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THE FEM APPLICATION IN NUMERICAL ANALYSIS OF SLEWING RINGS ROLLER/BALL COMBINATION BEARING

Slewing bearings are selected based on the characteristics of capacity, which determine the area of the permissible load of the bearing. This capacity of a bearing does not take into account the real operating conditions of a bearing. This implies a necessity to take into consideration all the factors having an influence on the bearing capacity during its determination. The way of determining of the static limiting load curves profiles (static capacity chart) of a double-row roller/ball combination slewing bearing is presented in this article. In the calculations, taking into account flexural-torsional flexibility of bearing rings, flexibility and number of bearing clamping bolts and the most important parameters of the contact zone of rolling elements with bearing raceways, is presented in the paper. Concluding results have been obtained in numerical way. Distribution of internal load, which is in individual rows of a bearing, is presented here. Basic problems of modelling the component unit of the slewing bearing are discussed. In calculating the profile, the initial clamp of the fixing bolt, flexible rings, flexible casing and variation of the contact angle bearing are allowed for. Particular attention is paid to modelling of elements that are equivalent for balls bearing. Obtained results are presented as graphs.

Keywords: *FEM, slewing bearing, load bearing capacity, load distribution*

1. Introduction

The rotation mechanisms of lifting devices are usually constructed with the use of slewing roller bearings. These are the sub-assemblies of machines that carry the entire load resulting from their operation. Due to the high load capacity, relatively compact construction and small dimensions, they are used not only in classic machinery and equipment such as excavators, all types of cranes and other construction machinery, military vehicles but are widely used in wind power plants, rail vehicles and many other devices, as well (Figure 1) [1].

The slewing bearing load capacity usually limits the maximum external loads of the designed machine and the correct estimation of it is an important part of the working machine calculation. Slewing bearings are usually selected for extreme loads, so that their work is at the limit of endurance. This requires careful and precise calculations of their performance parameters, of which still the most important is the static load capacity, more and more often supplemented by additional criteria like assembly, durability, determination of movement resistance etc. [2].

2. The load rating of a slewing bearing

The selection of a bearing is made based on its static capacity in the conditions of typical work of a slewing bearing in working machines. The static capacity is determined based on the strength criterion in the contact zone of the rolling elements and the bearing raceways. In this paper, the criterion of limiting relative plastic deformation was taken from Eschmann [3]:

$$\frac{\delta_{pl\lim}}{d} = 2 \cdot 10^{-4} \tag{1}$$

The permissible load of rolling elements was established based on the empirical equations of Brändlein and others [3], adequately for the point contact:

$$\frac{\delta_{pl}}{d} = \left(\frac{p_0}{2550 \sqrt[3]{c_p}} \right)^5 \tag{2}$$

where:

$$\frac{\delta_{pl}}{d} = \left(\frac{p_0}{2550 \sqrt[3]{c_p}} \right)^5 \tag{3}$$

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Figure 1 *Examples of the slewing bearings applications*

$$c_p = \frac{1.5}{\pi \mu_H \nu_H}\left[\frac{E}{3(1-\nu^2)} d\Sigma\rho\right]^{\frac{2}{3}} \tag{4}$$

and for the linear contact:

$$\frac{\delta_{pL}}{d} = \left(\frac{p_0}{1003.3\sqrt{c_{pL}}}\right)^5 \tag{5}$$

where:

$$p_0 = c_{pL}\sqrt{\frac{F}{dl_e}} \tag{6}$$

$$c_{pL} = \sqrt{\frac{E}{\pi(1-\nu^2)}\frac{d\Sigma\rho}{2}} \tag{7}$$

Relationships (2) and (5) were determined for common bearings with a hardness of rolling elements and a raceway equals 62 HRC, what corresponds to HV ≈ 750. In the slewing bearings the hardness of raceway is lower, for hardened raceways is equals 50 ÷ 56 HRC, therefore the hardness of a raceway takes into account the hardness factor f_H:

$$f_H = \left(\frac{HV}{750}\right)^2 \tag{8}$$

For steel the Young's modulus is E = 2.08·10^5 MPa and the Poisson's ratio is ν = 0.3, thus, the limiting values of the load of the rolling elements are obtained based on the above equations as: for the point contact

$$F_{\lim} = 9.9626 \cdot 10^7 \frac{fHd^2}{c_p^2} \tag{9}$$

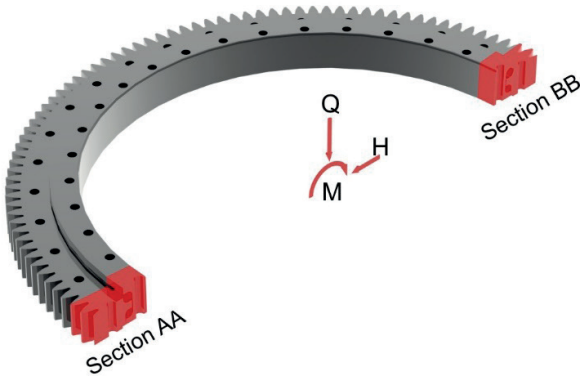

Figure 2 *Components of external load of a slewing bearing*

for the linear contact

$$F_{\lim} = 123.57\, f_H dl_e \sqrt{1 - \frac{d}{2a_0}\cos\alpha} \ \text{[N]} \tag{10}$$

The slewing bearing can be loaded by three components of the external load as it is shown in Figure 2. Two pairs of raceways are distinguished in every slewing bearing. Together with cooperating rolling elements they are called the computation rows of the bearing. The row, where interactions from the axial force Q and the tilting moment M are summed up, is called the capacity row and the second row-the support row.

Regardless of the method of the load imposing, the computations of capacity are carried out applying an iteration method. The distribution of the internal load of a bearing is computed and the maximum value of the load of rolling element in every row of a bearing is searched for the assumed value of the internal load. The strength condition of correct work of a bearing is as follows:

$$F_{i,j} \le F_{\lim j} \tag{11}$$

where: i is the index of the rolling part in the j-th row.

Iteration is interrupted if the maximum load of one of the rolling parts $F_{max\,j}$ fulfils condition

$$F_{\max j} = F_{\lim j} \tag{12}$$

in optional row (for the assumed accuracy of computations).

3. The double-row slewing rings roller/ball combination bearings

The double-row slewing rings roller/ball combination bearings (Figure 3) are aimed for applications with small eccentricities at relatively high axial loads, which call for a long service life, even with continuous oscillating motions, and where the structural

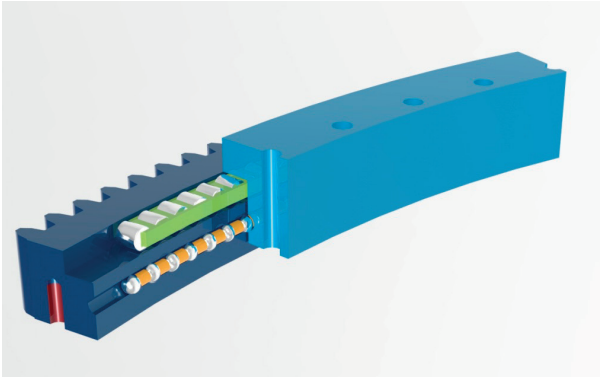

Figure 3 *The double - row slewing rings roller/ball combination bearings*

Table 1 Parameters of slewing bearings analysed in the study

Bearing parameter		carrying row (roller)	supporting row (ball)
Rolling diameter of a calculation row [mm]	d_t	3550	3506
Diameter of rolling elements [mm]	d	32	25
Number of rolling elements in the calculation row,	z_1	304	304
Roller length [mm]	l_1	30	-
Contact coefficient	k_p	-	0.96
Operation angle [°]	α_0	90	45
Race hardness [HRC]		54	54

design requires a large bearing diameter. For this bearing type, the eccentricity:

$$k = \frac{2M}{DQ} \tag{13}$$

should not exceed 1.2 under operating loads. If in extreme static cases „k" is found to be higher than 2, an accurate verification would be required.

The entire load capacity ranges, which lie under the static load limiting curve and the operating load curve, are covered by use of the grade 10.9 bolts [4].

Calculations of the load capacity profiles of slewing bearings were made for a double-row slewing rings roller/ball combination bearing with the parameters as presented in Table 1.

4. The numerical model of the slewing bearing

The slewing bearing is a complex construction. The numerical model of the bearing is made using the FEM. ADINA software was applied to this [5]. Two groups of problems can be distinguished during the model building: bearing modelling on a macro scale, it means modelling bearing rings and their mounting and modelling bearing on a local scale, it means modelling phenomena in the contact zone of rolling elements and bearing raceways.

Huge number of contact zones is present in the slewing bearing (quite often a few hundred). To avoid unwanted increase in the size of the numerical model, the rolling elements in the bearing are substituted by the so-called super-elements introduced in works [6]. The linear element with the non-linear characteristics, which is determined based on equivalent characteristics of the contact zone [7], is the main fragment of the super-element. The equivalent characteristics take into account a reduction in the distance of bearing rings caused by the load and results of connection of the truss element with the mesh built of the 3D elements (the so-called effect of concentrated force). The first stage of modelling a slewing bearing is the computation of the equivalent characteristics of the rolling elements. Those characteristics depend mainly on the sizes and parameters of the contact zone, as well as on the discretization method of bearing rings. Basically, they should be determined separately for each bearing, but a certain set of the typical characteristics of the rolling elements for the same sizes of the elements and similarity in shape of intersection of bearing rings can be prepared.

Rollers were substituted by the non-linear springs connected to nods of a mesh of bearing rings, as was applied in the numerical modelling in [8, 9].

In ball slewing bearings super-element additionally should simulate the change in operating angle of a bearing. The change in operating angle results from deformation of the contact zone under the load and from clearances in a bearing [10]. The super-element consists of the two truss elements of the high rigidity, connected to the node of the bearing ring at one of the ends. The second ends of these elements are placed in the centre of curvature of the bearing raceway profile and they are connected to the linear element with the non-linear characteristics determined based on the equivalent characteristics of the contact zone. Various forms of this type of super-elements applied in modelling of a slewing bearings were presented in work [11].

The relation between the deformation of each ball bearing and the force which produces it is given by the contact rigidity, which is a non-linear function of the material of the ball bearing and raceway and of the relative displacement between them [12].

In the analytical calculations of the slewing bearings, the basic parameter for deformations in the contact zone is accepted as the mutual approach of the bearing rings η under the acting of the force F. It is for this parameter's purpose that it is the most convenient to use the equation:

$$\eta = cF^w \tag{14}$$

The value of the exponent w is the measure of the "nonlinearity" of the deformation-load characteristics. In analytical calculations the exponent w is usually assumed to be w = 0.9 for the roller bearing and w = 2/3 for the ball bearing.

