So constant $K_{H,NPA}$ was set as 6.18 based on the assumption that the decorrelation time of EGNOS errors is 360 s. However, an analysis of this assumption was done in [3]. It therefore seems that presently this assumption has not been fulfilled by the EGNOS system [1, 3, 4].

4 GALILEO INTEGRITY CONCEPT

In the upcoming satellite navigation system Galileo, all satellites will broadcast integrity information, so it will be available worldwide. However the Galileo integrity mechanism will be different from EGNOS integrity one. Unlike the EGNOS concept, where the system computes horizontal and vertical limits for a given fixed integrity risk, a Galileo receiver will compute integrity risk for the user defining horizontal and vertical level (HAL – horizontal alert limit, VAL – vertical alert limit). Thus a Galileo integrity risk depends on the user specified alarm limit of interest [5]. The relation between both integrity concepts and possibilities of using information from both integrity concepts was analyzed for example in [6].

5 PRACTICAL EXPERIMENTS

The EGNOS system is certificated for use in avionic safety critical applications, but in railway applications it is necessary to analyze the real performance of the system on the earth ground and to validate the fulfillment of EGNOS parameters on earth ground, and so to verify the theoretical properties of the system. Data collection was carried out with the ground safety-related GNSS receiver PolaRx3. Data collection was performed by means of the current available EGNOS system over three days, from 10 to 13 May 2011 in Pardubice in Czech Republic.

Fig. 3 displays the position error (HPE) and HPL. HPL is computed by the receiver according to the above-mentioned equations. In the graph it seems that there are some relatively big jumps in the time behavior of HPL, while the level of HPE is approximately constant.

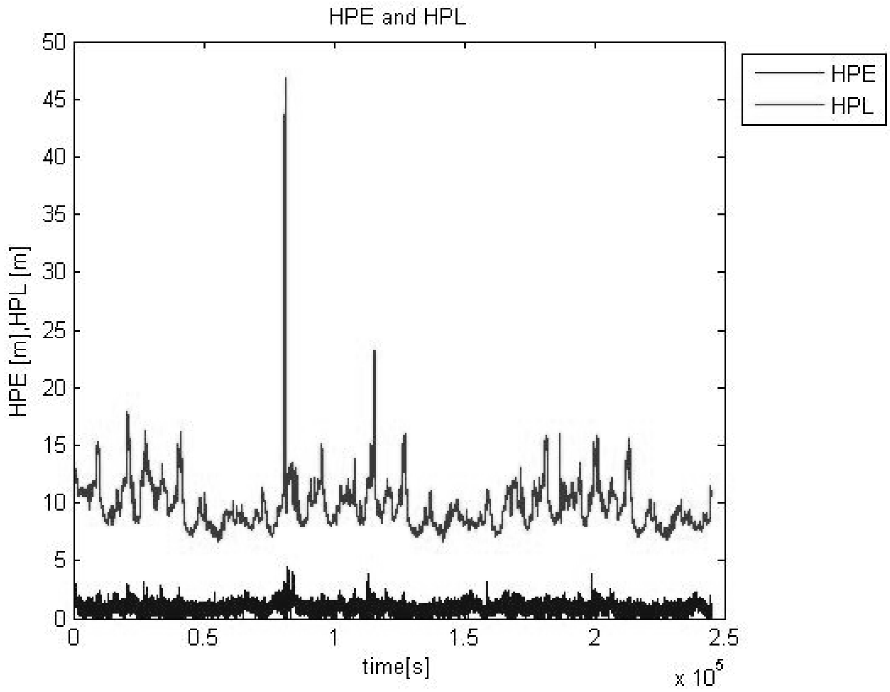

Figure3: Horizontal position error and horizontal protection level.

Fig.4 shows the measured position points (green points) and the true position of the antenna, which is marked by the red triangle. From the graph it seems that the variance in horizontal and vertical direction is approximately 3 meters. The mean value of measured points is marked by the red star. The red circle with the center at the antenna position means circular error probability (CEP). CEP means the radius of a circle which contains 50% of position points. It is computed according to the equation:

$$CEP(50) = 0{,}588(RMS_E + RMS_N)$$

where:

$$RMS_E = \sqrt{\frac{\sum_{i=1}^{N} Delta_{E,i}^2}{N}} \quad RMS_N = \sqrt{\frac{\sum_{i=1}^{N} Delta_{N,i}^2}{N}}$$

$Delta_E$, and $Delta_N$ are deviations between the true and measured position in east and north directions. RMS_E, and RMS_N are corresponding mean square errors in east and north directions.

The radius of the smaller blue circle is the distance root mean squared (dRMS), and the larger blue circle had a radius 2dRMS. It is computed per equations:

$$dRMS = \sqrt{RMS_E^2 + RMS_N^2} \quad 2dRMS = 2 \cdot dRMS$$

Parameters CEP, dRMS, and 2dRMS express 2D accuracy of GNSS receiver.

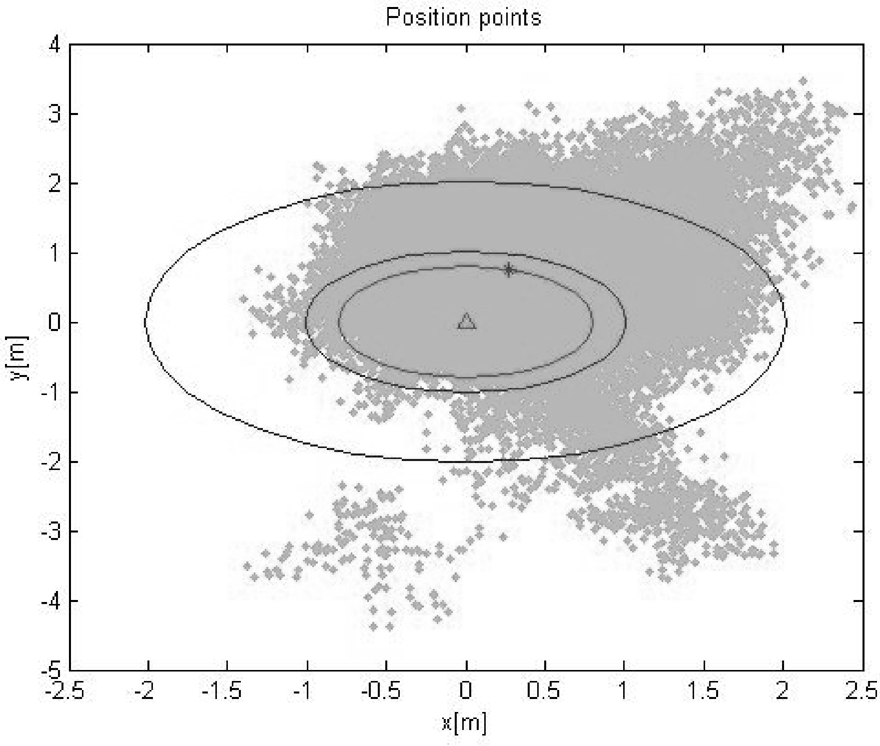

Figure4: Measured position points.

The number of available GPS satellites during data collection was between 5 and 12. The curve of numbers of satellites in time is periodic with the period of approximately 24 hours. Fig. 5 displays the histogram of HPE. It shows that the highest number of occurrences has a value of about 0.8 meters. Fig.6 shows the histogram of HPL. From the graph it is evident that the highest number of occurrences has a value of about 8.3 meters.

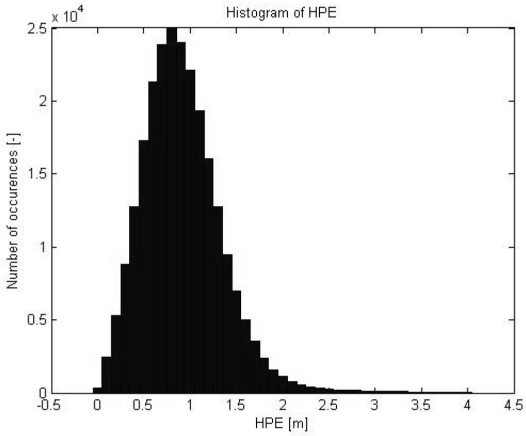

Figure5: Histogram of HPE.

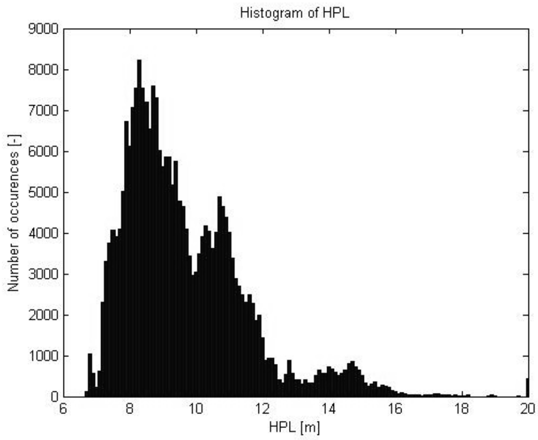

Figure6: Histogram of HPL.

6 CONCLUSION

The integrity mechanism of EGNOS system was analyzed in the article. The complex question of GNSS integrity in a railway environment was described. Equations for the computation of a horizontal protection level were shown. Real measured EGNOS data were presented at the end. According to the real data it seems that the level of HPL is too high at times. There are some unexpected high jumps in HPL time behavior, at times tens of meters. Therefore there are relatively frequent occurrences of false alarms. For the future capability of using EGNOS in safety-related railway applications, it is necessary to determine a methodology for finding the real failure rates of the EGNOS system at the earth ground. It is also necessary to find new methods of processing data from the EGNOS system with accordance to strict railway standards. More detailed analysis of real measured EGNOS data will be done in future work by means of statistical and time series analysis.

Especially the time series analysis of HPE and HPL may be fundamental for finding the real failure rates of the EGNOS system on earth ground.

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Geographical Location of Depopulation Areas in the Czech Republic and its Dependence on Transport Infrastructure
Part II: Case Studies

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ABSTRACT: Location of settlement in important routes of transport was always one of the key factors of its prosperity. However, in the car-oriented world of today the distance factor is not so important for many people and they prefer to live in calm rural areas. Simultaneously, many rural areas in peripheral locations are affected by the emigration of inhabitants and global decay. This study explains how good transport infrastructure should be beneficial for rural areas and how it is in reality in the Czech Republic. The study is part of a larger body of research, based on the component analysis of the localization of depopulation areas in the Czech Republic over the years 1869 – 2010. The role of transport is documented, not only by the localization of transport infrastructure, but also by the duration and orientation of the commute to work. Theories and premises are supported by quantitative analysis in all municipalities in the Czech Republic and also by three in-depth case studies, oriented more on qualitative indicators.

KEY WORDS: transport geography, regional development, depopulation areas, transport infrastructure, mobility.

Completion from last issue.

1 RESULTS OF CASE STUDIES

To improve understanding of transport impact on the process of area depopulation and to find factors which are unidentifiable by quantitative analysis, case studies were executed for three model areas, which, to a maximum extent, focus on factors that influenced in the past the current central structure and that were the causes of depopulation in these areas.

The questionnaire surveys show that the most important factors that make life difficult for inhabitants of depopulated areas are poor road conditions, an insufficient number of public transport services, financially demanding transport, and poor road maintenance in the winter season. These factors were marked in the questionnaires as problematic by more than 30 % of respondents, and even in open questions, most objections targeted these factors. Their importance grows with the smaller the size of a municipality or its part where the respondent lives. Small municipalities and their parts are often only connected by poor quality local roads, which are considerably worse maintained than main roads and which are often very old. Unless the villages are located on major routes, public transport services usually connect small villages less frequently, and the public transport stops are often located only on junctions of main roads and the local roads connecting the villages.