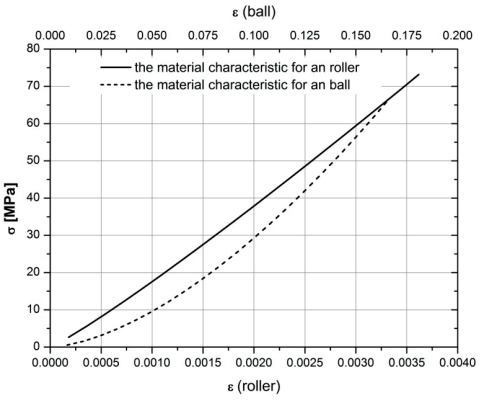

Figure 4 *Equivalent characteristics of rollers and balls*

The length of elastic element for rollers equals

$$l_T = d \tag{15}$$

and for balls

$$l_T = d\left(\frac{1}{k_p} - 1\right) \tag{16}$$

The non-linear characteristics of the truss element in super-element are computed according to conditions of applied FEM software. For the FEM calculating programs such as ADINA, the load-deformation characteristic should be noted as a stress-strain dependency. The ADINA program allows for the use an elastic material with a nonlinear characteristic for truss elements [5]. Such materials are used in this analysis. Figure 4 shows the schematic nonlinear characteristics σ - ε. The truss element modelling a roller transmits only the compressive forces. The computational cross-section area of the element A_t can be determined based on the replacement section, which, for the rollers and balls respectively, is given as:

$$A_t = \frac{F_{max}}{dl_e} \text{ and } A_t = \frac{F_{max}}{d^2} \tag{17}$$

The individual points of the material characteristics are determined by the equation for stress:

$$\sigma_i = \frac{F_i}{A_t} \tag{18}$$

and for strain

$$\varepsilon_i = \frac{\eta_i}{l_T} \tag{19}$$

Figure 4 presents the non-linear characteristics of the truss element in the ball bearing computed for the ADINA software.

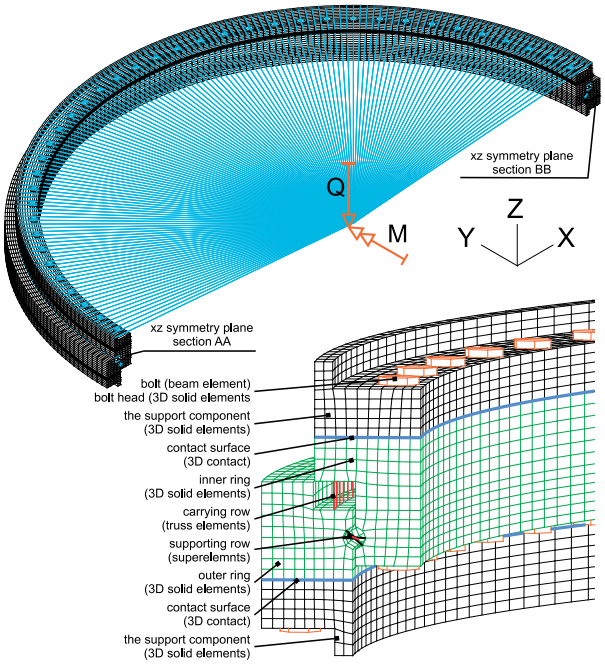

Figure 5 *Mesh of the numerical model of a double - row roller/ball combination slewing bearing (with sectional rings) and boundary condition*

The numerical modelling of a bearing on a macro scale is reduced to preparation of mesh of bearing ring models, acceptance of shape of mounting elements and acceptance of the method of modelling the bearing clamping bolts. Constructional details of elements to which a bearing is mounted are not known at the stage of computations of the catalogue capacity. It was assumed that the bearing rings are fastened to the ring-girders [9].

The 8-nod elements of 3D-SOLID type were applied to discretization of bearing rings. The following simplifications of the shape of bearing rings were introduced to model the bearing rings:

- toothing of bearing rings was not considered,
- small constructional details, such as grooves for gaskets, grease holes, etc., were not considered,
- holes for clamping bolts were not considered.

The last of the above simplifications is related to the modelling method of clamping bolts of a bearing. Full models of the bolt joints were not done to decrease the size of model. It was assumed that the bolts are modelled using the beam elements. This allows to introduce an initial tension in bolts. To achieve this, elements of the BOLT type are applied in the ADINA software.

The method of modelling the bearing rings and clamping bolts is shown in Figure 5 on the example of the mesh of a model of a three-row roller bearing. Segmentation of rings over the circuit is regular and mesh density is conditioned by the arrangement pitch of the rolling elements.

Due to symmetry of the problem (tilting moment is acting in the plane determined by axial and radial load) only a half of the ring structures was taken for computation. In the plane of division

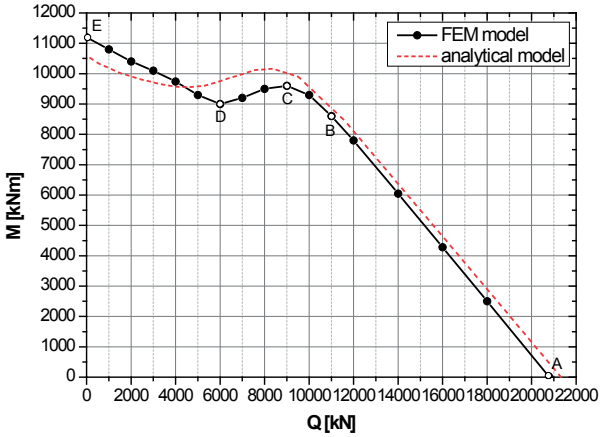

Figure 6 *Characteristics of a double - row roller/ball combination slewing bearing with parameters from Table 1*

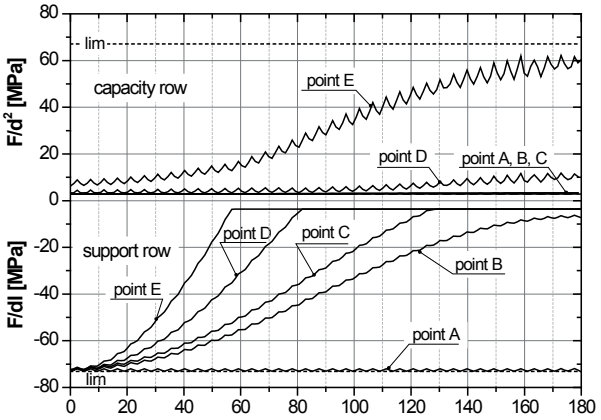

Figure 7 *Distributions of the internal load in a double - row roller/ball combination slewing bearing for individual points A, B, C, D marked in Figure 6*

of rings, the adequate constraints resulting from symmetry were applied. One of the girders of a bearing mounting is fastened at its bottom plane. It is called the support girder. The load is imposed on the second girder-called the load girder.

5. Results of calculation of the load capacity and analysis

Figure 6 presents the charts that illustrate the static load capacity profiles for the slewing bearings a roller/ball combination slewing rings. The charts also show the scopes of specific cases of bearings operation for nominal states (without play). In the AB range, the load capacity is determined by the load capacity of a row, which is limited by the permissible force F_{1lim} of a rolling element, which is present in the bearing node (section BB in Figure 2). The bearing node it is the sector of the bearing in the plane where the torque M is applied.

The AB range is the place where only the rolling elements of the load-carrying row are operating, while the rolling parts in the supporting row do not take part in transferring the external load. The rolling elements of the supporting row, which are present in the section AA (point C) they begin to carry small loads. At point D occurs a slight decrease in the bearing load capacity, due to the fact that the number of the rolling elements in the carrying row is significantly reduced. At the same time rolling elements in a supporting row are used to a small degree. In the range DE, there is an increase of the bearing capacity, which is derived from the large participation of the supporting row in the transmission of external loads.

Figure 7 presents the charts that illustrate distribution of internal load in the bearing for these specific operation points. At the point A, where the bearing transfers only axial forces, the load capacity is determined by the strength of the support row. This results from the higher operating angle of rolling elements in the bearing with play. The AB range is the place where all the rolling elements of the load-carrying row are operating, while the rolling parts in the supporting row do not take part in transferring the external load. From the point B on, the rolling elements in the supporting row start to operate; thus, an insignificant decline in the profile at this point (Figure 7). An additional increase in the load capacity occurs in the BC range due to even greater use of the rolling parts in the supporting row. Another decline in the profile is observed at point C (Figure 6).

The load capacity reduces until it reaches the point D with the lowest value. In the load area of the section CD, the play between the rolling elements and races causes that the active sections of the bearing's race are reduced with relatively insignificant use of the rolling elements in the supporting row; hence a decline in the load capacity in this range of load. An increase in the load capacity is observed in the DE range, which is caused by the higher contribution of the load capacity of the supporting row until it reaches the value at point E, where the rolling parts, present in the bearing node BB, reach the permissible load F_{1lim}.

Figure 8 shows the successive positions of the bearing ring, for each load point.

The next positions of bearing ring, were determined for individual points of its carrying capacity characteristics. As a result of power Q effects and M moment, there follows the axial transfer, radial and rotation of the ring in a plane of turning moment action.

The radial displacement results from the angle of balls action in the row supporting, which in the nominal state (i.e. in unbiased bearing is 45°) (Figure 8). As a result of the load transferred through the rolling elements in the supporting row, follows a change of the nominal angle value of their action. The maximum ranges of these changes are presented in Figure 9.

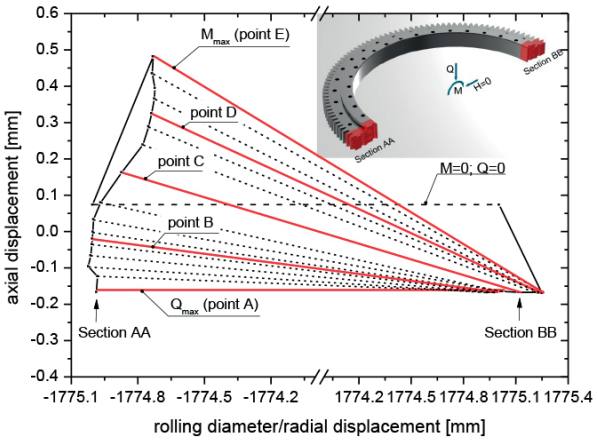

Figure 8 *Next positions of the inner ring of the bearing for individual points A, B, C, D marked in Figure 6*

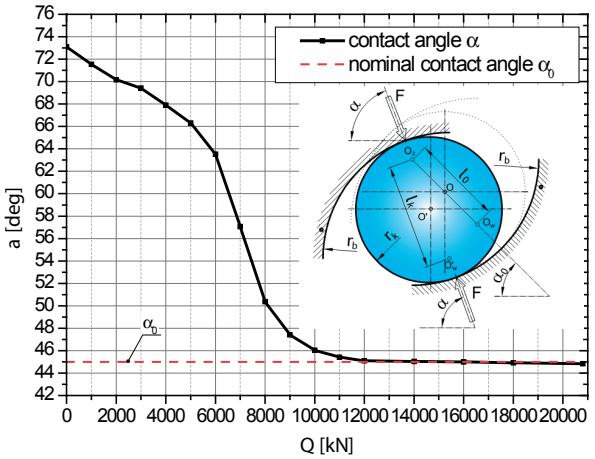

Figure 9 *Ranges of changes in the contact angle in a double - row roller/ ball combination slewing bearing*

6. Conclusion

Realization of a correct presented method of computing the catalogue capacity of slewing bearings allows the bearing characteristics to be determined exactly. Modern methods of modelling and the development of the FEM software make it possible to construct numerical models of the rings relatively quickly, especially the application of super-elements to simulate the rolling parts.

The presented analysis allows the force distribution in the individual rows of the bearings to be exactly determined, which is impossible using analytical methods. The analytical methods are reduced for the bearing computations by the assumption of the non-deformability of the bearing rings. The computational modelling allows all constructional and technological changes introduced into the geometry of the real bearing, to be quickly verified and also allows the geometrical characteristics of the mounting structure of the bearing in a machine to be taken into account. The method of modelling the rolling elements, which are replaced by special elements (super-elements), is the key stage in the presented computational methodology. Both the structure of the super-element and its substitute characteristics can have a profound influence on the obtained results of computations. To obtain an adequate characteristic of the bearing capacity, one must take into account both phenomena occurring in the contact zone of the rolling elements and raceways and the influence of the method of the rolling element modelling in the FEM numerical model of a bearing.

The computations in the proposed method, using the ADINA software, can be successfully applied in any other software. Model of working machine and the slewing bearing is the most important part of the computations. Nowadays, the types of models of supporting structures have reached a certain standard in the design of new machines and equipment. Due to that, the determination of the total capacity of a bearing requires only the additional construction of the model of a slewing bearing. Notes contained in this paper and the usage of marked references in the bibliography should make it easier to work out such a model.

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INFLUENCE OF REPAIRING USING WELDED STEEL PATCHES ON STRUCTURAL INTEGRITY OF A HIGH PRESSURE GAS PIPELINE

The present paper deals with complex material properties of DN 300 pipeline from the section Olesna – Barchov. The work was aimed at experimental verification of the effect of welded-on cover patches on the pipeline integrity. Two types of welded-on cover patches were evaluated. In the first case, just a single patch – steel plate was welded into the pipeline wall, replacing the damaged area. A lack of root fusion was found by means of the NDT. In the second case, the primary patch welded into the wall was covered by an auxiliary patch welded over the first one. No imperfection of the weld integrity was shown in the second case. The experimental programme contained an evaluation of the resistance of the repaired section to 10 000 pressure cycles induced by the inner water pressure at R = 0 cycle load asymmetry and maximum pressure of 6.3 MPa. The effect of these repairs on the limit state of the pipeline was verified by means of hydrostatic burst test. The tests comprised the evaluation of fracture surface morphology.

Keywords: *pipeline, hydrostatic burst test, repair patches, full scale test.*

1. Introduction

As a result of a specific geographical position of the Czech Republic, relatively dense network of high pressure gas pipelines of up to 1400 mm diameter goes through its territory. The pipelines operate under different pressure conditions up to 8.4 MPa. Significant part of the pipelines is located inside of populated areas and so it has to be maintained at the highest safety level. Pipeline accidents in such areas would result in considerable material losses and, in the worst-case scenario, in injuries or loss of lives. Even at present, serious accidents of gas pipelines are not rare [1]. The last one in Czech Republic occurred and fortunately, there was no loss of human lives in this case [2].

To make the prediction of the behaviour of gas pipelines containing different defect types, it is necessary to verify experimentally, how the defects react on the pressure changes and how they reduce safety and reliability. Numerous recent experimental programmes have dealt with the loss of wall thickness due to area corrosion, pitting corrosion [3, 4] and, last but not the least, with the stress corrosion cracking, when a reliable detection by internal inspections may not be easy [5]. The pipe wall can also contain differently oriented cracks [6, 7] or dents [8] generated during the pipeline construction.

Previous regulations for the pipeline structures admitted repairs of some types of defects by overlapping. Such overlapping was carried out mostly under the reduced working pressure and caused several accidents in 2002. That is why the operation of this gas pipeline (in Argentina) was brought to a standstill and these repairs were examined by seven full scale hydrostatic burst tests [9]. The repair patches were of different type and size. It was clearly visible from the strain gauges records that the repairs had influenced substantially deformations of the tube wall.

In six cases, fracture occurred outside the patches. At the fracture of the body, the pressure was at least twice as big as the operational one.

2. Experimental programme

In case of unsatisfactory circumferential welds of gas pipelines in Czechoslovakia in the past, a specific repairing procedure was allowed to be performed. It consisted of three steps: (i) cutting out a rectangular part of the tube very close to the circumferential weld to be repaired, i.e. a kind of a "window", (ii) using this window for a repair of the main circumferential weld from the inside and (iii) welding the cut-off part (the plate) back into the tube wall, i.e. "closing" the window – Figure 1. However, the plate welding was not successful in all cases and overlapping had to be carried out - Figure 2.

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Figure 1 *Steel repair-patch A*

Figure 2 *Steel repair-patch B*

Table 1 Chemical composition

Elements	C	Si	Mn	P	S
[wt. %]	0.12	0.29	0.35	0.013	0.024

Table 2 Mechanical properties of the pipeline

Direction of specimens	σ_y [MPa]	σ_{uts} [MPa]	Elong. [%]	CVN 0 °C [J]
longitudinal	*299*	*424*	*31*	*81.8*
circumferential	*271*	*432*	*26.5*	*160.8*

σ_y - yield stress, σ_{uts} - ultimate tensile strength, Elong. – elongation after fracture, CVN - absorbed energy in Charpy impact test at temperature 0 °C

Preliminary NDT (non-destructive testing) inspection showed the lack of root fusion in the whole length of repair patch A - Figure 1. On the contrary, no imperfection of the weld integrity was found in the fillet weld in patch B (Figure 2) during the NDT inspection.

To evaluate the material properties, a ring was cut out from the pipeline. Chemical composition of the tube is summarized in Table 1. According to these data it can be said, that the tube material corresponds to the 11 353 steel being commonly used for seamless tubes.

Investigations of microstructure and properties were carried out in longitudinal and circumferential direction. The base microstructure was ferrite-pearlite in both directions with uniform ferritic grains of the size 7.5 according to [10]. The pearlite colonies had typical lamellar morphology - Figure 3. A row-like structure was sometimes observed in the specimen centre.

Room temperature tensile tests of four specimens, two of longitudinal and two of circumferential direction, respectively, were performed using the EUS 40 testing machine. The DDA 50 – EU strain gauge with L_o = 85 mm was used to measuring the deformations. In a similar way, impact bend tests at 0 °C were performed at both directions, by three specimens each, using the PSWO 30 impact testing machine.

The measured values comply with those of 11 353 steel. Their mean values are given in Table 2.

After the mechanical tests have been performed, the pipeline sections with repair patches were welded together to one pressure body – Figure 4. Both ends were blinded with bottoms. In the surroundings of patches, the thickness of the tube wall was measured in nodal points of the network of 100 x 100 mm. In the surroundings of patch A, the lowest value of the wall thickness was 7.01 mm and the highest one was 9.09 mm. In case of patch B, the lowest and highest values were 6.81 mm and 8.89 mm, respectively. Considerable differences in the wall thickness were quite apparent.

Prior to the full scale hydrostatic burst tests, the patches were equipped with strain gauges by means of which the local deformations were measured during the test. The arrangement of strain gauges and the strain values evaluated as dependent on pressure during the full scale test are shown in Figures 5 and 7 (patch A), and in Figures 6 and 8 (patch B), respectively.

In the case of the repair patch A, six strain gauges were used - Figure 5, two of them oriented longitudinally (strain gauge 13 situated in the centre of the repair patch A and strain gauge 17 distant 200 mm from the centre of the repair patch A in the longitudinal direction). Three strain gauges were oriented in the circumferential direction (strain gauge 12 situated in the centre of

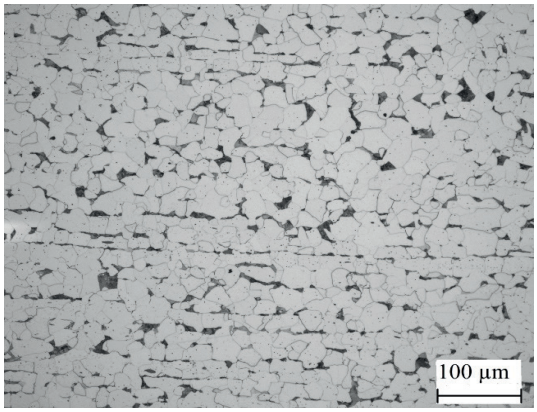

Figure 3 *Ferrite-pearlite microstructure of the pipe*

Figure 4 *Pipeline with two types of welded repair patches*

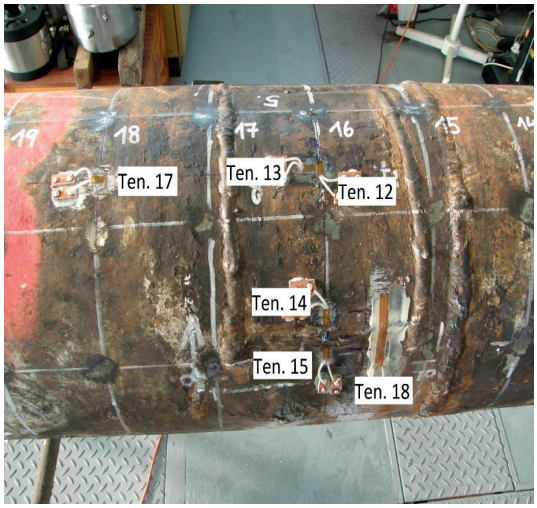

Figure 5 *Gage location on repair patch A*

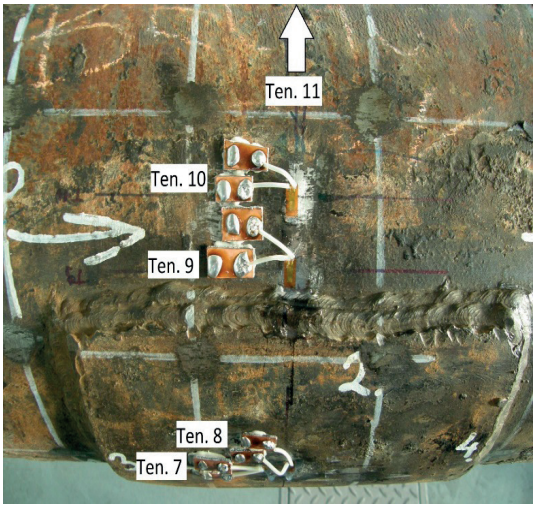

Figure 6 *Gage location on repair patch B*

the repair patch A, strain gauge 14 placed near the weld in which – according to NDT inspection – a lack of root fusion occurred along its whole length). Strain gauge 15 was situated also near the weld, but it was placed at the tube side. Special, very long strain gauge of the base length 50 mm was bonded across the whole weld.

For measurement of the deformation of the repair patch B, five strain gauges were applied - Figure 6. Four strain gauges were oriented circumferentially, one of them was used for measurement of the circumferential strain in the centre of the patch B (strain gauge 8), the remaining three were situated on the tube wall (strain gauges 9, 10, 11). One strain gauge was oriented longitudinally and was placed in the centre of the patch B.

The body equipped with strain gauges was first tested by 10 000 pressure cycles. The cyclic loading asymmetry approached to R = 0, maximum pressure approached to the operational one p_{max} = 6.3 MPa. During the first cycle, values from all the strain gauges were continuously recorded. All strain gauges showed linear dependencies of deformation on pressure and only very small residual deformations were observed after the unloading. The residual deformations were likely caused by some initial setting of the body on the supports. Analogous measurements of residual deformation were carried out at regular intervals after specific number of cycles. Fluctuation of deformations after 10 000 cycles is the same for all strain gauges. The changes arose rather from the temperature dilatations than from the real plastic deformation.