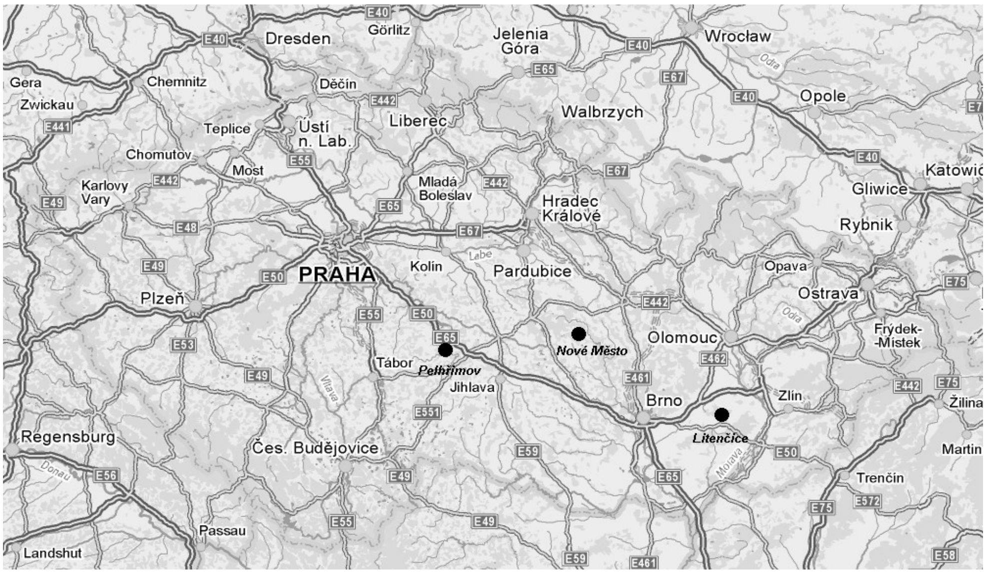

Figure 1: Localization of three model areas where case studies were executed. (www.mapy.cz)

Particularly the problematic funding of public transport in depopulating areas make the inhabitants depend on their passenger cars, since the public transport is unable to meet all their needs. However, the use of passenger cars is a relatively expensive matter for individuals, especially when taking into account the significantly lower average salaries in rural areas than in towns. Consequently, in some cases, improvised forms of car sharing appear in rural areas, and according to the respondents it is possible to decrease costs to an amount even lower than that for public transport.

The aggravating poor road conditions, caused by their age and insufficient maintenance, together with the non-existence of roads to some local parts (particularly groups of solitary houses), is subsequently reflected in the development of the population number in such remote localities. In some extreme cases, small villages were completely abandoned by permanent residents and the existing housing is only used for recreation purposes. However, this process is not irreversible. In some localities where new roads were built and where the aesthetic value of the surrounding countryside is high, the houses became used again for permanent residency. In less attractive areas, particularly agricultural or industrial production areas, this positive trend is scarcely expected, since the abandoned buildings are unused even for recreational purposes and gradually dilapidate.

Interesting results were found within a historical-geographical analysis concerning the issue of transport infrastructure importance for town and village development, when unambiguously the higher quality transport infrastructure has a significantly positive impact on the development opportunities in a region. In model areas some cases were documented where the construction of an important road enhanced the significance of a municipality located on such road, in comparison with other municipalities located away from that road. The most well-known example in the Czech Republic is the decline in importance of the former regional centre town of Chrudim. It resisted the connection to a railway at the expense of the current regional centre town of Pardubice, which is now located on the busiest railway in the Czech Republic. For this reason Pardubice significantly outgrew its competitor. However, the importance of the location on a main road decreases with the size of a municipality. Small villages have only little benefit from such a road, unless they can offer services. The importance of main roads does not decrease in mountainous regions, where the passability of local roads is worse.

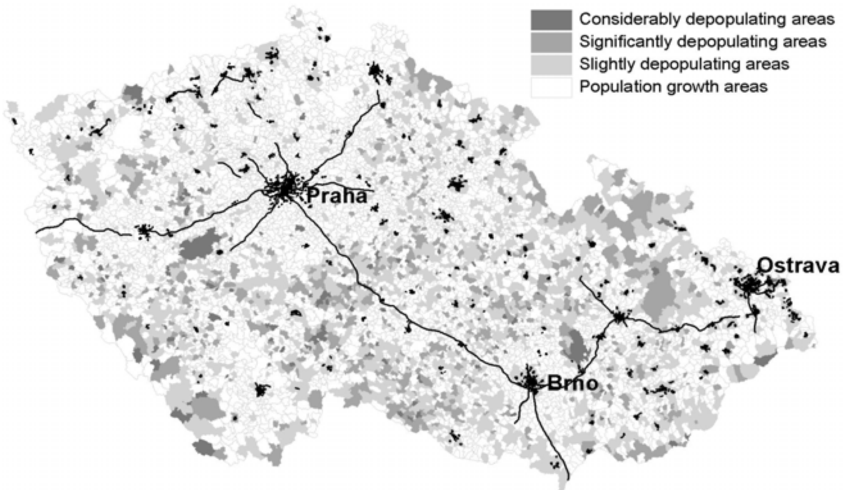

Figure 2: Depopulation areas in the Czech Republic between 2001 and 2010 and their relation to spatial distribution of main roads.

The research of spatial mobility of population shows that localities most affected by depopulation are such localities where respondents spend a minimum of their free time outside their home. If a given municipality is unable to offer facilities for spending free time and if such a municipality is unattractive for residing for a certain reason, there is a gradual migration from such a place to more convenient localities. This unattractiveness of some regions is reflected in spatio-temporal travel behaviour of the population, which in turn leads to a centralization of some larger municipalities where inhabitants of small villages spend more time.

Another important finding is the sensitivity of rural area inhabitants to road fee collection, which was discovered in the model area of Pelhřimov region. Despite the fact that this area is directly adjacent to the artery of the whole Czech Republic, motorway D1, the inhabitants use it rarely for commuting, unless they travel longer distances. A large number of inhabitants of this model area commute to the town of Humpolec, which is located directly on the motorway. Most respondents choose a route along local roads, since, according to their answers, they are unwilling to be charged for using the motorway while there is an option just several minutes longer. Therefore, the inhabitants do not use the potential of the motorway, since it is too expensive for them.

2 DISCUSSION

If the obtained results are compared with other studies dealing with rural area marginalization problems, we find they come to similar conclusions, though through different methods. The definition of problem areas, for example, corresponds very much with the study of Musil and Müller (2006), who analyzed a range of indicators from the economic and social sphere. Nevertheless, the definition on the basis of totally different indicators is, to a large extent, in accordance with the definition of problem areas on the basis of inhabitants' mobility demographic indicator. Many similarities can be analogically found with studies of Havlíček and Chromý (2001), Řehák (2004), Čermák (2005) and others. The time dimension of this hard-to-solve problem can be understood when the current results are compared with older studies, e.g., Musil (1988) or Řehák (1979). The geographical allocation of marginalized areas has not been changed for many decades, which raises the question whether it is caused only by misdealing with the problem, or whether these areas cannot be successfully developed simply due to the current state of society, life style, and technology solutions.

The results of quantitative analysis can be compared with fewer studies than in the previous case, where the most relevant is the study by Marada (2001). He focuses in his study especially on physio-geographic and administrative factors, where from the analyses arise the fact that the agricultural areas, more extensively exploited, are often marginalized areas. By comparison with state administrative boundaries of various levels, Marada comes to the conclusion that most boundaries have no effect on the allocation of marginalized areas, but it is rather the factor of main centre distance that matters. This finding is in accordance with the results of Commuting Out of the District Boundaries Indicator. The fact that the distance of commuting does not have a big effect on depopulation denies meaningfulness to some studies working with this factor (e.g., Řehák, 1979).

The case studies carried out represent rather isolated research in the Czech Republic focused on problematic rural areas, where such specialized sociological research has been carried out here only once, within the study of border areas (Jeřábek, Dokoupil, Havlíček, et al., 2004). The specific focus of the survey on transportation and spatial mobility of inhabitants is unique within Czech specialized literature. No survey of travel behaviour of inhabitants in rural areas had ever been executed here before this study, and so it is very difficult to compare. Some of the rural area problems are more often reflected by media than by specialized literature (e.g., the issue of rural road maintenance), where the professional public rely on hard data rather than on opinion polls. It is apparent that even the data on the number of kilometers of repaired roads can be misleading, as the roads in the worst condition are not repaired at all. On the contrary, the opinions on public transport frequency are always to be taken with a pinch of salt, as demand for it will always be higher than offer. However, the finding of how significantly the financial factor affects the transport behaviour of inhabitants (not using motorways due to cost saving, as the yearly motorway toll costs about 50 EUR) is certainly appropriate to take into account.

3 RECOMMENDATIONS

As mentioned above, the issue of depopulation of some areas is largely caused by their distance from strong centres. The distribution of these centres in time is relatively stable and therefore the distribution of problematic areas is also a long-term matter. The options to reverse the negative trend and development of these areas are rather limited, since the reduction of the spatial distance factor may only be reached with difficulties. The only way to face this factor is virtually just the technological progress together with the development of transport infrastructure in such localities, which allows for lower commuting times to work. However, this strategy faces the fact that populations in rural areas are often less educated and professionally more focused on work in agriculture and industry. Therefore, populations in rural areas are unable to compete with better qualified inhabitants of more advanced regions, thus the necessary transport costs will still be a burden and will keep them demotivated when taking into account the low salaries in not very prosperous industries.

The solution may lie in supporting local centres. In future, local centres may play a more important role in redeveloping depopulated regions, since they may have jobs corresponding with the education and qualifications of inhabitants of these remote areas. In order to ensure the prosperity of these centres and a sufficient number of jobs for their inhabitants, it is essential to provide good quality infrastructure to connect higher level centres. Not only is transport infrastructure to be considered, but also technological infrastructure, while currently it is the high-speed internet which has the highest priority. It is probable that despite strengthening local centres, some smaller villages will still face complete depopulation. However, it is a process which has always been present.

Regarding technology, it is necessary to focus on inexpensive and energetically economical technologies, since the financial factor significantly affects decisions of inhabitants in problematic areas. What may help is more extensive service of some transport modes such as car sharing and car pooling, while it would be necessary to adapt these ideas to specific target groups. Similarly, new approaches and the optimization of public transport organization may improve the mobility of the population of these areas, or reduce the financial factors of commuting to work. Last but not least, it is essential to provide good maintenance of the existing roads, since building new roads is unnecessary if the existing ones are of good quality.

4 CONCLUSION

Fighting the decline of remote rural regions is one of the priorities of the European regional policy. Due to the complex nature of causes of this issue, finding a solution is a difficult task which requires measures in different areas. This article aimed to explain which measures may be applied in the field of transport, in order to limit the negative factors as much as possible, or even reverse them. It has been proven that just the presence of transport infrastructure is insufficient to stimulate regional development; it is crucial to take into account the qualitative conditions of the infrastructure, as well as the parameters which are perceived by its users.

Inhabitants of depopulated areas are characterized by lower education and qualifications and worse paid jobs, which needs to be taken into account when designing measures in order to support their mobility. These measures should be very sensitive to the economical demands of transport. Although building new high-quality roads will not always bring about the intended effects on regional development, it should be said that in general it is beneficial with regard to development. Considering the financial demands when building new infrastructure, local centres need to be found, based on their commuting conditions, and connected to quality infrastructure that would allow for delivering products which are produced there to consumers. The local centres may then become development poles and prevent the depopulation and decline of the existing marginalized regions.

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Estimation of Accident Frequency at Newly-built Roundabouts in the Czech Republic

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ABSTRACT: Roundabouts have become one of the most popular traffic easing and safety improving measures implemented on roads in the Czech Republic. The decision on he ealization of each new roundabout should be based on the knowledge of the expected realization costs and benefits resulting from the future operation, especially changes in traffic and safety performance. This study introduces a negative binomial regression model that enables the quantification of the safety performance of roundabouts in terms of accident frequency in relation to their traffic and geometric characteristics. Model design and estimation of parameters is based on the sample of 90 roundabouts situated on all types of roads in the Czech Republic. Results suggest that the number of accidents depends on the number of lanes on entering arms, vehicle speed in the vicinity of roundabouts, width of traversable apron and, of course, also on the annual average daily traffic. Resulting model structure is in accordance with structures of accident prediction models used in other EU countries and the US. Certain differences can be found in the degree of effects of particular model variables.

KEY WORDS: accident prediction model, roundabout, negative binomial model.

1 INTRODUCTION

Road intersections are one of the most risky parts of road networks; according to iRAP's Road Safety Toolkit (iRAP, 2010), intersection accidents are one of the most common types of accidents worldwide. Retting et al. (1999) report that about 40 % of motor vehicle crashes in the US occur at intersections or are intersection-related. According to Czech Police data, approximately 25 % of all accidents happen at intersections. The underlying level of risk is closely related to the number of conflict points and lower speed of passing vehicles. For that reason, the conversion of level intersections to roundabouts is one of the most popular safety measures. At a roundabout the driver has to travel in one direction around a central island, which minimizes the number of conflict points.

Several studies have shown that the conversion of intersections to roundabouts is associated with substantial reductions in the number of accidents. For example, Schoon & van Minnen (1994) analyzed 181 Dutch intersections and found a 47 % reduction. In the before-and-after study of the conversion of 23 roundabouts in the US, Persaud et al. (2001) identified a 40 % decrease in the number of accidents compared to the previous intersections. Elvik's (2003) meta-analysis of 28 studies of non-US roundabout conversions showed a reduction of fatal accidents by 50 to 70 %. As for the Czech Republic, results of research project BESIDIDO (Pokorný, 2011) showed on the sample of 8 conversions from intersections to roundabouts a reduction in accident frequency of 36 %.