The full scale hydrostatic burst test was carried out with continuous measurement of deformations and one planned dwell at the yield point with regard to the biaxial state of stress p_{oy} = 16.8 MPa. The increase of deformation in both repair patches was linear up to 15.5 MPa. After that, a rapid increase of deformation occurred (see Figures 7 and 8). Destruction occurred at 19 MPa in the repair patch B, which was overlapped. The reached stress value 19 MPa was at least three times higher than the operational one. It was shown that in this specific case this type of repair ensured quite a good safety level.

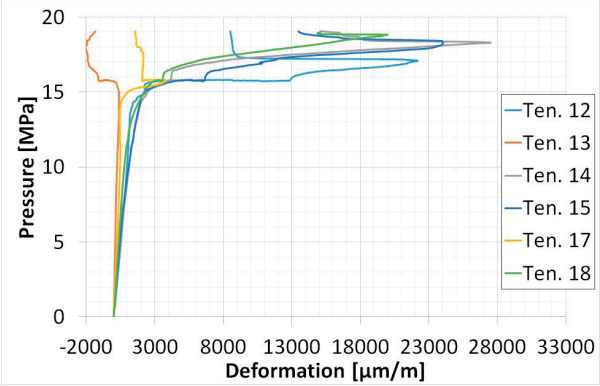

Figure 7 *Dependency of pressure on deformation of the patch A*

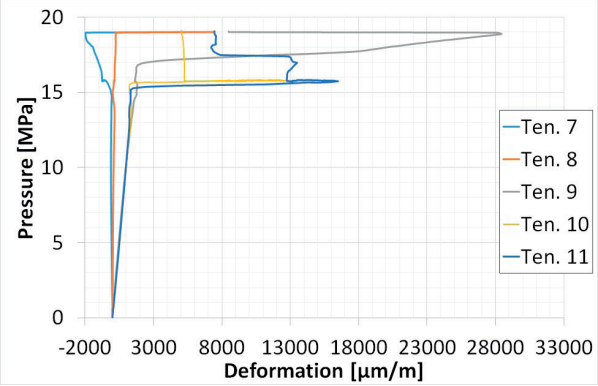

Figure 8 *Dependency of pressure on deformation of the patch B*

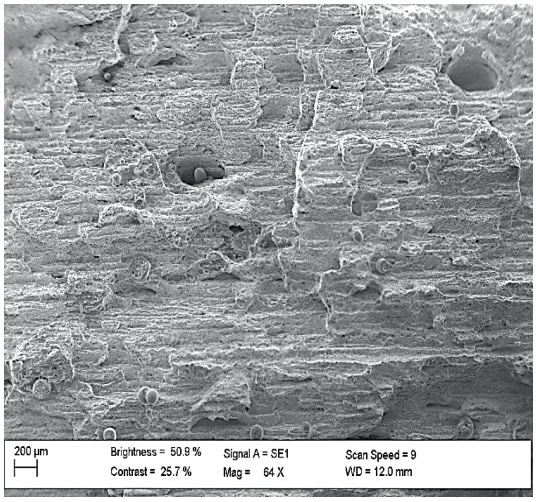

Figure 9 *Woody fracture*

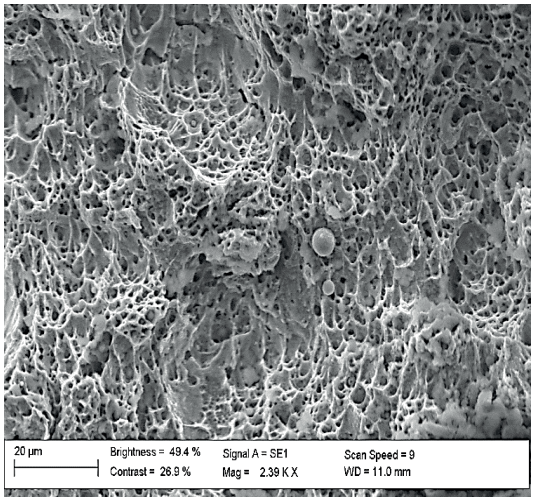

Figure 10 *Dimple morphology of woody fracture*

Area of the fracture initiation was cut out and investigated by means of the Zeiss EVO MA 10 scanning electron microscope. Failure initiation occurred at the fusion zone which represented the boundary between the weld and the heat affected zone and formed a notch effect in the structure. No structural defects (pores, cracks, inclusions) were found inside the area of failure initiation. The fracture type can be classified as woody fracture that occurs in wrought steels in connection with a bad metallurgical quality (Figure 9). It is known in general that woody fracture can be related to row-like structure, inhomogeneities in phosphorus and sulphur contents, presence of gas bubbles or hydrogen [11]. A more detailed analysis of the woody fracture revealed its dimple morphology (see Figure 10). In areas more distant from the fracture initiation, the shear fracture prevailed.

3. Conclusions

An extensive experimental programme aimed at evaluation of the effect of repair patches welded into the pipe wall during the gas pipeline repairs on pipeline integrity, strength and resistance to pressure cycles, was carried out. Limit states, safety and reliability of the pipeline with repairs made by the "welding-on" procedure were evaluated. In this specific case of the repairs, failure occurred at a pressure three times higher than the maximum service pressure. The failure of the tested pipeline section actually occurred in the repair patch, namely the patch B, which was an overlapping patch. This was a fairly unexpected result, because according to the NDT inspection, a fairly worse quality was indicated in the case of the single patch, just welded into the wall, not overlapped.

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Adam Balazs*

CRYSTALLIZATION KINETICS OF COMMERCIAL PLA FILAMENT

The Poly-Lactic Acid (PLA), the often used material for 3D printing and the rapid prototyping is very important in development process in automotive industry, as well. The commercial PLA filament was chosen and isothermal melt-crystallization and melting behavior was investigated by the DSC (differential scanning calorimetry). The PLA is a semi - crystalline biopolymer but the crystallization process is slow and sensitive to the changing of the cooling rate. Avrami equation was applied to analyze the crystallization. Arrhenius equation was used to calculate the activation energy and the equilibrium melting temperature was determined by the Hoffman-Weeks linear method. These results are the basis for further experiments.

Keywords: *3D printing, PLA, isothermal crystallization, DSC*

1. Introduction

The rapid prototyping is an important part of product development process in several industry sector include automotive. There are more 3D printing technologies, and they have become popular and available. Besides the multinational and small companies, everyone as a private person, can buy a 3D printer and make own products. One of the frequently used 3D printing technology is the fused deposition modeling (FDM), which is based on the melt extrusion. The FDM is a layer by layer method built by melted thermoplastic fibers [1]. A lot of polymers are optional for printing but there is one special type-the Poly-Lactic Acid, the PLA.

The PLA is a biodegradable and compostable polymer produced from renewable resources, such as starch and sugar. The PLA is thermoplastic, semi-crystalline polyester and it is based on the lactic acid (LA), which can be produced by fermentation or chemical synthesis. There are two polymerization routes, one is polycondensation from the LA, and the other is the ring-opening polymerization from lactide, it is the dimer of the lactic acid. The LA has two stereoisomers L-lactic acid and D-lactic acid. The commercial PLA are copolymers of PLLA, poly (L-lactic acid) and PDLLA, poly (D, L-lactic acid), but the L-lactic is the main fraction. Depending on the copolymer ratio, properties, glass transition and the melting temperatures can be different.

Nowadays, the environmental protection is very important so the biopolymers as the PLA have become the center of interest. The elevated environmental awareness and the good properties (high tensile strength and Young's modulus, good flexural strength) have resulted in an expanded use of the PLA for consumer goods and packaging applications; furthermore it is expected that novel technological advances will lead to the biopolymers market boom in transportation and automotive industry [2-4].

Unfortunately, there are some drawbacks, for example the PLA is brittle material and the crystallization process is slow. The mechanical, thermal and optical properties, depend on the crystallinity, so investigating the crystallization is very important [2-4].

In this work, the isothermal melt-crystallization and melting behavior of a commercial 3D printing filament from the PLA was investigated. The Avrami equation was applied to analyze the crystallization kinetics. This study will be of the basis for the further experiments like nucleation, to improve crystallization and provide better mechanical properties.

2. Experimental

2.1 Material

The used PLA is a filament with 1.75 mm diameter and metallic blue color from Orbi-Tech GmbH. The Orbi-Tech Company gives only general information. There is no datasheet. We know only the diameter and the color.

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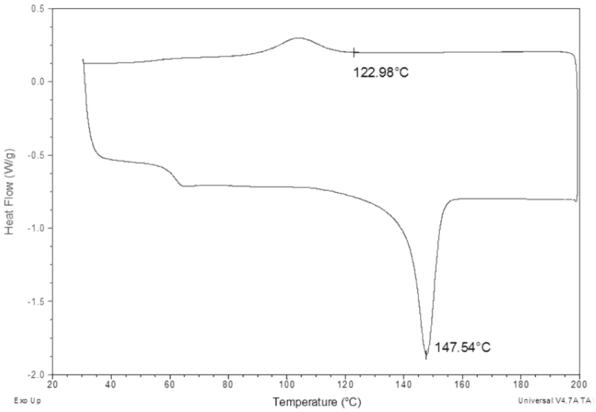

Figure 1 *Heat - flow versus temperature, the starting temperature of crystallization and the melting peak temperature*

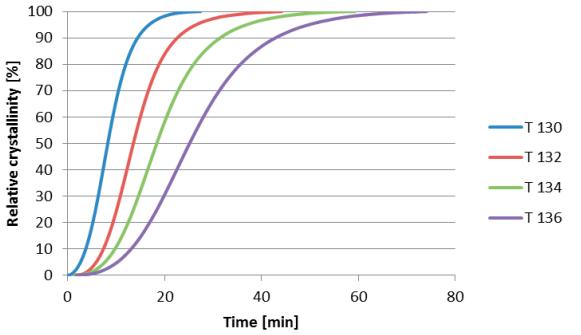

Figure 3 *Relative crystallinity as a function of isothermal crystallization time*

2.2 Method

The thermal behavior of the PLA was measured by differential scanning calorimeter (DSC), TA Q200 heat-flux DSC instrument, which was calibrated by Indium. The sample weight was 5.37 mg. The applied gas during the DSC scan was nitrogen; the using flowing rate was 50 ml/min. The temperature range was from 30 °C to 200 °C.

The first the sample was heated to 200 °C at a heating rate of 20 °C/min to eliminate any thermal history. Then the sample was cooled (by 5 °C/min) to the crystallization temperatures, which were 130, 132, 134 and 136 °C. After the set time of crystallization, heating scan of 20 °C/min was used. This heating rate is too fast, so there is no time for recrystallization [5-8].