The degree of the safety benefit of roundabouts seems to depend on their geometrical parameters. Results of Elvik's above-mentioned meta-analysis showed that the majority of small roundabouts (a small diameter of the central traffic island) are safer than large roundabouts (a large diameter of the central traffic island). According to TRB's (1998) the synthesis of world-wide roundabout experience, safety benefits seem to be greatest for single-lane roundabouts in rural conditions.

The first roundabouts in the Czech Republic started to appear about 20 years ago. Up to now, there are approximately 3000 roundabouts designed according to various guidelines (V-projekt, s.r.o., 2000, Centrum dopravního výzkumu, v.v.i., 2005, CityPlan spol. s r. o., 2009). None of them, however, deals with the assessment of road safety.

The main objective of the study is to develop a tool that will enable the quantification of safety at roundabouts in the Czech Republic. In the results we will be able to say what geometric or traffic parameters influence the expected number of accidents at roundabouts and what is the degree of the influence. The next section presents data used for the analysis, after that follows a short description of methods applied in accident prediction models and results of the analysis. The paper is concluded by discussion of results.

2 DATA

The study integrates data from several sources – data on road accidents, data on road geometry and data on traffic volumes.

Data on road accidents come from the database of the Police of the Czech Republic. Each record contains information on location, involved parties, type of accident, injuries and property damage. Due to the recent change in the methodology of data collection (since 1st of January, 2009 the property damage limit when an accident has to be reported to police changed from 50 000 CZK to 100 000 CZK), only accident data from years 2009 and 2010 were used in the analysis. During the data preparation phase all incomplete and defective records were removed; only accidents within 100 m radius from the nearest observed roundabout were selected knowing that the maximum radius of roundabouts in the dataset is 73 m; and finally three accidents involving pedestrians were removed due to missing data on pedestrian flows. The resulting road accident dataset consists of 188 records corresponding to 136 accidents without injury, 44 accidents with one slight injury, 5 accidents with two or three slight injuries and 3 accidents with one serious injury. Please note that as property damage-only accidents up to 100 000 CZK (about 4000 EUR) are not being registered, they are not included in the analysis.

The sample of 90 roundabouts was selected in two steps on a non-probability base. First, all roundabouts from the database of the Road and Motorway Directorate of the Czech Republic (RSD) with known traffic flow data on all entering arms and no construction adjustments since 1st of January 2009 (48 out of the total of 286 roundabouts) were selected. In order to correct for the lower number of roundabouts with arms that are not registered in the RSD database, another 42 roundabouts surveyed within the mentioned previous project BESIDIDO were added to the sample. As there is no central database of all roundabouts in the Czech Republic, the additional sample is a result of a detailed search using web map applications.

Data on road and roundabout geometry are from two data sources. Basic data on first, second and third class roads and respective roundabouts were provided by the RSD. Additional data were collected using Google Earth that enables a reasonably precise estimation of road geometry. Details of the data, including key descriptive statistics, are shown in Table 1.

Table 1: Descriptive statistics of geometrical, traffic, and accident data.

Denotation	**Description**	**Variable type [Units]**	**Source ***	**Descriptive statistics** (*mean/SD/min/max* or *counts of binary values*)
AADT	AADT at roundabout	Continuous [veh/year]	RSD/B	17993 / 9873 / 3181 / 52952
URBAN	Urban area	Binary [1=URBAN]	RSD	1: 80; 0: 10
LANES_R	Two-lane roundabout	Binary [1=YES]	GE	1: 6; 0: 84
LANES_A	Arm with two lanes	Binary [1=YES]	GE	1: 5; 0: 85
OUTER_D	Outer diameter	Continuous [m]	GE	42 / 24 / 18 / 146
BYPASS	Bypass present	Binary [1=YES]	GE	1: 15; 0: 75
ANGLE	Max. angle between arms	Continuous [degree]	GE	118 / 25 / 65 / 180
APRON	Traversable apron width	Continuous [m]	GE	2.1 / 1.2 / 0 / 6
ISLAND	Central island diameter	Continuous [m]	GE	24 / 23 / 7 / 120
ARMS	Number of arms	Continuous	GE	4 / 0.6 / 3 / 6
CRASH	Accident frequency	Continuous [acc./2years]	PCR	2.1 / 3.6 / 0 / 22

* RSD – Road and Motorway Directorate of the Czech Republic; B – project BESIDIDO; GE – Google Earth; PCR - Police of the Czech Republic

Data on annual average daily traffic (AADT) on entering the arms of the roundabouts are from two sources. The main source is the National Traffic Census from 2005 that contains data on all first, second and third class roads. Information about the AADT on roads that were not found in the census comes from the internal survey executed within the project BESIDIDO in 2001-2004 (Simonová & Hrubý, 2004). In order to get AADT values corresponding to the year 2010, all values were multiplied by coefficients of annual traffic growth published by Ministry of Transport (2005) for surveys executed in 2000 to 2004 and Road and Motorway Directorate (2005) for data from 2005 National Traffic Census.

3 METHODOLOGY

The aim of the study was to identify geometric and traffic variables that influence the safety of roundabouts and quantify the size of the corresponding effect. This task was solved by means of regression modeling, where the set of geometric and traffic variables was used to estimate the expected value of accident frequency at a given roundabout.

The basic form of the regression model was selected with respect to the characteristics of the response variable (accident frequency) and the standard practice in accident prediction modeling. Data on accident frequency take the form of count data. Literature on count data modeling (Kennedy, 2008) suggests the log-linear Poisson model as an appropriate choice provided that the variance and the expected value of response variable are of about the same value. The model is described as a generalized linear model (GLM), where the response variable Y has a Poisson distribution with parameter λ and takes non-negative integer values y with probability

$$\Pr\{Y = y\} = \frac{e^{-\lambda}\lambda^{y}}{y!}$$

for $\lambda > 0$. It can be shown that

$$E(Y) = \mathrm{var}(Y) = \lambda$$

which means that data suitable for Poisson regression violate the assumption of homoscedasticity required in classical linear regression models.

Finally, the linear combination of explanatory variables $\mathbf{x}$ and unknown parameters β is related to the response variable via log-linear link function

$$\ln(\lambda) = \mathbf{x}\beta$$

that ensures non-negative values of parameter λ and thus non-negative expected values of counts. Exponentiation of the formulae leads to the mean function

$$\lambda = e^{\mathbf{x}\beta}$$

expressing the relation between the linear predictor $\mathbf{x}\beta$ and the expected value of response variable. The vector of model parameters β is estimated using maximum likelihood estimation method. Kmenta (1986) provides more technical details on the topic.

The variance of accident frequency in our data is about 1.7 times higher than the mean, suggesting that the basic assumption of Poisson regression on the equality of these two statistics is violated. Indeed, so called overdispersion appears in most data on accident frequency (Zhang et al., 2007). The problem was solved by a slight change of the model specification, through the introduction of unobserved heterogeneity into the mean function, so that

$$\lambda = e^{(\mathbf{x}\beta+\varepsilon)}$$

where e^{ε} is a gamma distributed error with mean equal to unity and variance α. Integration of ε out of the specification leads to the negative binomial distribution for the number of observed traffic accidents with mean λ and variance $\lambda + \alpha\lambda^2$. Positive values of parameter α correct for overdispersion in data, while values close to zero lead to the above described Poisson model. Parameters α and β of the model were estimated using a maximum likelihood estimation method.

Several negative binomial models with all theoretically plausible combinations of explanatory variables were estimated using available data. All models include an exposure variable in the form of a natural logarithm of AADT and the set of geometric and location specifications. The logarithmic form of AADT ensures zero expected accident frequency in the case of the zero value of AADT. The basic specification of the expected accident frequency takes the form

$$\lambda = AADT^{\beta_1} \cdot e^{\gamma + \sum_{i=2}^{n} \beta_i \cdot x_i}$$

with γ as an intercept. The goodness-of-fit of estimated models was evaluated using Akaike information criterion (AIC). Moreover, a likelihood ratio test was used to test whether the difference between the fit of the two best performing models is significantly high.

The proportion of variability in data explainable by the model (systematic variation) and proportion of systematic variation explained by the model was calculated using Freeman-Tukey goodness-of-fit measure for systematic variation in Poisson regression models. Details on the calculation of Freeman-Tukey R^2 are provided in Freeman and Tukey (1950).

4 RESULTS

The model with the best fit to the data at hand and all coefficients of explanatory variables different from zero at 0.1 significance level is presented in Table 2.

Table 2: Explanatory variables and parameter estimates of the resulting model.

Explanatory variable x_i	*Estimate* β_i	*Std. Error*	*z value*	*Pr (>|z|)*
(Intercept)	-1.91	2.04	-0.94	0.349
AADT	0.39	0.21	1.82	0.068
URBAN	-1.27	0.30	-4.18	< 0.001
APRON	-0.17	0.10	-1.74	0.082
LANES_A	1.66	0.39	4.21	< 0.001
AIC	322.04			
Estimate α	2.12			
Std. Error α	0.83			
2 x Log-Likelihood	-310.04			

The positive value of the dispersion parameter and the respective standard error confirm the overdispersion of the response variable and justifies the use of a negative binomial model.

In accordance to other empirical studies (TRB, 2007, Daniels et al., 2010, 2011) and manuals on road safety at roundabouts (Eenink et al., 2008, Maycock & Summersgill, 1994), AADT, as the exposure variable, is one of the key factors in the accident prediction model with a positive impact on the expected number of traffic accidents.

As for the location and geometric attributes of roundabouts, three variables turned out to be significant – URBAN, APRON and LANES_A. Roundabouts in urban areas appear to be safer than roundabouts in rural areas. It stands to reason that the location itself doesn't improve safety, but rather that URBAN is just a proxy for another unobserved variable, most likely the difference in the average speed of vehicles approaching the roundabout. Roundabouts in urban areas with a speed limit of 50 km/h seem to be safer than roundabouts in rural areas, where the maximum speed in the immediate vicinity may reach up to 90 km/h. Furthermore, roundabouts with two-lane traffic on one of the entering arms (LANES_A) perform significantly worse in terms of road safety than roundabouts with single-lane traffic on all arms. And finally, the width of apron (APRON) has a positive effect on the number of observed accidents.

Figure 1 depicts the relation between the expected accident frequency in the time interval of two years (CRASH) and the continuous variables AADT and APRON in the case of the most common type of roundabouts in the Czech Republic – urban roundabouts with all single-lane entering arms. As can be seen, the accident frequency increases with AADT, while the growing width of apron (APRON) pushes its values down towards zero. Please note that expected annual accident frequency can be calculated by simple multiplication of the variable CRASH by a factor of 0.5.

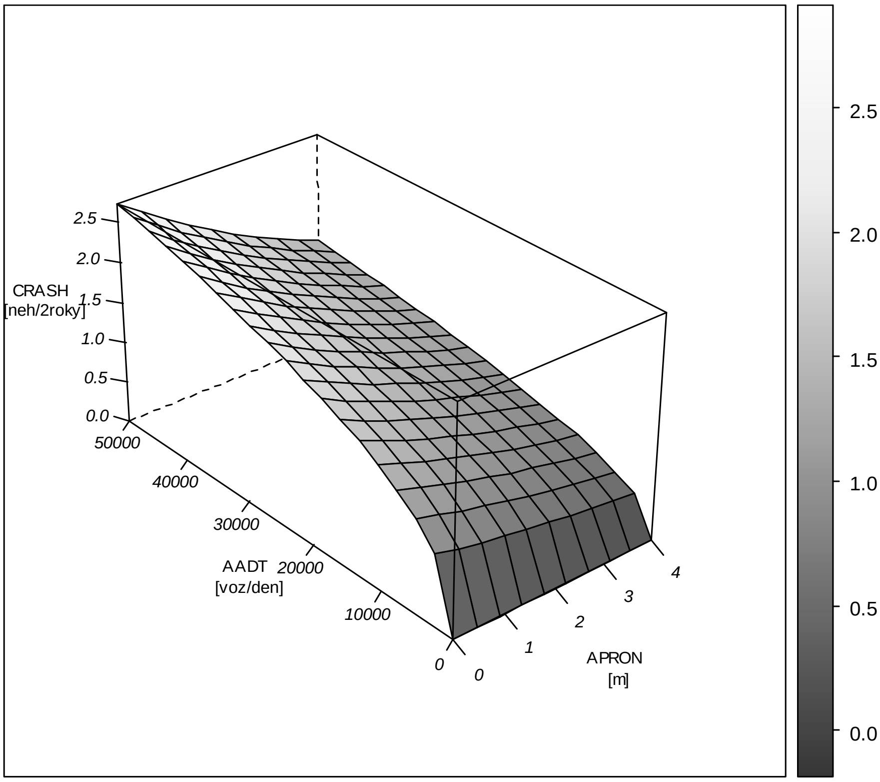

Figure 1: Relation between expected accident frequency, AADT and apron width in the case of urban roundabouts with all single-lane entering arms.

An overview of the resulting specifications of accident prediction models is presented in Table 3. Please note that the model specification for roundabouts in rural areas with two-lane traffic on one of its arms is omitted due to their rarity.

Table 3: Overview of model specifications by location and type of entering arms.

Location	*Two-lane entering traffic*	*Model specification*
Urban	Yes	$CRASH_{1\ year} = 0.11 \cdot AADT^{0.39} \cdot e^{-0.17 \cdot APRON}$
Urban	No	$CRASH_{1\ year} = 0.02 \cdot AADT^{0.39} \cdot e^{-0.17 \cdot APRON}$
Rural	No	$CRASH_{1\ year} = 0.07 \cdot AADT^{0.39} \cdot e^{-0.17 \cdot APRON}$

Value of $CRASH_{1\ year}$ refers to expected number of accidents within one year.

The ability of the model to explain the variation in the data was evaluated using Freeman-Tukey R^2. Results showed that within 66% of “explainable” systematic variation present in the data, 41% is explained by our model.

4 SUMMARY AND DISCUSSION

The aim of the study was to develop accident prediction models suitable for roundabouts in the Czech Republic. The resulting negative binomial regression model involves accident frequency as a response variable and AADT, location, number of traffic lanes, and apron width as explanatory variables. Results showed that in the case of car-only accidents roundabouts in urban areas appear to be safer than roundabouts in rural areas, probably due to different speed limits in the vicinity. The accident frequency is also higher for roundabouts with two-lane approaches. This is consistent with general experience that multi-lane roundabouts provide higher number of conflict points and more space for lane changing and higher speed (TRB, 2010). Finally, the accident frequency seems to decrease with the growing width of the traversable apron. Aprons slow down vehicles passing straight through the junction, which has in result a positive effect on safety. To sum up, the safest roundabouts in the Czech Republic are the urban ones with a single lane and wider apron.

It is worth mentioning that, with respect to the diversity of geometric and traffic characteristics of roundabouts, the sample used in the analysis is admittedly too small for a mechanical generalization of results. Accident prediction models introduced in the study fit the most common types of roundabouts in the Czech Republic relatively well. Descriptive statistics in Table 1 can serve as a clue as to what is meant by the word "common". Application of the prediction model to atypical roundabouts should be done with special caution.

A relatively low percentage of explained systematic variation in data may be attributed to other, non-geometrical attributes related to accident frequency, such as behavior of local drivers, weather conditions, etc. Moreover, available data didn't provide enough details for a separate analysis of safety at roundabouts themselves and safety on adjacent arms. Most accident prediction models for roundabouts account for interaction among entering traffic flow and traffic flow circulating at the junction (Turner, 2000, TRB, 2007). The collection of data that will enable the comparison of specification and parameter estimates of the accident prediction model for roundabouts in the Czech Republic with accident prediction models applied in other countries is thus a challenge for future studies on the topic.

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Comparison of HIC Values during Train-Car Collisions

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ABSTRACT: Accident statistics show that a collision of a train with a car has a significant share of the number of traffic accidents. It also ranks among the most tragic. Three crash tests were made simulating the side impact of a railway vehicle with a car on a level crossing to monitor the biomechanics of possible injury. This study pays particular attention to head injuries. Head acceleration in all three axes was captured on a mannequin during an impact with Skoda Superb and Skoda Favorit vehicles. The most common head injury criterion (HIC) was selected as a quantitative indicator for comparison. It transpired that the contact of the head with an element of the car interior, whether or not the out-of-position occurs during the impact, plays an important role in the severity of head injuries.

KEYWORDS: Biomechanics, head injury criterion, train-car collision, crash test.

1 INTRODUCTION

In developed countries, where the statistics of traffic accidents are processed, a number of organizations (Railway Infrastructure Administration and Railway Inspectorate in the Czech Republic, The Community of European Railway and Infrastructure Companies and European Transport Safety Council in Europe, International Union of Railways worldwide) deal with safety on trains, originating from an attempt to eliminate this kind of accident, or at least minimize them. As stated by the Railway Inspectorate of the Czech Republic, "In recent years, the Rail Safety Inspection has recorded a very high number of fatal accidents at railway crossings. While previously people died in every tenth accident at crossings, it is now every sixth accident." (Drážní inspekce, 2011)

Almost half of all accidents take place at crossings equipped with a light signalling device, which make up only a quarter of the total number of crossings. There were 8,161 crossings under RIA administration on 31st of December 2010, of which 4,453 were secured in the basic way with a cross and 3,708 were secured with various devices of various types and technical levels.) (Drážní inspekce, 2011). The development of accidents at level crossings (including accidents involving pedestrians, cyclists, etc.) is shown in the graph in Fig. 1a. In train collisions with a car 34 people in 240 accidents were killed in 2010, 12 persons in 99 accidents have been killed so far in the period from January to August 2011 (Policie ČR, 2011a, 2011b). In comparison with the total number of traffic accidents - 75,522 in 2010 - only approximately 0.3% of them happen at crossings, but, in addition to the high mortality of such accidents, they cause the highest average financial damage, which is 275,931 CZK for one such accident. The number of accidents at level crossings is available for the European Union, which amounted to 1355 accidents in 2006, 1295 accidents in 2007 and 1124 accidents in 2008 (European Railway Agency, 2010). A comparison with the situation in the United States is shown in Fig. 1b. In most of the cases of collisions of a train with a car there are no injuries or deaths of persons within the train, although rare cases of train derailment due to car have occurred (Leibenluft, 2008).

On the other hand, for the occupants of a car the crash is often fatal, death occuring in more than 10% of all accidents at crossings. Thorson and Lundström (1986) showed that if a car is not wedged under the front of the train locomotive, and instead is pushed to the side, there is a chance of survival. Bjornstig, Bjornstig, and Eriksson (2008) believe that such pushing can be achieved by changing the design of the front of the locomotive in order to prevent fatal collisions.

Figure 1a: Number of accidents at level crossings and deaths caused by them. Emergencies, i.e., all accidents at level crossings (including accidents involving pedestrians, cyclists, etc.) and the number of injured and killed people in the Czech Republic in 2004 to 2010 (The Railway Safety Performance in the European Union, 2010).

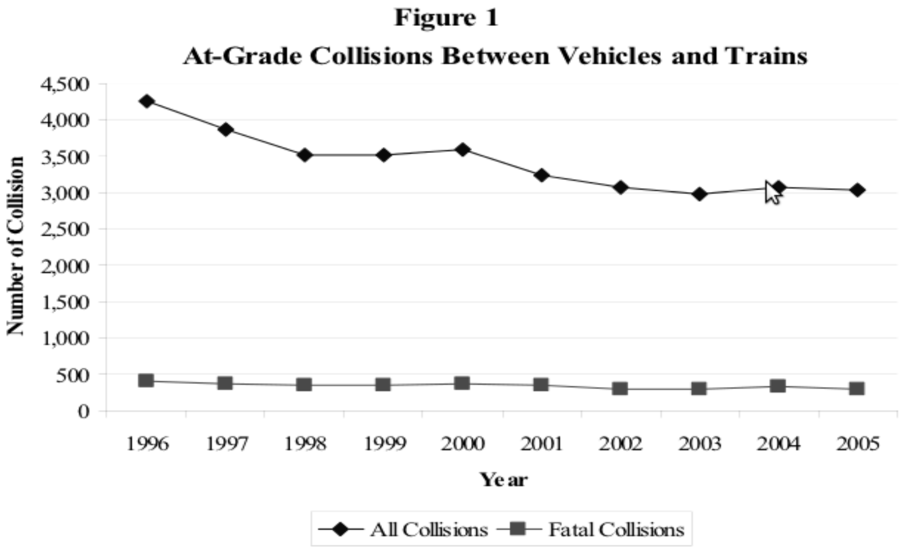

Figure 1b: Number of collisions of vehicles and trains at level crossings and deaths caused by them in the U.S. between 1996 and 2000 (Raub, 2007).

Side impacts in traffic accidents in general (not just train and car) have resulted in 20% - 40% of injuries and deaths (Laberge, Bellavance, Messier, Vézina, & Pichette, 2009). Two-thirds of those concern collisions between two vehicles and one-third of cases concern hitting a stationary object (Chipman, 2004). In three-quarters of fatal collisions the direction of impact angle is between 60 ° and 120 ° and between 240 ° and 300 °, while head injuries were more frequent in the oblique impacts and chest injuries were more frequent in perpendicular impacts (Walz, Niederer, Zollinger, & Renfer, 1977). More than 70% of injuries in passenger cars are to passengers on the impact side (Fildes, Gables, Fitzharris, & Morris, 2000). Use of a seat belt reduces the risk of death to 40% and risk of injury to the spleen to 76% (Reiff, McGwin, & Rue, 2001). According to research involving 4032 accidents (Chipman, 2004) the most common serious injuries in a vehicle hit from the side were those to the neck (31%), head (23%), upper limbs (15%), legs (13%), chest (8%), and abdomen (4%). Iharashi, Ehama, and Sunabashiri (1998) mention that in Japan during side impacts with an AIS rating greater than 3 a passenger is most commonly injured in the head, secondly chest, then in the pelvis and the fourth most common injury is to the abdominal cavity. Additionally, they add that the head and chest injuries combined represent more than 50% of injuries of AIS 3 or higher. AIS - Abbreviated Injury Scale is a system of injury evaluation concerning its fatality. AIS 1 signifies a light injury, AIS 6 signifies a fatal injury.

The issue of side impacts has been thoroughly examined, especially concerning car to car impact or car to solid obstacle impact. Regarding the impact of very heavy objects (e.g., a train) to car, the occupants' injury biomechanics have not been published in detail.

A crash test, characterized as an encounter of a rail vehicle with a car on a level crossing, was performed in the area of CKD Kutna Hora siding in 2010. A rail vehicle - 850 Series motor vehicle - crashed sideways into Skoda Favorit and Skoda Superb cars. The occupants inside the vehicle were represented using a Manikin dummy. It was equipped with accelerometers for the detection of acceleration values for the subsequent analysis of the biomechanics of injury.

2 MATERIAL AND METHODS

The whole crash test was prepared and performed by VÚKV a.s.. Advanced Engineering s.r.o. installed a dummy and took measurements from the passenger car. VÚKV a.s. took measurements from the railway vehicle.

Three crash tests were carried out within a day (average temperature, cloudy, without precipitation). The instigator of the impact was a rail vehicle - motor number 850, 50.5 t in weight. The rail vehicle has two standard plate bumpers in the front, 53.5 cm in front of the body. The subjects of the impact were 2 Skoda Favorit vehicles (green and white) with an operating curb weight of 915 kg, produced from 1988 onwards, and 1 Skoda Superb vehicle of operating curb weight 1530 kg, produced in 2001. All the cars were left-hand drive. The estimated impact speed was 30 km/h for the Skoda Favorit vehicles and 50 km/h for the Skoda Superb vehicle. The cars were at rest, perpendicular to the direction of travel of the rail vehicle and the point of impact was in center of the vehicle, to the left side of Favorit, to the right side of Superb (see Fig. 2).

Figure 2: Detail of impact of the rail vehicle with the Skoda Favorit (left) and the Skoda Superb (right).

The rail vehicle was additionally equipped with a swept-bumper in front of the buffers during the impact with the green Skoda Superb and Favorit (see Fig. 3).

Figure 3: Detail of the front of the railway vehicle for the crash into a green Skoda Favorit and Superb.

On the driver's seat inside the vehicle a Manikin dummy was placed and the seatbelt fastened. The dummy was equipped with a triaxial accelerometer in the head CG, a uniaxial accelerometer for measuring acceleration in the chest and a uniaxial accelerometer for measuring acceleration in the pelvis.