3. Results and discussion

Determination of temperatures and the holding times of the isothermal crystallization can be quite difficult. Prior to the isothermal measurements, it is necessary to perform an anisothermal scan (Figure 1) to determine the starting temperature of crystallization. The endotherm curve shows the

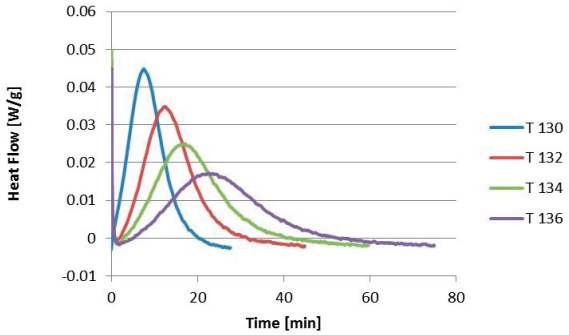

Figure 2 *Heat-flow versus time during isothermal crystallization*

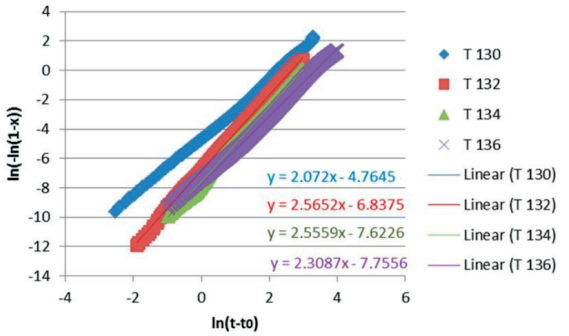

Figure 4 *Straight lines obtained by the Avrami equation*

melting, and the exotherm curve shows the crystallization. On the exotherm curve, when the line begin to change, it is the starting temperature of the crystallization.

The isotherm temperatures need to be higher than the start temperature of crystallization, but lower than the melting temperature. Several pre-tests were used to find the correct data, so in this work the first holding temperature was 130 °C. The applied temperature step was 2 °C from 130 to 136 °C.

Figure 2 shows the change of the heat flow versus isothermal crystallization time. The time zero (t_0) is that point when the real temperature reaches the setting temperature.

The asymmetrical shapes of the exothermic peaks suggest that the crystallization process presents some secondary crystallization. When the isothermal temperature was increased, the maximum of the heat flow was lower and the time of the crystallization was longer.

Figure 3 shows the relative crystallinity as a function of isothermal crystallization time.

The time to reach the end of the crystallinity increases with the increase of crystallization temperature. The change of the relative crystallinity with time can show the rate of the crystallization. The slope of the curve is reduced when the isothermal temperature increased and it means that the rate of the crystallization became lower.

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Table 1 Avrami exponent, rate constant and melting temperature versus crystallization temperature

$T_{c\,iso}$ [°C]	$T_{c\,iso}$ [1/K]	n	ln K	T_m [°C]
130	0.00363343	2.072	- 4.765	155.31
132	0.003626973	2.562	- 6.8375	156.71
134	0.003627052	2.556	- 7.6226	158.11
136	0.003630318	2.308	- 7.7556	159.22

Table 2 Relationship between Avrami exponent and geometry of crystallite [9]

Dimension	Geometry	n	
		athermic nucleation	thermic nucleation
1	Fibril (cylinder)	1	2
2	Lamella (disk)	2	3
3	Spherulite (orb)	3	4

The Avrami equation (1) was used to analyze the increment of the relative crystallinity with time (Figure 3):

$$x(t) = 1 - \exp(-Kt^n) \quad (1)$$

where x is the relative crystallinity, K is the rate constant of crystallization, t is the time and n is the Avrami exponent. The values K and n are considered to be diagnostic for the mechanism of crystallization [6-9].

After the relative crystallinity was transformed by the Avrami equation, almost the straight lines were obtained (Figure 4). The equation of the linear lines can show the Avrami exponent, which is the steepness and rate constant of the crystallization is the intersection of the y axis.

Table 1 summarizes the result derived from the Avrami analysis and the melting peak temperatures after the isothermal crystallization. The heating rate was 20 °C/min.

Table 1 Avrami exponent, rate constant and melting temperature versus crystallization temperature

The Avrami exponents were in the range of 2.1-2.6 for the temperature range of 130-136 °C, suggesting a change in crystal growth from two to three dimensional with athermic nucleation. The rate constant is reduced as expected by increasing the isothermal crystallization temperature [4, 6-9].

The activation energy of the crystallization process was determined from the rates of crystallization by the Arrhenius equation (2):

$$K = A\exp\left(-\frac{E_a}{RT}\right) \quad (2)$$

where K is the rate of crystallization, A is a constant, T is the crystallization temperature, R is the universal gas constant and E_a is the activation energy. The activation energy can be obtained from the slope of the plot of K as a function of reciprocal of crystallization temperature in Kelvin (Figure 5) [6-9].

The activation energy of this PLA is 670324.5 J/mol·K. The four points in Figure 5 are not collinear, so this activation energy is just an approximate value and further experiments are required.

After the isothermal crystallization, there were heating scans and the melting temperatures were measured. The applied heating rate was 20 °C/min. Figure 6 shows that if the isothermal crystallization temperature was higher, the melting peak temperature was higher too, because the crystallites became bigger and contain less mistakes [6-9].

The equilibrium melting temperature can be determined from the change of melting temperature. It is based on the linear method of Hoffman-Weeks (3):

$$T_m = T_m^0\left(1 - \frac{1}{\gamma}\right) + \frac{T_c}{\gamma} \quad (3)$$

where T_m is the melting temperature, T_m^0 is the equilibrium melting temperature, T_c is the crystallization temperature and γ is the lamella thickening factor. The linear method means that it is assumed that there is no lamella thickening. The equilibrium melting temperature was determined by the relationship between the apparent melting temperature and the crystallization temperature. The plot of T_m as function of T_c gives straight lines whose intersection points with the line $T_m = T_c$ determine T_m^0 (Figure 7) [5-9].

The equilibrium melting temperature of the PLA filament is 203.85 °C.

4. Conclusion

The commercial PLA filament was measured by the isothermal DSC method. The crystallization temperature range was between 130 and 136 °C using 2 °C steps. The Avrami equation was applied to analyze the crystallization process. The Avrami exponent showed that the nucleation is athermic and the geometry can

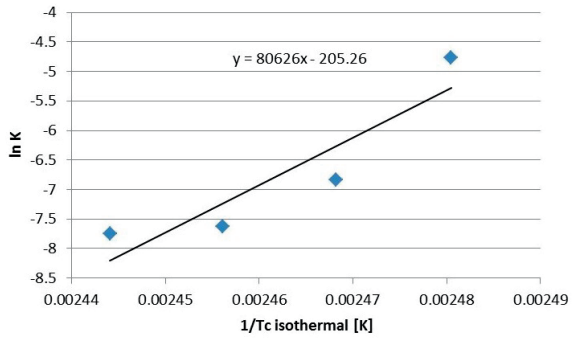

Figure 5 *Rate constant versus reciprocal of isothermal crystallization temperature in Kelvin*

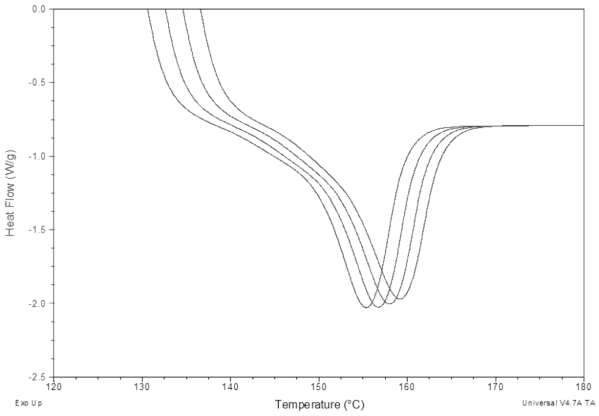

Figure 6 *Changing of the melting peak temperatures*

be change from 2 dimension to 3, but the transformation is not complete. The activation energy was calculated from the

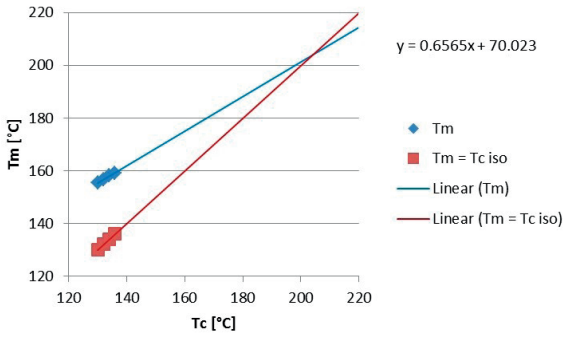

Figure 7 *Determination of the equilibrium melting temperature*

change of rate constant by the Arrhenius equation. Finally, the equilibrium melting temperature was determined from the melting temperature by the Hoffman-Weeks linear method. These results are the basis for further experiments, like nucleation to improve crystallization and provide better mechanical properties for the 3D printing model.

Acknowledgement

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Attila Bata - Gergely Toth - Karoly Belina*

MELT SHEAR VISCOSITY OF ORIGINAL AND RECYCLED PET IN WIDE RANGE SHEAR RATE

Among the plastic materials, the PET is the most often used one. Collecting of the material to be recycled is partially solved. This way we have great quantity of regrinded PET. During the regrinding the structure of molecules changes, and these properties can be measured by rheological methods. Polymer melts are-newtonian fluids and the flow curves of the materials can be used to characterize the molecular weight and the molecular weight distribution. This research is focused on the characterization of original and regrinded PET materials. Inherent viscosities (IV) were determined to characterize the materials. Flow curves of pure and blended materials were measured at different temperatures.

Keywords: *PET, regrind, oscillation rheology, capillary viscosity*

1. Introduction

Nowadays polyethylene terephthalate (PET) is one of the most common plastics, because of its widespread use. There are certain places where recycled PET is already used and produced. Our goal is to increase the quantity of the recycled PET. From the recycled materials the new bottles, products can be made. This requires a development path and a more sophisticated technology since it is not easy to determine for once used bottle what was stored in it, how it was used previously [1]. PET is a hygroscopic thermoplastic polymer, therefore drying process is very important, since it affects the rheological properties of the material, the subsequent processing, and the product characteristics [2]. The rheological analysis mentioned in this paper is of polyethylene terephthalate (PET) base material, in which a specific raw material - a melt viscosity of structural, elastic and viscoelastic behavior was investigated. The study was carried out by ARES-G2 type oscillational rheometer, and Goettfert Rheograph 25 capillary rheometer with which the material was examined at low and high shear rate. The original granule wereanalyzed between 270-290 °C. Then, the original raw material was processed BT injection molding machine and then it was granulated again. There was a full investigation at the same temperatures. The measuring values are presented on diagrams and from these the conclusions were drawn.

2. Material

RAMAPET N180 is a general purpose, non-reheat PET resin for bottles, film, thermoformed containers and other transparent applications. It has good optical properties, the mechanical properties are representative for PET resin. The PET is hygroscopic in little extent, and since moisture adversely affects the IV during the melt processing of the polymer, it must be dried prior to molding. Undried PET pellets can contain up to 0.2 % (2000 ppm) of moisture. After drying, the moisture content is typically below 50 ppm [3].

PET has good surface hardness, stiffness, and dimensional stability. It has good gas barrier properties and good chemical resistance except for alkaline materials (which hydrolyze it). Its structure varies from amorphous to fairly high crystalline; it can be highly transparent and colorless but thicker sections are usually opaque and off - white. The PET material is heat - resistant until 180 °C, it does not decrease in strength, its melting temperature is around 260 °C. Above 250 °C the crystallite section is continuously disappearing, so the melting process of the material could be observed. Usually, the material is processed in the molten state, so it is worth to study the rheological properties only above this temperature [4]. The measurements were performed at 270 °C, 280 °C and 290 °C.

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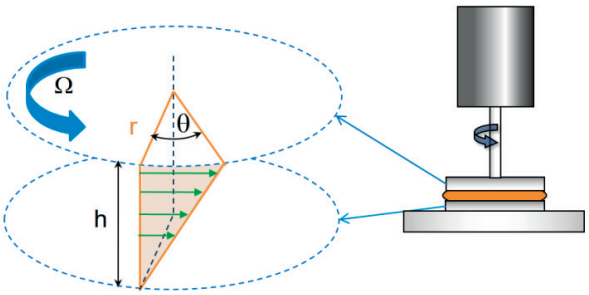

Figure 1 Rotation viscometry CMT conceptual layout and marking system [5]

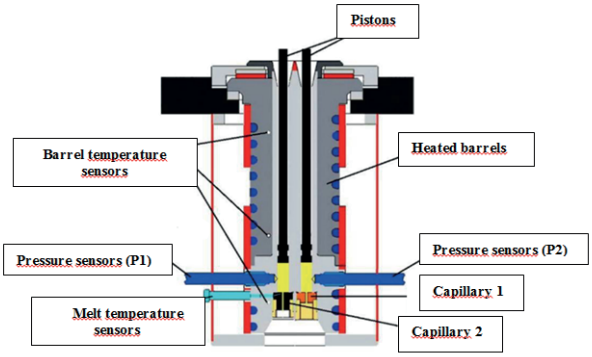

Figure 2 Capillary rheometer conceptual layout [7]

3. Method

3.1 The rotational viscometry

Our measurements were carried out by a shear viscosity investigation method; that means a low range of shear rate and temperature steps near the processing temperature. This was the reason why the rotational viscometry was measured in the low shear rate range (0.05-20 ^{1}/s). With the rotational viscometry we could measure torsion flow in a polymer melt between parallel plates. The measuring technique conceptual layout is shown in Figure 1. The CMT means combined motor and transducer concept [5].

From the marking system the stress, deformation and deformation rate components can be calculated with the equations described below:

$$\sigma = \frac{2}{\pi r^3} \times M \quad (1)$$

$$\gamma = \frac{r}{h} \times \theta \quad (2)$$

$$\dot{\gamma} = \frac{r}{h} \times \Omega \quad (3)$$

where **r** is the circular plate radius; **h** is the gap between the plates; **θ** is the driving engine rotation (rad); **Ω** is the driving engine angular speed (rad/s) and **M** is the torque (μNm) [5].

The stress and deformation rate can be calculated from Equations (1) to (3) and the shear viscosity can be defined. It is a frequent measuring technique to determine shear viscosity for small molecular liquids, or oils and thermoplastics at low shear rate. ARES G2 is equipped with Forced Convention Oven (FCO). With this accessory materials can be examined at higher temperature (to 600 °C) and the degradation process can be monitored. For our testing TA Ares G2 type rotation viscometer was used with cone - plate geometry in 25 mm diameter. The trim gap was 0.09 mm, while the measuring gap was 0.04 mm. SMT (Separate motor and transducer) layout was used. In this type of rotation viscometer, the drive engine and the transducer are separated [6].

3.2 The capillary rheometry

The capillary rheometer is a measuring device in which the shear viscosity of thermoplastics can be measured. The shear rate ranges were between 100 and 10 000 ^{1}/s near to the processing temperature [7]. The Goettfert Rheograph 25 capillary rheometer was used for the measurements. The measuring method is based on continuous melt flow in known geometry capillary (dies), while the pressure drops is measured between the capillary inlet side and the atmospheric pressure (Figure 2).

The variable parameters were the barrel temperature and the piston speed (which means the deformation rate). In this case, the shear viscosity depends on temperature and deformation (shear) rate. In our tests, the shear rate was changed between 100-10.000 ^{1}/s and the barrel temperatures were changed in three steps around processing temperature, that is for the material of the supplier recommended, at 270-290 °C. The measuring method used two other geometry capillaries because of the entrance and exit effects (pressure drop). With this equipment in one step the Bagley correction can be done, which corrects the pressure drop and gives the real shear viscosity [8].

4. Results

4.1 The rotational viscometry

The viscosity curves were determined in function of the shear rate. The measurements were performed with original material and with recycled material. The viscosity of the original material is shown in Figure 3 at different temperatures.

The curves measured at different temperatures are not the same. It can be observed that the viscosity is the highest at 270 °C. The higher is the temperature, the lower is the viscosity. From the differences of the curves, the transformation of the molecular structure can be determined. The viscosity of the recycled materials is shown in Figure 4.

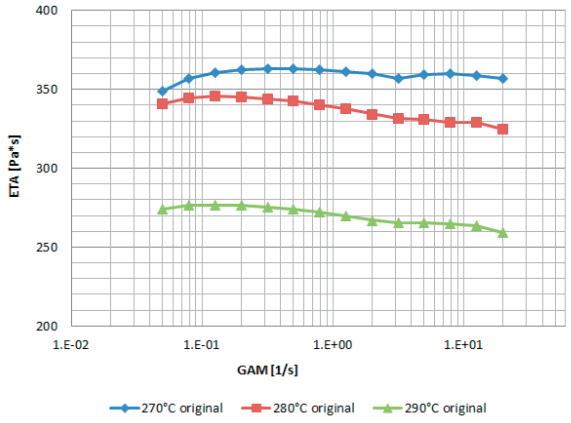

Figure 3 Shear viscosity curves of original PET

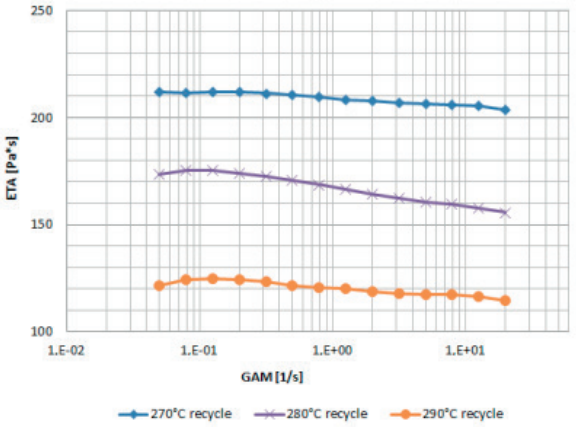

Figure 4 Shear viscosity curves of recycled PET

The recycled material shows the same tendency (Figure 4). Increasing the temperature the viscosity decreases. During the recycling and grinding processes, the molecules in the materials can easily degrade. This is caused by the rising thermal and mechanical strain during the processes. The degradation makes the molecular weight lower, so the molecular density dispersion widens. The polymer with shorter chains can move easier. Above the glass transition temperature the segments of the polymer move increasingly. The viscosities of the original and recycled materials are shown in Figure 5.

In each diagram the viscosity curves show a tipical form (Figure 5). In the curves of newtonian fluids it could be recognised that the curves are almost linear and do not depend on the shear rate. In our measurements, the viscosity curves approach the horizontal line, but they decrease within a small range. It was confirmed that these materials behave like non newtonian fluids. At a constant temperature, the difference between the original and the recycled materials approaches 150 Pa*s. The impact of the recycling is the continously decreasing molecular weight. The lower molecular weight means easier molecular movement.

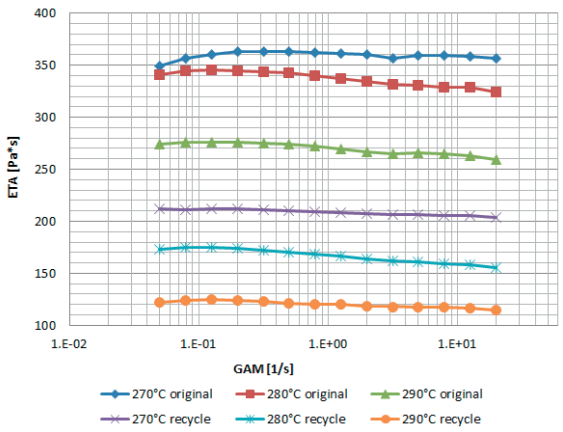

Figure 5 Shear viscosity curves of original and recycled PET

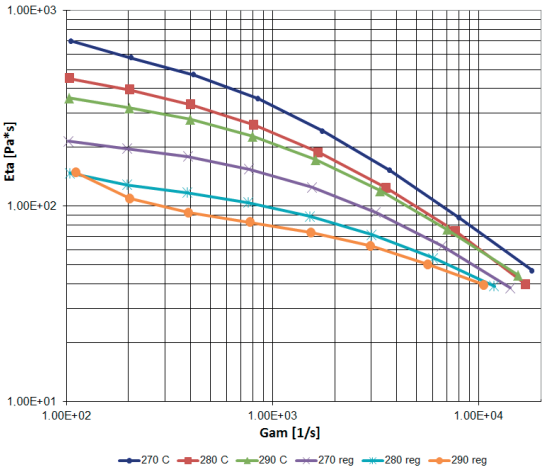

Figure 6 Shear viscosity curves of original and recycled PET

4.2 The capillary rheometer

The measurements were performed with original material and with recycled material. The viscosities of the original and recycled materials are shown in Figure 6.

Comparing the data to the 270 °C viscosity curve in the lower shear range: There is a ~30-35 % reduction at 280 °C, and at 290 °C we can see a 40-50 % reduction. As we approach the larger shear ranges (10000-18000 ^{1}/s) the differences are reduced: at 280 °C ~15-18 %, while at 290 °C ~7-3 %. In the initial shear speed range, the recycled material shows a 70 % reduction at 270 °C, while in the higher shear range this value shows a 15%-30 % reduction. We could observe the following viscosity reductions in the results: at 280 °C, ~ 65 % and at 290 °C ~ 50 %. Although the initial viscosity values at 290 °C show a different tendency compared to the curve we measured at the previous two temperatures, this can be attributed to a measurement error with a great certainty. From these values we can conclude that we have to consider the viscosity change of the material during the recycling,

because with such a degree of deviation we could assume that the material will not be able to withstand the requirements, which are set by design.

5. Conclusion

In our investigation one type of material was measured, but at different temperatures and in different conditions. An original and a recycled material were examined. The measurements were performed by an ARES G2 rotational rheometer and a Goettfert Rheograph 25 capillary rheometer at 270 °C, at 280 °C and at 290 °C. The shear rate was changed from 0.05 to 20 ^{1}/s and 100-10 000 ^{1}/s. It was determined that the viscosity of the recycled material is lower than the value of the original material at each temperature. The molecules of the recycled material were supposed to shorten during the grinding process. If the temperature increases, the shear viscosity decreases, but there was no linear correlation between these two variables. The structure viscous behavior of the polymer melt was revealed. This area offers lot of possibilities for further research, so we intend to continue investigations.