A PULSE Multi-analyzer system of Brüel & Kjær brand type 3560-B with its own power supply, 5 measuring channels and one output channel was used for the measurement. A three-axis accelerometer with a measuring range of 7500 m-2, Brüel & Kjær Triaxial DeltaTrontype 4504 A was mounted on this portable compact unit for measuring the acceleration of the head in X, Y, Z axes and two uniaxial accelerometers, Brüel & KjærDeltaTrontype 4514 – B with a measuring range of 4900 m-2, to measure the acceleration on the chest and pelvis in the Y axis. HyperWorks software package was used to evaluate the measured acceleration, namely the applications HyperView and HyperGraph. Data were filtered according to the EuroNCAP (European New Car Assessment Programme) (EuroNCAP, 2011) methodology after importing.

To assess the severity of injury Head Injury Criterion (HIC) was used. This is defined as:

$$HIC = \left\{ (t_2 - t_1) \left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right)^{2,5} \right\}_{\max}$$

where $a\ (t)$ is the resultant acceleration of the head and t_1 and t_2 are variable initial and final time intervals during which HIC reaches its maximum value.

3 RESULTS

Skoda Favorit – Green

The real impact speed of the rail vehicle during the crash test with the green Favorit was 29.3 km/h. Initial contact was between the plate bumpers and the A and C pillars of the car (Fig. 4). Contact of the rail vehicle body with the car door space followed. No contact between the car and the plow installed on the rail vehicle was registered from an analysis of the video. The dummy was slightly diverted from the point of impact afterwards, shoulder leaning against the side of the passenger seat (Fig. 4).

Figure 4: Detail of primary contact of the rail vehicle with the green Skoda Favorit (left), final position of a dummy after the crash test (right).

Data from the accelerometer (see Fig. 5) was filtered using CFC 1000 filter after importing into the HyperGraph according to the methodology of Euro NCAP. CFC 1000 is characterized by the following parameters: 3 dB limit frequency is 1650 Hz, stop damping is -40 dB and sampling frequency is at least 10 kHz.

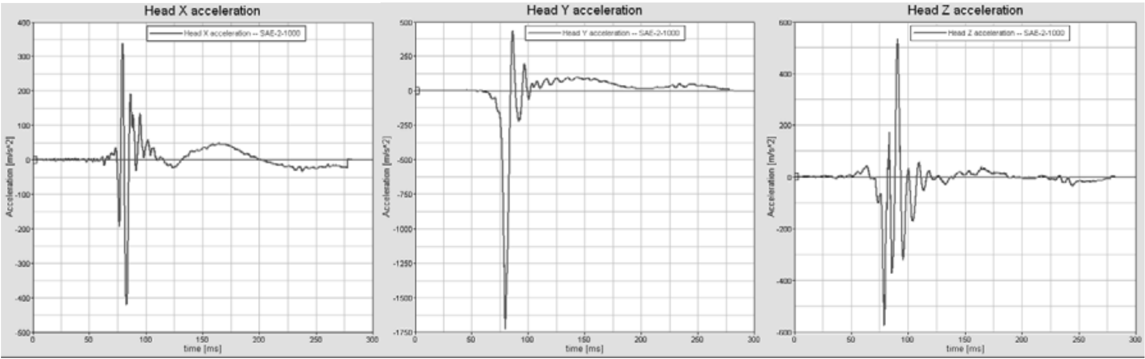

Figure 5: Recording of the accelerometers in X, Y, Z axes (left) after SAE-2-1000 filter.

Furthermore, the values in each axis were converted to a final value of the acceleration of the head (Fig. 6) and the value of HIC = 1131 was calculated.

<u>Skoda Favorit – White</u>

The impact speed in the crash test with the white Favorit was 25.3 km/h. The initial contact was again with the plate bumpers into the A and C pillar of the car. In this case, the addition of the plow was not used. The dummy had been diverted from the point of impact at an angle of approximately 45 degrees, elbow propped on the seat part of the passenger seat. The values of the accelerometer for individual directions were filtered by CFC 1000 and converted to a final value of the acceleration with the calculation of HIC = 469 (Fig. 6).

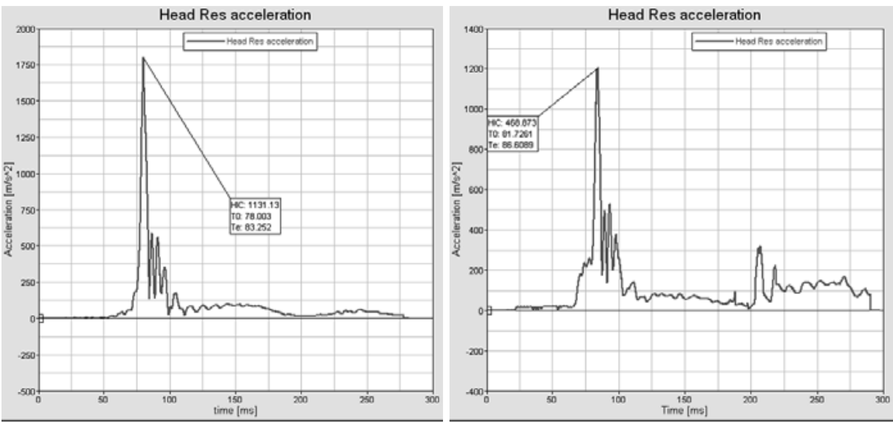

Figure 6: The resulting acceleration of the head for the green Favorit (left) and white Favorit (right).

Skoda Superb

The impact speed for the Superb was 47.5 km/h. The impact was directed onto the passenger side, one plate of the bumper to the A-pillar and the second into the glass space above the luggage compartment before the C-pillar. The rail vehicle was equipped with an additional plow and the contact of the plow with the vehicle body was clearly visible (see Fig. 7). The values of the accelerometer were filtered by CFC 1000, converted to the final value and value of HIC = 17,700 was calculated (Fig. 7).

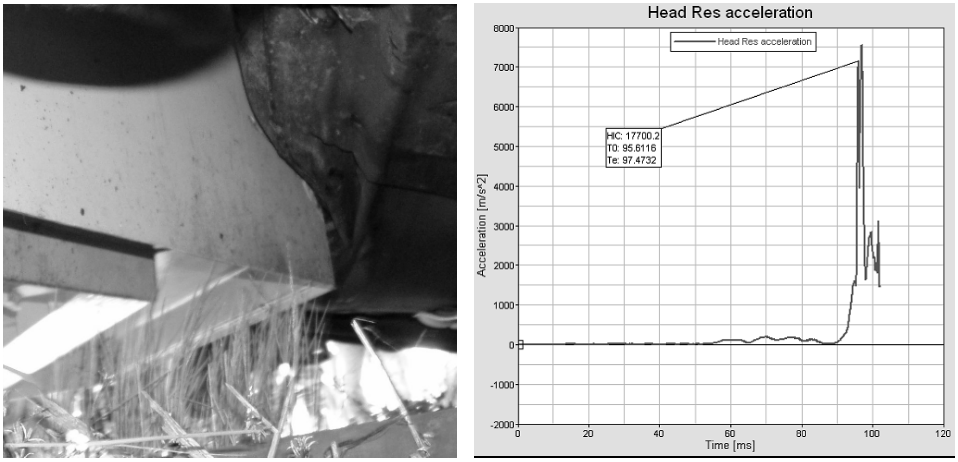

Figure 7: Detail of the rail vehicle plow contact with the car threshold (left) and the resulting acceleration of the head for Superb (right).

4 DISCUSSION

Cars are more usually equipped with airbags these days. According to McGwin, Metzger, and Rue (2004), passengers sitting on the affected side in vehicles equipped with side curtain airbags are at a 75% lower risk of head injuries. Side chest protection reduces the risk of injury to this body part by 68% (McGwin et al., 2004). McCartt and Kyrychenko (2007) found that side airbags that usually combine head protection with chest protection reduce the risk of death of a car driver by 37%. On the other hand, side airbags can be dangerous as well. One study (McGwin et al., 2004) found a higher relative risk (Relative Risk is defined as a ratio between event observation probability in the affected (with airbags) and unaffected (without airbags) group.) of medium (AIS ≥ 2, RR = 2.75) and middle (AIS ≥ 3, RR = 2.45) upper limbs injuries among cars with side airbags. In the crash tests carried out no airbags were used.

The dominant mechanism of injury occurs immediately after impact, when the vehicle or dummy's head is being accelerated by the force of the railway vehicle acting on the car that is standing still, and then the head impacting with the interior elements. After the initial increase and decrease in acceleration stays the acceleration value at a physiological level to a full stop.

According to the results of the accelerometers in each axis of the Skoda Favorit we can assume that there was no "hard" contact between the interior element and head of the dummy when out of position. The head hit the B-pillar of the vehicle (see Fig. 8). Due to the identical configuration of impact the size of HIC can be compared. The impact with the green Favorit was not affected by the rail vehicle plow. For the green Favorit the impact speed was 29.3 km/h and HIC = 1131, for the white Favorit the speed was 25.3 km/h and HIC = 469.

The increase in impact speed by 4 km/h caused a significant increase in HIC, over 2.4 times as much, and the limit value HIC = 1000 was therefore exceeded.

Figure 8: Contact of the head with the B-pillar, green Favorit, 75ms time from initial contact (left) and head contact with the B-pillar, white Favorit, time 85 ms from the initial contact (right).

For the Skoda Superb car the crash test came out negative. It can not be compared directly with the Favorit vehicles, because the impact speed was 47.5 km/h, i.e., 40% higher, but the HIC = 17700 greatly exceeded the limit value of 1000. This high value was caused by a "hard" contact with the interior element in an out-of-position during impact. Although the impact was with the side opposite that of the driver, restraint systems had not kept the dummy in a proper position and the head probably hit the inner side panel of right front door (see Fig. 9).

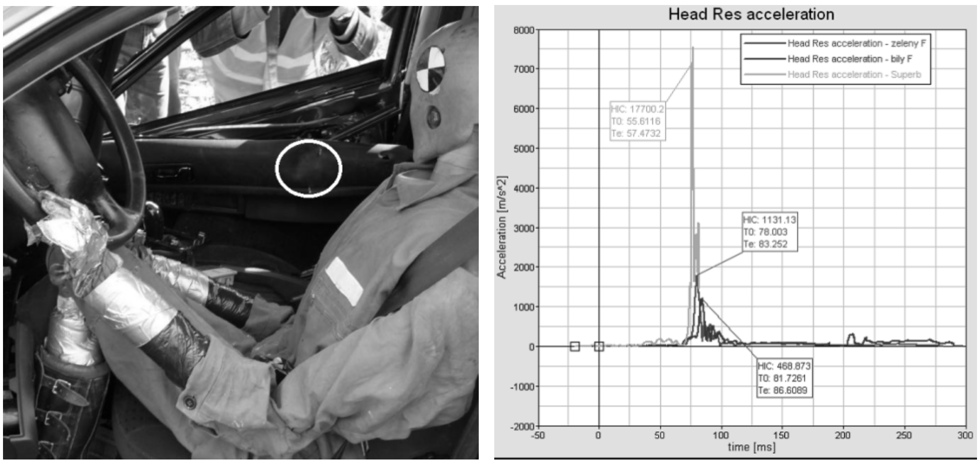

Figure 9: Probable point of contact of the head with door panel (left), and a comparison of the resulting accelerations (right).

5 CONCLUSION

The severity of injuries in the crash of a train with a car is obvious. Side impact with such a heavy object is destructive. During side impact on the driver's side there is often contact of the driver's head with the B-pillar. The severity of the injury is then dependent on the speed of the impact. In crash tests with the Favorit cars it has been shown that with an increasing impact velocity the HIC also sharply increases. The situation could be positively affected by the use of side and curtain airbags, which significantly reduce the impact strength. During the impact with the Superb on the passenger side there was probably the out-of-position and therefore a very high HIC. This situation would again be improved with side airbags, even if they were not tested in this particular situation. A negative effect can be also expected, due to the delayed contact of the head with the airbag (due to the distance to the right side of the car). For this reason car manufacturers are trying to have occupants remain in the in-position during an accident.

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Whiplash Injury and Head Injury Criterion during Deceleration

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ABSTRACT: Cervical spine injuries have become an urgent problem in modern society. Regardless of social status or background, the high rate of neck injuries is a serious healthcare issue worldwide. The cervical spine injury is mainly caused by external impact and is termed as whiplash injury. In addition, the head also performs a whiplash movement during rapid deceleration. The aim of this study is to monitor and describe physically the natural response of the head to rapid deceleration. The methodology of using an impact simulator was adopted for simulating a load which is applied to passengers wearing a seat belt in a head-on collision of a car at the speed of 30 km/h. Furthermore, a series of comparative tests of two versions (impact with and without a blindfold) were conducted to determine the influence of vision and consciousness on risk and the seriousness of trauma and the results were compared with measurements on a dummy.

KEYWORDS: Biomechanics, head injury, neck injury, whiplash, impact, deceleration.