Acknowledgement

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komunikácie
COMMUNICATIONS

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VIBRATION ANALYSIS BY THE GABOR TRANSFORM METHOD

This paper deals with description and application of the Gabor transform for vibration analysis. This transform belongs to the group of linear time-frequency processes. Thanks to its properties, it may be successfully used in the area of non-stationary and transitional signals describing various natural processes. Use for analysis of vibrations caused by railway transport represents quite an interesting application area of this transform. This paper contains mathematical analysis of the transform, a case study and practical experience obtained, as well as recommendations for its practical use.

Keywords: *railway switches, rail fastenings, vibration, time-frequency analysis, linear time-frequency transform*

1. Introduction

Generally, the time series (measured signals) analysis may be implemented in the time domain, in the frequency, or the time-frequency area. Selection of the appropriate domain depends on the signal type, or the analysis type, and the required result.

The information on any technical, physical or other processes is represented by the time changes in the immediate value of the appropriate physical quantity described by the signal [1]. At the time level, there are quite a lot of methods that may be applied to the measured signal. Among the best-known, there are various sorting methods, searching for local and global minimum and maximum values relative to time, correlation analysis, analysis of signal attenuation and, in particular, various statistical methods. However, direct interpretation of time amplitude representation is neither easy nor expedient in many applications. That is why the signal transformation from the time into the frequency domain is often used. The Fourier transform is the most frequently employed method of conversion from the time to the frequency domain. If the measured signal is a non-stationary one (the frequency content changes in time), the usual process of frequency analysis may not be used for interpretation (localization of frequency components), but other transformation processes and calculation methods should be employed.

2. Time-frequency analysis

The so-called time-frequency transform is determined for connection of information that may be obtained from the time and frequency domains. They enable determination of the frequency behaviour in time or time distribution of the frequency spectrum. It means that one of possible methods of data processing is use of the so-called time-frequency transforms. Linear time-frequency transforms represent a very important group of the time-frequency processes. Decomposition of the analysed signal into elementary time-frequency units is a basic principle of calculation of all the linear time-frequency processes. It means that the signal may be presented in the time-frequency domain as *N*-multiple sum in accordance with the following equation [2, 3]

$$x(t) = \sum_{k=0}^{N-1} a_k \cdot \phi_k(t) \tag{1}$$

where $x(t)$ is the signal, $\phi_k(t)$ are time-frequency units (basic functions) and a_k are the corresponding coefficients. The time-frequency position of the basic functions and the amplitude of their coefficients describe the signal in the time-frequency domain. A certain variant of the Short-time Fourier Transform, i.e. the Gabor transform, represents one of interesting processes from the group of linear time-frequency processes.

The Short-time Fourier Transform (STFT) localizes the frequency components in time with a constant (linear) discrimination. The basic idea of this method consists in portioning the signal into sufficiently small samples that may

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be thought of as being stationary (or ergodic). This is done by multiplying the signal by a certain window function. The Fourier transform is applied to the resulting cut-out part of the function with the window moving as time goes by. In this way the short time Fourier sort of trades off the time representation for a frequency one. It may be defined by the following integral [3, 4]

$$STFT(\tau,f) = \int_{-\infty}^{\infty} [x(t) \cdot g^{*}(t-\tau)] \cdot e^{-j \cdot 2 \cdot \pi \cdot f \cdot t} \tag{2}$$

where g is a window function, * denotes the complex conjunction, t is time, τ the time shift of the window, $x(t)$ the signal function and STFT(τ,f) its time-frequency representation. Equation (2) suggests that, generally, the short time Fourier transform is linear and complex. If a discrete data sequence is processed, integral Equation (2) has to be modified into a summation form according to Equation (3) as a function of frequency $f = k.\Delta f$ and shift $\tau = r.\Delta t$

$$STFT(r,f) = \sum_{n=0}^{N-1} x(n) \cdot g[n-r]^{*} \cdot e^{\frac{-j \cdot 2 \cdot \pi \cdot k \cdot n}{M}} \tag{3}$$

where $r = 0, 1, 2, \ldots, \frac{N-M}{S} - 1$ and $k = 0, 1, 2, ..., M$. Here, N, M, and S denote the lengths of the data sequence, window sequence and shift, respectively. It should also be noted that the window segments may overlap.

The time-frequency plotting of the short-time Fourier transform is subject to certain limitations. The resulting time and frequency resolutions are limited by the Heisenberg's uncertainty principle [4].

$$\Delta t \cdot \Delta \omega = const. \tag{4}$$

The time and frequency resolution cannot be infinitely small at the same time and their proportion can be expressed by the above principle of indeterminacy. The signal component cannot be represented by a point in a time-frequency space. In a given time-frequency domain, its position inside the rectangle $\Delta t \, . \Delta \omega$ can be determined. The relationship between the time period Δt of the window function $g(t)$ and the bandwidth $\Delta \omega$ of the window function $G(\omega)$ in the frequency plane is given by the following equations. For Δt, we have:

$$\Delta t^{2} = \frac{\int_{-\infty}^{\infty} (t-t_0)^{2} \cdot |g(t)|^{2} \cdot dt}{\int_{-\infty}^{\infty} |g(t)|^{2} \cdot dt} \tag{5}$$

where t_0 can be calculated using the equation

$$t_0 = \frac{\int_{-\infty}^{\infty} t \cdot g(t)^{2} \cdot dt}{\int_{-\infty}^{\infty} |g(t)|^{2} \cdot dt} \tag{6}$$

Note that the denominator in Equation (5) expresses the energy of the weighing window function $g(t)$. Equations (5) and (6) are analogous to those of the probability theory defining mean value and variance. By analogy, the bandwidth in the frequency domain can also be calculated using the equation

$$\Delta \omega^{2} = \frac{\int_{-\infty}^{\infty} (\omega-\omega_0)^{2} \cdot |G(\omega)|^{2} \cdot d\omega}{\int_{-\infty}^{\infty} |G(\omega)|^{2} \cdot d\omega} \tag{7}$$

where ω_0 is given as

$$\omega_0 = \frac{\int_{-\infty}^{\infty} \omega \cdot |G(\omega)|^{2} \cdot d\omega}{\int_{-\infty}^{\infty} |G(\omega)|^{2} \cdot d\omega} \tag{8}$$

Thus, the result of the Short-time Fourier transform is given by the choice of the window function and its width.

The Gabor transform is a special-type of the short-time Fourier transform. It uses a Gauss function to partition the signal into sufficiently small samples, which can be thought of as stationary (or ergodic). The use of a Gauss function brings some advantages. Particularly useful is that it generates the least time-frequency window possible given the Heisenberg's uncertainty principle. The Gauss function and its Fourier transform are defined as follows [4]:

$$g(t) = \frac{1}{s} \cdot e^{\frac{-\pi \cdot t^{2}}{s^{2}}} \tag{9}$$

$$G(\omega) = \frac{1}{\sqrt{\pi}} \cdot e^{\frac{-s^{2} \cdot \omega^{2}}{4 \cdot \pi}} \tag{10}$$

where $g(t)$ is the Gauss function, $G(\omega)$ its Fourier transform, s is the width of the Gauss function (scale) and ω is frequency. Substituting into (5) and (7) yields the following equations for the parameters Δt and $\Delta \omega$ of the window function:

$$\Delta t^{2} = \frac{s^{2}}{4 \cdot \pi} \tag{11}$$

$$\Delta \omega^{2} = \frac{\pi}{s^{2}} \tag{12}$$

Thus, using (11) and (12), we can define the Heisenberg's uncertainty principle for the Gabor transform by:

$$\Delta t \cdot \Delta \omega = \frac{1}{2} \tag{13}$$

The Gabor transform is among the basic and fast methods used the for time - frequency analysis of signals. Its precision and fitness are largely dependent on the width of the Gauss function used and on the way the neighbouring segments overlap.

Plotting the values of the Gabor transform into a graph will provide spectrograms. These may be displayed in a 3D space

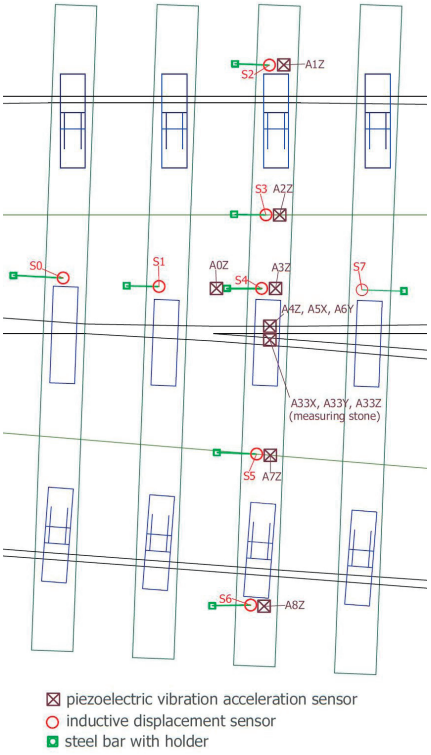

Figure 1 *Sensor placement methodology*

(frequency, time, amplitude or frequency, time, spectral density). The axonometric projection is very clear but, in many cases, may lead to ambiguities. This is the reason why the two-dimensional mapping is used by means of density spectrograms in which a colour shade is assigned to each amplitude or spectral function value. Using iso-lines is another option. In some sophisticated cases, it may be of some use to complete the time-frequency plot of a spectrum by frequency and time sections. In this way, a strong graphical support of the time-frequency analysis is obtained.

3. Case study

Hereafter we present use of the Gabor transform in the area of railway engineering. It is a transient process analysis, vibration analysis.

Permanent pressure to increase the transport speed and the operational load on the railway resulted in huge development of new technologies. The decision on modernization of the corridors became the impulse for development of all areas of the railway transport, either in the area of vehicles or infrastructure. In accordance with the above-mentioned trend, application of new experimental processes should continue for evaluation of the quality and suitability of individual constructional solutions.

The superstructure vibrations are influenced by its quality, operational and technical conditions, climatic events and, most

Figure 2 *View of the measurement site*

importantly, by dynamic load on the railway vehicle axle. The fact also relates to construction of the railway switches representing the key points of the railway roads.

The measurement methodology, certified by the Ministry of Transport of the Czech Republic is available for measurement of dynamic effects influencing the railway switches. The certified methodology was developed by the team of engineers of Brno University of Technology, Institute of Railway Structures and Constructions, under the leadership of prof. Smutny [5]. The methodology (see Figure 1) consists of three parts [6].

The first of them deals with measurement of the construction movements. Particularly, it is an analysis of shifts of individual parts of the switches under load. The second part deals with distribution of vibrations around the crossing nose and replacement of the switches and namely with effect of the vibrations on the bed of ballast. Within the third part, measurement of the force application is performed. Application of the time-frequency analysis of the obtained data forms a part of the interpretation methodology.

The two switches, namely switches No. 3 and No. 4, were selected for presentation of the Gabor transform application in the analysis process of dynamic forces from the train units. The selected switches are located on the "trebovsky"' throat of the Usti nad Orlici station and it represents a simple crossover (Figure 2). Except for the elasticity of the fastening system [7], the two switches are identical. The No. 3 switch is fitted with a new rail fastening type that is more elastic and better absorbs vibrations transmitted from the rail to the bed of ballast.