1 INTRODUCTION

Scientists have been trying to reveal the mechanisms of acute neck injury and invent new treatment procedures for more than 50 years. The exercise regimes and general advice are considered to be the most effective treatment (McKinney, 1989), The implementation of prevention strategies into the automotive safety elements plays an important role. The mechanism of the cervical spine injury may occur during everyday activity (sport, etc.), however, it is mainly caused by a crash of two or more vehicles. The most common situation when neck injury occurs is a rear-end collision and almost one third of all neck injuries are diagnosed after a head-on collision (Kullgren, Krafft, Nygren, & Tingvall, 2000). Approximately 65 % of all cervical spine trauma are sustained at low speeds (Castro et al., 1997).

The injury which is caused by a rapid, unexpected head movement due to external impact is called "whiplash injury" (Fig. 1). The injury originates from the principle that the head, or the neck especially, is sharply flexed or extended and the movement is suddenly followed by a massive rebound in the opposite direction. The most common cause of whiplash injury is a traffic accident (head-on, rear-end, and side collision). Not only do drivers face the risk of whiplash injury, but also all other passengers. Whiplash describes a range of signs and symptoms following the injury that often progress to chronic pain which can be felt for months or even years.

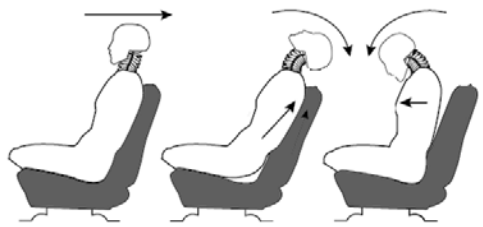

Figure 1: A demonstration of whiplash injury caused by the sudden motion of the head through an unexpected impact.

Hyperflexion of the neck resulting from car accidents is a serious health problem which can give rise to medical and economical complications (Spitzer et al., 1995). In 1969, a head restraint was integrated into the seat as an automotive safety element which limits or avoids extensive movements of the neck, thus preventing cervical spine injuries (Ruedmann, 1969).

The current papers have also discussed the possible mechanisms of cervical spine injuries. The model obtained by measuring pigs by (Svensson, Lovsund, Haland, & Larsson, 1993) proved that intracranial pressure massively increased after a sudden and powerful rear-end impact. The increase led directly to the degeneration of neurons. Other studies show cases where the ligaments of the cervical spinal region were damaged (Obelieniene, Shrader, Bovim, Misericiene, & Sand, 1999; Panjabi, 1998). In addition, damage of the cervical joints is considered to be another mechanism originating from external loading (Panjabi, 1998; Yoganandan, Pintar, & Kleinberger, 1999). An extensive number of studies have analyzed rear-end collision situations. This effort was driven by the general belief that cervical spinal injuries happen during a rear-end collision. Recent studies have suggested that a significant number of cervical spinal injuries occur after a head-on collision (Kullgren et al., 2000; Yoganandan et al., 1999). Furthermore, the muscles may play a pivotal role in the occurrence of cervical spinal injuries. Kumar, Narayan, and Amell (2002) believe that the muscles in the cervical spine area are mostly damaged by a rear-end impact at low speeds. Numerous experiments have been carried out, and dummies were chosen to be the first tested objects. Those studies were limited because no data of the muscle activity and neuromuscular responses were collected. Extensive development was achieved thanks to the study on the medical research cadavers, where obvious muscular and vertebral injures were classified. Active research activities on human beings started in 1955 (Severy, Mathewson, & Bechtol, 1955). As the tests were executed at a speed of 50km/h and micro traumas and permanent injuries occurred, ethical committees in many countries soon set the maximum allowed speed for experiments at 36km/h. It is crucial to realize that, according to unpublished studies, the cause of the acute syndrome as a result of cervical spine injuries lies at low speeds. Moreover, the injury-causing speed does not frequently exceed the speed of 36km/h.

Considering head injuries that occur during rapid deceleration, at low speed there is no direct contact between the head and a solid obstacle (car interior), thus no head injuries are listed. There are two major mechanical causes of the various mechanisms leading to head injuries. One is a direct impact involving a collision of the head with another solid object at an appreciable velocity, and the other is a non-contact impact involving a sudden head motion without direct contact with another solid object (Goldsmith, 1972). The research on the direct contact impact of the head has been led by many researchers. Kenner and Goldsmith (1973) investigated experimentally the problem of a striker impacting on a simple model of the human head. Ruan, Khalil, and King (1994) studied the impact response of the human head using a 3D finite element analysis. Willinger, Kang, and Diaw

(1999) simulated anatomical details, including the skull, falx, tentorium, subarachnoid space, cerebral hemisphere, and brain.

This study aims to reveal the issue of non-contact impacts. The data were obtained from accelerometers which had been fixed on human participants' heads, as well as on the dummies' heads. The head injury criterion was calculated (the 3ms criterion), and the influence of the impact expectancy on the results was stated.

2 MATERIAL AND METHODS

The experiment was run using eight participants who were measured during impact at the simulator. The head acceleration in three axes and the neck muscle activity (EMG) were scanned. Firstly, each participant underwent the impact blindfolded and then again without a blindfold. The values for the head acceleration were obtained through accelerometers fixed on the participants' forehead; furthermore, the acceleration on the impact desk was measured. The information from the left and right m. sternoleidomastoideus and from the left and right m. trapezius was scanned by using an EMG. The whole setting of the impact was additionally monitored by Qualysis and a digital video camera which enabled slow motion recording.

The HIC (Head Injury Criterion) and 3ms criterion were employed to compare the seriousness of the head injury. This criterion is applicable not only for the head injury. The limiting value is 80g and this means that acceleration higher than 80g must not last over 3 ms.

The head Injury Criterion (HIC) is defined as:

$$HIC = \left\{ (t_2 - t_1) \left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)dt \right)^{2,5} \right\}_{max}$$

where *a (t)* is the resultant acceleration of the head and t_1 and t_2 are variable initial and final time intervals during which HIC reaches its maximum value. Head injury criterion HIC use is based on the proposal of the National Highway Traffic Safety Administration (NHTSA), 1972 (Marjoux, Baumgartner, Deck, & Willinger, 2008). For the effects of direct impact it has been demonstrated that HIC is an acceptable discriminator between severe and less severe injuries (Tarriere, 1981). It also correlates with the risk of fractures of the skull. Determination of time interval appears to be an important parameter for calculating the HIC value. According to regulation EHK 94 (First, 2008) the threshold is then determined as HIC = 1000 and acceleration that is greater than 80 g for no longer than 3 ms. HIC_{36} was designed to protect the head against injuries, such as fractures of the skull, with a longer exposure when there is no contact with the hard parts of the interior.

The software package HyperWorks (application HyperView and HyperGraph) was used for evaluating the measured data. The data were filtered after importing according to the EuroNCAP methodology (EuroNCAP, 2011).

The experiment plan description: In this study, a model of the experiment and methodological study was used. The keystone of the experiment was a practical measurement framework. The point of the methodological study was to summarize possible neck injuries and compare the differences between the real head and the dummy; furthermore, it was to consider the influence of the blindfold on the seriousness of head injuries.

Test group: The dummy Manikin and eight participants of middle age (1-6 were men, and 7-8 were women) were tested. The participants were healthy and had never suffered from pain in the cervical spine.

The measurement of variables and used instruments: The biomechanical response of the participants wearing a seat belt to the impact was measured. A simulator was borrowed from the BESIP Team, for the Ministry of Transport provides the agency EuroNet.CZ, spol. s.r.o. The simulator imitates rapid deceleration.

3 RESULTS

The design of the experiment is shown in Fig. 2. Each participant was placed in the seat and a 3-point seat belt was fastened during the sled impact test. The first two measurements were taken on the dummy, followed by two measurements on each participant. Firstly, the experiment was conducted with blindfolded participants, and secondly, with full vision ability. According to the video analysis, the impacts at such low speeds do not induce the whiplash head movements.

Figure 2: The experimental video record, left - the dummy during impact, middle – a participant before impact, right – a participant during impact.

The data from the accelerometers were imported into the software HyperGraph and filtered according to the method of Euro NCAP – filter CFC 1000. CFC 1000 is characterized by the following parameters: 3 dB limit frequency is 1650 Hz, stop damping is -40 dB, and sampling frequency is at least 10 kHz.

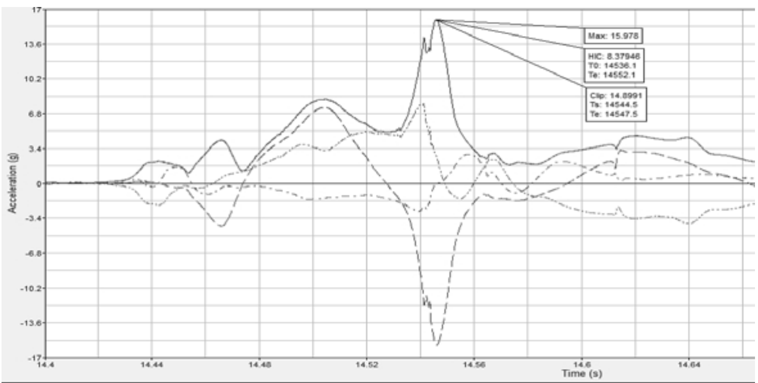

Figure 3: The measured values of the head acceleration in three axes x, y, and z and the resultant acceleration.

The values of the recorded accelerations in three axes were converted to the resultant acceleration of the head (Fig. 3) and the values of the HIC, 3ms criterion, and the maximum acceleration were computed. At the same time, acceleration of the simulator was measured to compare it with the magnitude of individual impacts.

The summarized results are listed in the tables below. For the participants see Table 1 and for the dummy see Table 2.

Table 1: The measured results for the participants (AV = Average, SD = Standard Deviation, X = failed measurement).

	Max. head acceleration (g)		HIC 36		3 ms criterion (g)		Simulator acceleration (g)	
	Without eyes	With eyes	Without eyes	With eyes	Without eyes	With eyes	Without eyes	With eyes
Person 1	10,3	7,7	5,1	3,1	10,0	7,6	29,1	29,3
Person 2	16,0	10,0	8,4	4,9	14,9	9,6	26,3	24,0
Person 3	14,1	7,0	7,0	2,6	13,5	6,8	26,8	26,4
Person 4	8,2	5,8	2,5	2,5	7,7	5,7	27,5	28,4
Person 5	13,7	14,7	7,1	11,4	12,3	13,2	X	X
Person 6	9,6	6,0	3,7	2,1	9,2	5,8	X	X
Person 7	12,9	7,6	6,3	3,5	12,3	7,3	X	X
Person 8	12,0	6,6	5,7	2,0	11,8	6,5	X	X
AV	**12,1**	**8,2**	**5,7**	**4,0**	**11,5**	**7,8**	**27,4**	**27,0**
SD	**2,4**	**2,8**	**1,8**	**2,9**	**2,2**	**2,3**	**1,1**	**2,1**
T-test	**0,004**		**0,129**		**0,004**		**0,563**	
	p<0,05		p>0,05		p<0,05		p>0,05	

Table 2: The measured results for the dummy (AV = Average, SD = Standard Deviation).

	Max. head acceleration (m/s/s)	HIC 36	3 ms criterion (m/s/s)	Simulator acceleration (m/s/s)
Dummy 1	20,0	17,8	17,5	28,7
Dummy 2	21,9	22,2	19,5	31,6
AV	**20,9**	**20,0**	**18,5**	**30,2**
SD	**1,0**	**2,2**	**1,0**	**1,5**

4 DISCUSSION

According to the results from the accelerometer located on the simulator the magnitudes of the impacts were equal (mean 25.2g) for all the tests. In addition, the linear regression approach proved there was no relationship between the magnitudes of the accelerations on the simulator and the maximum values of acceleration measured on the head, thus the matched tests (with and without a blindfold) were compared. The statistics show a positive relation between the blindfold and the maximum head acceleration (the head acceleration is higher in the second test while wearing a blindfold). The mean decrease of the maximum value between the two tests was 3.9g (38.3 m/s^2), which is equal to 32 %. On the other hand the significant effect (p value .05) on the HIC_{36} was not evidenced in the tests; however, the HIC_{36} was lowered by 1.7 (29 %) while wearing a blindfold. The 3ms criterion reached lower values (decreased by 3.7g – 32 %) when the test was completed with full vision ability.

It is important to state that the measurements on the dummy showed higher values for all the injury criteria than on the participants. The maximum value of the dummy's head acceleration was greater (by 106 %) than that of the human head; moreover, the HIC_{36} was higher by 312 % and the 3ms criterion by 92%.

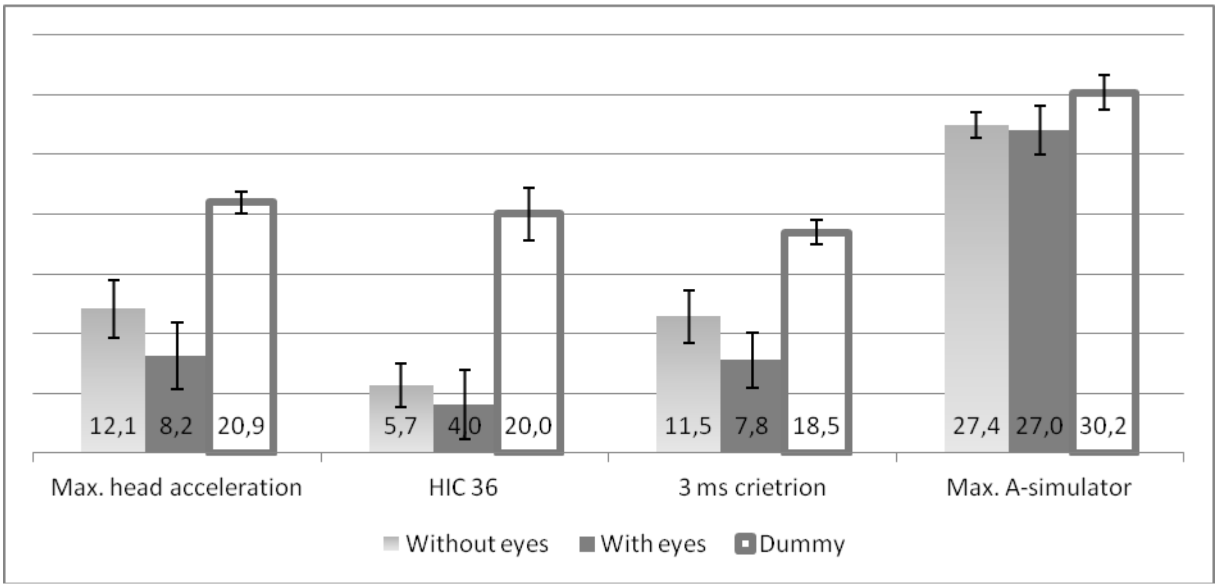

Figure 4: The values comparing the results between the dummy and the participants (with and without visibility).

A series of non-impact tests published by Gong, Lee, and Lu (2008) employed the finite element method (FEM) approach (a model of the head and neck) which was integrated with the Articulated Total Body (ATB) (McHenry, 2004), see Fig. 5. This model was placed on the model of a seat, fastened with a seatbelt, and the accelerations of 13.3, 23.5, and 33.7g were applied.

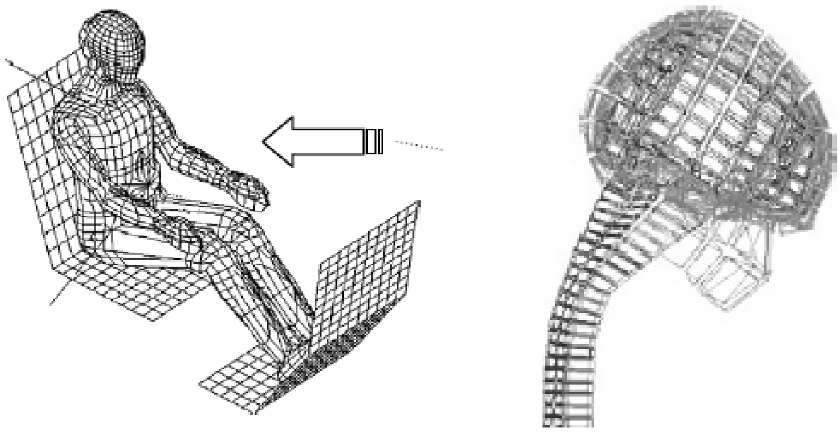

Figure 5: The model built by Gong et al. (2008) for non-impact tests.

The main goal of the study (Gong et al., 2008) was to identify intracranial pressure and shear stress. Nevertheless, the values of the head acceleration were of three orders higher than the initial acceleration of the impact (see Fig. 6). Viewed from the perspective of biomechanics, the results (Gong et al., 2008) of intracranial pressure, brain injury, considering the resultant head acceleration, matched the aforementioned results in this study. However, the real simulation of impact did not validate the abovementioned injuries in account of the initial deceleration.

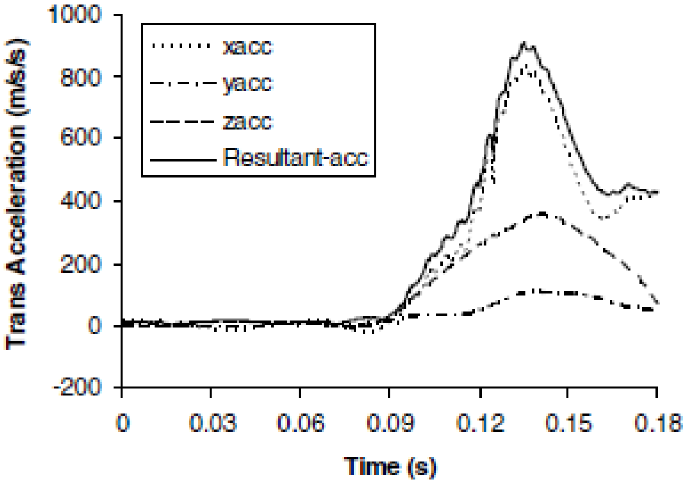

Figure 6: Resultant acceleration (Gong et al., 2008) during non-impact tests with initial acceleration 33.7 g.

ACKNOWLEDGEMENTS

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The Role of Personality Qualities in Driving

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ABSTRACT: The main cause of traffic accidents is the human element. This implies that the most significant traffic safety factor is the driver's behaviour and their psychological qualifications for driving (Antušek, 1998; Havlík, 2005; Stránský, 2000; Štikar, Hoskovec & Štikarová, 2003). Generally, the driver's behaviour reflects their personality characteristics and the specific situation. The present article focuses on the personality variables which, according to recent research, are particularly associated with the driving of motor vehicles. The personality characteristics, of which the understanding is important for the development of a methodology for the selection of suitable candidates for the position of a driver, are described. The role of personality in a narrow sense, the specific qualities of a driver and a risky driver, the individual traits posing risk in terms of driving, and aggressiveness are also addressed.

KEY WORDS: driver, personality, safety.

1 PERSONALITY

Personality psychology still features a plurality of conceptual frameworks, as scholars have failed to reach consensus about the definition of personality. The literature provides a range of notions of the personality and approaches to its study. Cloninger (2009), for example, refers to the following main perspectives of personality studies: biological, cognitive, humanistic, dynamic, the learning theory and the trait approach. For each of the approaches, their key concepts and representatives are also stated.

One of the prominent authors who tried to define personality by means of compiling others' definitions was G. W. Allport. In 1937 Allport posited that "personality is the dynamic organization within the individual of those psychophysical systems that determine his unique adjustments to the environment." (Allport, 1937, p. 48). The personality characteristics may be used to infer how individuals behave within their environment and experience it, including road traffic. Nevertheless, predictions will never be perfect – "people are strongly influenced by situations and, moreover, most behaviours are the expression of several traits – no perfect consistency in behaviour may be expected" (Allport, 1937, in Pervin, 2003, p. 40).

The basic categories of personality psychology are the structure and the dynamics. Nakonečný (2009) defines the structure of personality as the inner arrangement (a configuration of components, dispositions, or elements) of personality which indicates a more permanent state of the psychological determination of a human being. In addition, he suggests the existence of two categories of psychological characteristics of personality: a) characteristics of the properties of psychological processes (such as memory, thinking, and perception), b) characteristics of the psychological qualities of personality. It is the latter that this chapter will focus on.

According to Mikšík (2007), personality qualities may be divided into substructures: a) character qualities (including temperament and types and forms of behaviour), b) the motivational system (focus, content, direction of interactions), and c) abilities.

The personality dynamics gives the individual personality structures an "impetus", determines the focus on the achievement of a goal, and motivates behaviour. Personality blends in itself an array of motivational tendencies to behaviour which, together with certain dispositions in the structure of the personality, constitute a variability and make each human personality unique (Nakonečný, 2009).

1.1 Personality Traits

The trait approach to personality psychology was made famous by R. Cattell. His theory is based on a descriptive approach to personality (traits constitute the principal elements). He places an emphasis on prediction and applies the psychometric approach (Drapela, 2003). This perspective is suitable in describing personality in a situation of high demands on a standardised process, speed, and the effectiveness of psychodiagnostic assessment, which is exactly what is needed in traffic-psychology diagnosis.

Helus (2003) views personality traits as partial qualities of personality that provide long-term characteristics and are bound to specific situations (e.g., a human resources professional needs to know whether a candidate for the position of an air traffic controller can follow several panels at the same time and their attention does not waver for a set period of time).

English and English (in Kolaříková, 2005) suggest that a trait is an enduring characteristic of a person which makes it possible to distinguish such a person from others and is consistently manifested despite numerous changes in the external circumstances.

1.2 Driver's Personality

Within the system of transportation (driver – means of transport – traffic environment), the driver stands as a high-risk element. One of the reasons is the very personality of the driver, which is unique and irreproducible.

Each personality's uniqueness also makes it difficult to find a standard method of assessing the driver's personality that can capture the individual features of each personality qualified for driving. Only the qualities that are generally beneficial and risky for the personality of a driver can be identified. Two such categorisations from the perspective of traffic psychology are presented below.

Antušek (1998) suggests that the driver's conduct is especially influenced by their temperament and character. Good drivers tend to have well-balanced and strong types of nervous system; their reactions are accurate and quick. On the other hand, problem drivers show elements of irresponsibility, lack of caution, impulsiveness, emotional hypersensitivity, and sometimes indecisiveness and anxiousness.

"The personality of a problem-free driver features a well-balanced structure, emotional stability, adaptability, self-control, reasonable self-confidence, resilience to stress, conscientiousness, and reliability. Social qualities, such as altruism expressed by the effort to think of others and predict their behaviour, should not be disregarded either" (Havlík, 2005, p. 13).

On the contrary, drivers who cause traffic accidents more often tend to be more peculiar, egocentric, dynamic, aggressive, and emotional, and have reduced self-regulation, a disharmoniously structured personality, and impaired self-esteem, but show reasonable psychological performance. Unfailing individuals are efficient, adaptable, responsible, and emotionally stable, and can control themselves and cope with difficulties and stress (Havlík, 2005).

1.3 Driver Typologies

Research studies have arranged risky drivers into various typologies in order to identify different categories and qualities which are hazardous for traffic situations. Such efforts were intended to facilitate better orientation in assessing people's qualifications for driving.

One of the oldest typologies is that of Chorvát and Orlík (1980). It introduces six types of dangerous drivers whom we should avoid in road traffic or in the presence of whom we should at least be very alert (racer, gambler, exhibitionist, chaser, rusher, and faintheart).

Larson (1996, in Šmolíková, Hoskovec, & Štikar, 2008) developed a typology comprising five types of aggressive drivers:

1. the Speeder – tries to reach the destination as soon as possible. When others get in their way, they quickly become enraged;

2. the Competitor – tries to beat other drivers, competing with them on the road;

3. the Passive Aggressor – obstructs others' attempts at overtaking, driving fast, and merging; challenges other drivers' self-confidence;

4. the Narcissist – shows rigid driving behaviour and becomes angry when others do not drive in the same manner, and

5. the Vigilante – feels himself to be a superior judge of other drivers and seeks to punish them for any of their violations.

Using the data collected from 2524 respondents, Ulleberg (2001) distinguished six subtypes of driver personality and identified the two subtypes posing the highest risk. He suggests that the riskiest drivers are males characterised by low levels of altruism and anxiety and high levels of sensation seeking, irresponsibility, and driving-related aggression. The second high-risk group consists of people showing high levels of sensation seeking, aggression, and anxiety, and inclined to driving anger. Moreover, the two highest-risk types are the least responsive to traffic safety campaigns.

Two more typologies, presented by Štikar, Hoskovec, and Štikarová (2003), are provided below for illustration.

The one proposed by McGuire accounts for six groups of drivers. The first group comprised well-balanced and efficient individuals who are excellent drivers in terms of accident involvement. Groups 2-5 suffer from emotional problems, while Group 6 encompasses people who are physically or mentally ill. The characteristics of each group are summarised in Table 1.

Table 1: Personality groups identified among drivers and behaviours typical of the drivers belonging to each group (in Štikar, Hoskovec, & Štikarová, 2003, p. 148).

Groups	Driving behaviour
1) Well adapted; they seldom become disconcerted and collect themselves quickly.	Do not tend to be involved in accidents or violate traffic regulations.
2) Have mental problems, but are socially responsible and control themselves.	Do not tend to be involved in accidents or violate traffic regulations.
3) Have mental problems, but are socially responsible, but may become disconcerted over long periods of time.	May be prone to accidents and traffic violations within certain periods of time (weeks or months).
4) Socially responsible, but have mental problems and inclinations to being permanently distempered.	Involved in a large number of accidents and violate regulations frequently.
5) Show permanent tendency to unsociable or antisocial behaviour.	Chronic violators of traffic regulations who may show high accident rates.
6) Miscellaneous (epileptics, diabetics, the mentally defective*,etc.)	Unpredictable behaviour; driving behaviour may range from very bad to very good.

On the other hand, Quenault's typology divides drivers into four groups, also taking into account, in addition to the observation of their driving behaviour in terms of speed and overtaking, their unusual manoeuvring and use of rear-view mirrors (Štikar, Hoskovec, & Štikarová, 2003).

2 CHARACTERISTICS OF A RISKY DRIVER

The personality characteristics of a bad – risky – driver need to be stated in order to identify the key qualities necessary for the determination of the methods of selection of suitable candidates qualified for driving a vehicle.

* The originally used terminology has currently been replaced by terms which emphasise the disorders and illness rather than their bearers.

As early as 1940 Selling recognised the relationship between personality and risky driving among his psychiatric patients with a history of frequent road accidents (Selling, 1940).

The relationship between personality traits and risky driving may be conceptualised by means of drivers' attitudes (Ulleberg & Rundmo, 2003). The risky drivers' attitudes mostly concern factors such as obedience to traffic rules, a tendency to take chances in traffic jams, and positive attitudes to traffic jams (Yilmaz & Çelik, 2004). West and Hall (1997) adopt a similar view by regarding positive attitudes to road violence as significant predictors of traffic accidents.

Perpetrators of road accidents tend to be unstable, extrovert, less adapted individuals with lower intelligence and inclinations to aggressive conduct (Fernandez-Seara, 1978). Štikar, Hoskovec, and Štikarová (2003) provide evidence that drivers with a higher record of accidents are likely to be eccentric, impulsive, and psychopathic.

People who are prone to risky behaviour (particularly those who are immature) often show little responsibility towards others and an insufficiently developed ability to anticipate, seek situational excitement and adventures, like to flaunt themselves in front of others, and show false self-confidence and the need to compensate for their sense of inferiority (Stojan et al., 2008). Research conducted by Machin and Sankey (2008) showed that inexperienced drivers underestimate the risks connected to a number of driving situations.

Aspects of personality traits considered by Stránský (2000) as contraindications for driving include emotional instability, maladaptivity, egocentrism with excessively increased self-esteem, hypersensitivity, irritability, intolerance, impatience, and chronic dissatisfaction. Other such traits include timidity or, on the contrary, carelessness, recklessness, irresponsibility, the inability to consider the consequences of one's actions, a lack of self-discipline, clear-cut antisocial attitudes, a strong need to assert oneself, aggressiveness, and negative attitudes towards the safety of oneself and others.

According to Hanzlíková (2004), the predominant traits of high-risk or dangerous drivers include little responsibility for their own actions, hostile attitudes to people, emotional instability, the unpredictability of their reactions, low tolerance of frustration and resistance to stress, poor self-control, tendencies to irritability, and aggressiveness. In addition, Hanzlíková reports on earlier findings made by Mikšík, who attempted to draw up a personality profile of "accident-prone" drivers using the IHAVEZ and SPIDO questionnaires. Mikšík found that their significant traits include lower personality self-regulation and inner control related to a reduced degree of anticipation and responsibility, carelessness and a tendency to take chances, emotional excitability and instability, unregulated emotionality, reduced variability of emotional adaptability, situation-induced disorientation, a loss of self-confidence, and the failure of an integrated way of dealing with a "surprising" development of a situation.

2.1 Selected elements of driver's personality

On the basis of the above-mentioned typologies and research into risky characteristics of drivers reported in both the Czech and foreign literature, we provide the following summary of a driver's risky personality variables:

a) Personality trait characteristics:

- dominance, the need to assert oneself, egocentrism,
- emotional stability × instability (neuroticism),

- hypersensitivity, anxiety,
- level of self-confidence, self-esteem,
- extraversion × introversion,
- self-control, self-discipline, obedience to traffic regulations,
- conscientiousness,
- low tolerance of frustration and stress resistance, psychological resilience and fatigue.

b) Other aspects of personality with an impact on driving:
- type A behaviour,
- seeking of situational excitement and adventure; sensation-seeking,
- antisocial attitudes × prosocial attitudes, altruism,
- LOC – internal locus of control with reduced anticipation,
- attribution.

c) Aggressive tendencies:
- aggressiveness,
- aggression,
- anger,
- hostility.

3 CONCLUSION

Special attention should be paid to the above characteristics in the psychological testing and selection of drivers in order to prevent the failure of the human factor in road traffic. As suggested in the present article, the driver's personality features a range of factors which are potentially indicative of the driver's risky behaviour. These potential factors are triggered in combination with specific situational variables. Therefore, it is recommended that the testing and selection of drivers should especially consider the context of the driver's performance and focus on the personality characteristics that play the key role in the given situational context.

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Technical Notes on Balloting process of selected committees of ASTM International

by Karel Pospíšil, *CDV – Transport Research Centre, karel.pospisil@cdv.cz*

Introduction

ASTM International is one of the largest voluntary standards development organizations in the world. It is a trusted source for technical standards for materials, products, systems, and services. There are over 130 ASTM technical committees covering diverse industry areas ranging from metals to the environment. The author of the technical note is a balloting member of five of them. They are:

- Committee C09 on Concrete and Concrete Aggregates
- Committee D04 on Road and Paving Materials
- Committee D18 on Soil and Rock
- Committee D35 on Geosynthetics
- Committee E07 on Non-destructive Testing

Above mentioned committees took a vote on 543 documents, see Table 1.

Table 1: Number of Ballots in Specified Committees.

	Number of Ballots				
Ballot	Committee C09	Committee D04	Committee D18	Committee D35	Committee E07
1/11	39	36	14	40	32
2/11	50	34	24	17	11
3/11	1	1	34	8	16
4/11	13	-	51	1	24
5/11	46	-	2	-	-
6/11	36	-	13	-	-
Sum in the Committee	185	71	138	66	83
Total Sum in Specified 5 Committees	543				

The objective of the Technical Note is to inform about the selection of technical problems solved by the above mentioned committees in 2011 from the author point of view. It is neither an official nor comprehensive report from the life of the committees.

Committee C09 on Concrete and Concrete Aggregates

The committee was balloting about new standards, guides and practices or their revisions. The following ones seem to be interesting as relate to actual domestic tasks: terminology relating to concrete and concrete aggregates, test method for organic impurities in fine aggregates for concrete, test methods for sampling and testing fly ash or natural pozzolans for use in Portland-Cement Concrete, specification for latex and powder polymer modifiers for hydraulic cement concrete and mortar, test method for determining bond strength between hardened roller compacted concrete and other hardened cementitious mixtures point load test, test methods for air content of freshly mixed concrete by the volumetric and by the pressure methods, test method for effectiveness of pozzolans or ground blast-furnace slag in preventing excessive expansion of concrete due to the alkali-silica reaction, test method for potential alkali reactivity of carbonate rocks as concrete aggregates rock-cylinder method.

Committee D04 on Road and Paving Materials

Asphalt and bituminous materials have taken large part of the committee effort, i.e. terminology relating to materials for roads and pavements, test method for thickness or height of compacted bituminous paving mixture specimens, practice for determining the separation tendency of polymer from polymer modified asphalt, practice for sampling bituminous paving mixtures. The committee was involved in “non-asphalt issues” as well, i.e. specification for preformed silicone joint sealing system for bridges and specification for plowable, raised retroreflective pavement markers.

Committee D18 on Soil and Rock

The Committee has been involved in preparation or revisions of test methods, guides and other documents, such as terminology relating to soil, rock, and contained fluids, guide for conducting borehole geophysical logging: mechanical caliper, test methods for one-dimensional consolidation properties of soils using incremental loading, guide for maintenance and rehabilitation of ground-water monitoring wells, test method for determination of water moisture content of soil by the time-domain reflectometry TDR method etc.

Committee D35 on Geosynthetics

Interesting test methods, guides, practices and other documents were discussed in the Committee, e.g. test method for trapezoid tearing strength of geotextiles, guide for selecting test methods for experimental evaluation of geosynthetic durability, specification for circular-knit geotextile for use in subsurface drainage applications, specification for hybrid geosynthetic paving mat for highway applications, practice for the nondestructive testing of geomembrane seams using the spark test, test method for swell index of clay mineral component of geosynthetic clay liners, etc.

Committee E07 on Non-destructive Testing

Non-destructive testing committee has been involved in various documents, i.e. terminology for nondestructive examinations, guide for computed tomography CT imaging and practice for computed tomographic CT examination, test methods for atmospheric leaks using a thermal conductivity leak detector, practice for digital imaging and communication in nondestructive evaluation for ultrasonic, digital radiographic, computed radiography X-ray and computed tomography test methods, test method for noise equivalent temperature difference of thermal imaging systems etc.

Summary and Acknowledgement

The Technical Note informs about selected problems solved by ASTM International, what author considers interesting from his point of view. Comprehensive information about ASTM International can be obtained form their website www.astm.org. Author’s participation in ASTM International is partly supported by the grant of Ministry of Education, Youth and Sports of the Czech Republic no. LA 09007.

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Papers based on accepted abstracts and prepared in accordance to these guidelines are to be submitted through the journal's web site www.transportsciences.org. All papers, using Microsoft Word2000 (or newer) are limited to a size of at least 4 and no more than 8 single-spaced pages on A4 paper size (297 mm X 210 mm), including figures, tables, and references and should have an even number of pages. The paper's top, bottom, right and left margins must be 2.5 cm. No headers, footers and page numbers should be inserted.

2 TITLE, AUTHORS, AFFILIATIONS

The title of the paper must be in title letters, Times New Roman, font size 16, and aligned left. Use more than one line if necessary, but always use single-line spacing (without blank lines). Then, after one blank line, aligned left, type the First Author's name (first the initial of the first name, then the last name). If any of the co-authors have the same affiliation as the first author, add his/her name after an & (or a comma if more names follow). In the following line type the institution details (Name of the institution, City, State/Province, Country and e-mail address of a corresponding author). If there are authors linked to other institutions, after a blank line, repeat this procedure. The authors name must be in Times New Roman, regular, and font size 12. The institution details
must be in Times New Roman, italic, and font size 10.

3 ABSTRACT

The abstract should start after leaving eight blank lines. Type the text of the abstract in one paragraph, after a space behind the word abstract and colon, with a maximum of 250 words in Times New Roman, regular, font size 12, single-spaced, and justified. After leaving one blank line, type KEY WORDS: (capital letters, Times New Roman, font size 12), followed by a maximum of five (5) key words separated by commas. Only the first letter of the first key word should be capitalized.

4 THE TEXT

The main body of the paper follows the key words, after two blank lines (i.e., two blank lines between the first heading and the key words). The body text should be typed in Times New Roman, font size 12 and justified. The first line of the paragraphs should be indented 5 mm except the paragraphs that follow heading or subheading (i.e., the first line of the paragraphs that follow heading or subheading should not be indented). Never use bold and never underline any body text.

4.1 HEADINGS AND SUBHEADINGS

The headings are in capital letters, Times New Roman, font size 12. Subheadings are in title letters Times New Roman, font size 12. The headings and subheadings must be aligned left and should not be indented. Leave two blank lines before and one after the heading. There should be one (1) blank line before and after the subheadings. All headings and subheadings must be numbered. If a heading or subheading falls at the bottom of a page it should be transferred to the top of the next page.

4.2 FIGURES AND TABLES

Figures, line drawings, photographs, tables should be placed in the appropriate location, aligned centre, and positioned close to the citation in the document. They should have a caption, Times New Roman font size 12, with a colon dividing the figure number and the title (Figure 1: Material properties) and should be numbered consecutively, e.g. Figure 1, Figure 2, Table 1, and Table 2.

4.3 REFERENCES

At the end of the paper, list all references with the last name of the first author in alphabetical order, underneath the heading REFERENCES, as in the example. The title of the referred publication should be in italic while the rest of the reference description should be in regular letters. References should be typed in Times New Roman font size 12. citation standard ISO 690.

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