Passage of the unit SC Pendolino at 160 km.h^{-1} was chosen for comparison of dynamic stress in both of the switches. Due to shortness of the paper the authors concentrate on analysis of the data read from the sensor located on the sleeper under the crossing nose. It provides the vertical components of acceleration of vibrations in the fixation point. The analysis is given in figures consisting of three diagrams. The upper diagram describes behaviour of acceleration of the vibrations in time. The diagram

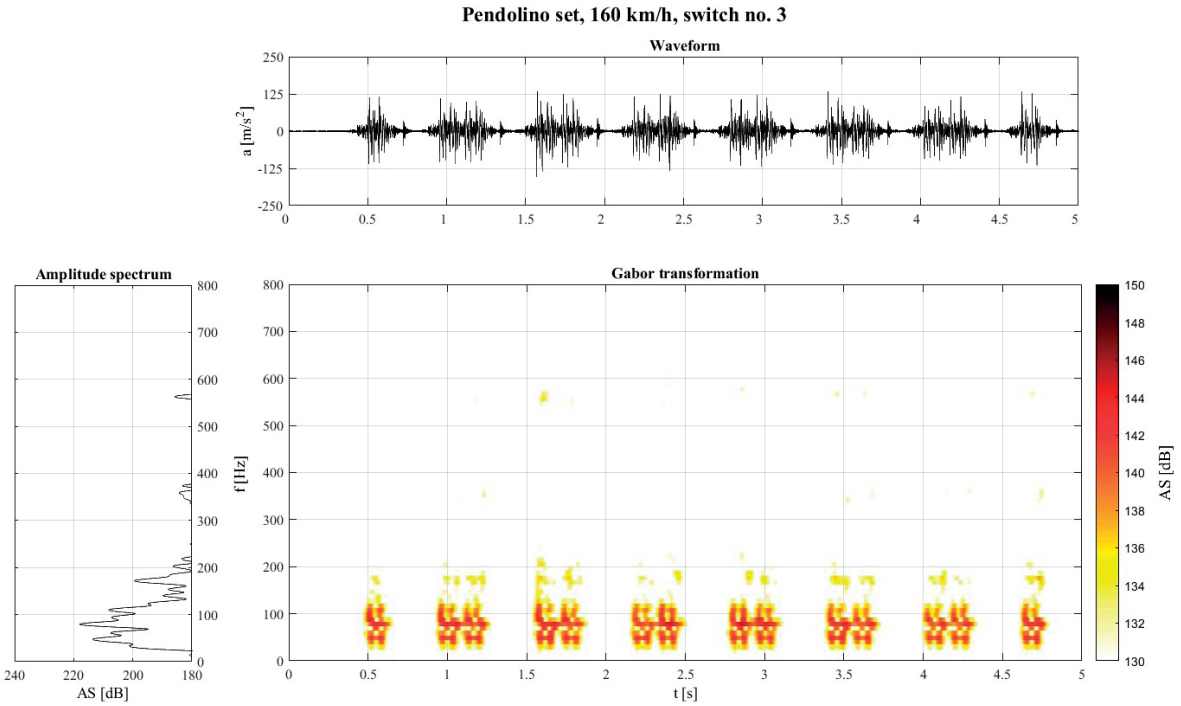

Figure 3 *Time history of acceleration (up), amplitude spectrum (left) and jointed time - frequency spectrum in the vertical direction (right) for switch No. 3*

to the left gives the amplitude spectrum of the vibration response calculated using the Fourier transform. The diagram in the middle gives the 3D image of the time-frequency behaviour of the vibration response amplitude spectrum. The values of the vibration acceleration in the decibel scale are shown in the middle graph as different colour areas, while the maximum value is black.

It is obvious from the diagrams of acceleration behaviour in time (Figures 3 and 4, the upper diagram) that the higher acceleration values were obtained in the No. 4 switch (usual rail fastening type) if compared to the No. 3 switch with the new rail fastening type. In this case the diagrams show the worse geometry of the transfer from the wing rail to the crossing nose, the higher dynamic shock and this way the worse absorption of the vibration source, i.e. passage of the wheel through the crossing nose.

The diagrams on the left (Figures 3 and 4) show the amplitude spectra of the vibration acceleration, calculated from the time signals using the Fourier transform. The amplitude spectra are presented in the frequency interval from 1 Hz to 800 Hz, while the frequency values up to approx. 600 Hz are important for dynamic stress on the permanent way construction parts.

From the amplitude spectrum diagram of the No. 3 switch it is obvious that there are four important frequency bunches in the spectra. The first one is from approx. 30 Hz to 60 Hz with maximum at 40 Hz; the second one is in the interval from 75 Hz to 100 Hz with maximum at 80 Hz; the third one from 100 Hz to 130 Hz with maximum at 110 Hz, and the fourth one from approx. 180 Hz to 210 Hz with maximum at 180 Hz. It is obvious from the frequency spectrum, obtained from the signal measured at the No. 4 switch, that the frequency bunches are wider, with higher maximum spectrum values. It may be concluded from the spectra that they show more complex vibration processes in the area of passage of the wheels through the crossing nose and higher energy to the disadvantage of the switch with the usual rail fastening system (No. 4).

The colour spectrograms calculated by application of the Gabor transform were used for evaluation of vibrations in the time-frequency domain. It concerns the diagrams in the middle of the figures No. 3 and No. 4. Extreme values of the vibration amplitude spectrum are depicted in the diagram as small red areas corresponding to time intervals of the wheel (axle) passage over the sensors. It is obvious from the diagrams that the time occurrence of important frequency components in the spectrum is different in the two constructions. In the diagrams, it may be identified at which moment the appropriate process occurred (which wheel, axle participates) and which frequency components relate to the process. It means that the linear time-frequency analysis provides the true and correct data complementing the conclusions obtained from the time and frequency analysis.

Finally, we may state that from both, application of the whole methodology and the results obtained from the sensor located on the sleeper under the crossing nose, the positive effect of the more elastic rail fastening is evident. It better absorbs the peak values of the vibrations acceleration upon transfer from the wing rail to the sleeper and the bed of the ballast.

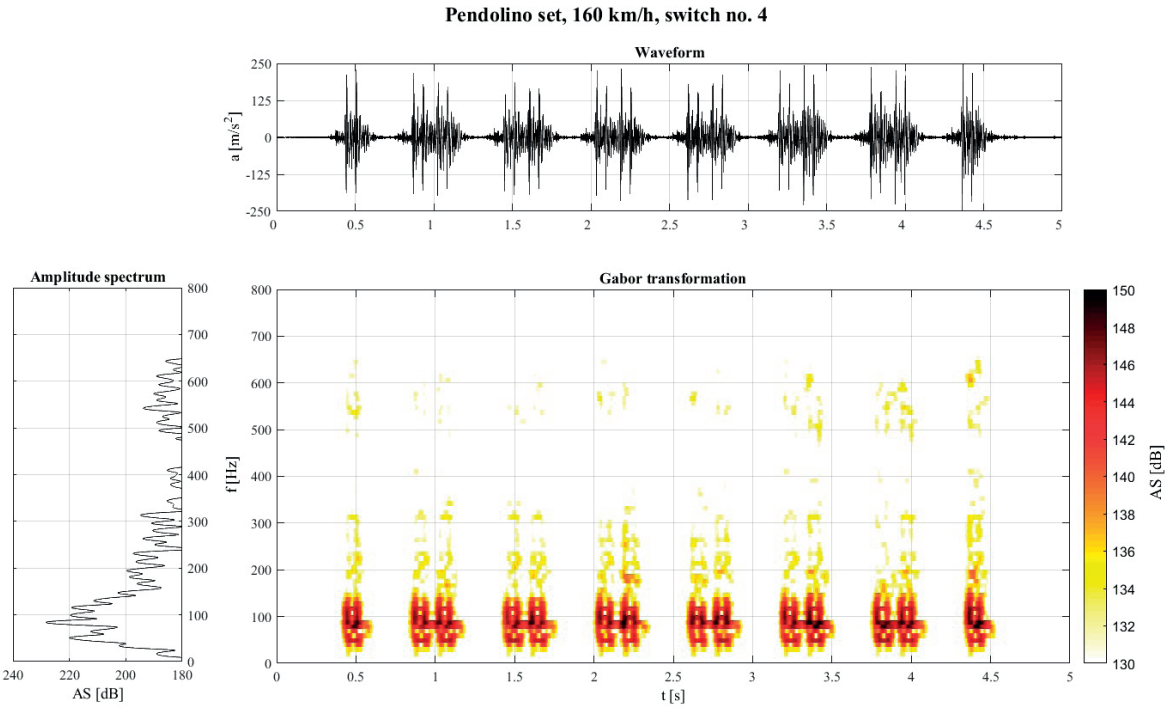

Figure 4 *Time history of acceleration (up), amplitude spectrum (left) and jointed time - frequency spectrum in the vertical direction (right) for switch No. 4*

4. Conclusions

If compared to other methods, the time-frequency analysis enables time localization of the frequency components contained in the measured signals. This way it enables overall view of the transition or non-stationary characteristics of the analysed processes.

As a benefit, the Gabor transform enables rapid calculation and satisfactory time-frequency resolution. A certain disadvantage of the method is the fact that the resulting resolution in time and frequency is limited by the so-called Heisenberg uncertainty principle. It means that the signal frequency component may not be presented as a point in the time-frequency space, but its position may be determined only inside the rectangle Δt . Δf in the given time-frequency domain. It should be noted that Δt represents a minimum time interval or a time step, while Δf represents the minimum frequency interval or the frequency step. In spite of the small disadvantage the Gabor transform may be recommended as one of the basic methods of the analysis of non-stationary signals. It must be said that in practice the process often proves successful if the signal is processed with the Gabor transform with additional frequency section first. This enables to obtain the basic information about the given signal in the time, frequency and time-frequency domains. An analysis of the obtained results may serve as a basis for selection of a more advantageous transformation for subsequent analysis.

Finally, it may be stated that the used methodology provides good results and conclusions. The measured and calculated values are accurate enough and provide sufficient informative value. It may also be stated that the up-to-date signal analysis means that the Gabor transform, made the first-rate processing of the measurements possible. Based on the interpretation of results, it may be said that the new rail fastening system (with different rail pads, which reduce the overall stiffness of the track) in the No. 3 switch, seems to be very promising. It shows a positive effect on decrease of dynamic effects on the sleeper and the bed of ballast.

Acknowledgments

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LIABILITY IN AUTONOMOUS VEHICLE ACCIDENTS

Nowadays, due to the constant change in the society's expectations regarding transportation, the main area of automotive development is the implementation of autonomous vehicle control functions. While with the gradual introducing and spreading of autonomous functions-even based on the previous experience-the decrease of the number of traffic accidents is expectable, parallel we have to prepare the emergence for the new types of accidents, in which autonomous vehicles will be involved. Needs of follow-up examination and reconstruction of such type accidents makes necessary the general use of the event/accident data recorders in road vehicles and application of the new methods and tools in accident reconstruction and examination of causes of accidents. Examining a road accident it is necessary to investigate the liability issues, as well, what requires new approaches and developing of a uniform practice.

Keywords: *autonomous vehicles, driver assistance systems, accident reconstruction, distribution of liability, EDR*

1. Introduction

Today, society's needs and expectations regarding transportation are undergoing major changes. In order to satisfy the demand of maximizing traffic density, minimizing the number of accidents, optimal utilization of natural resources, minimizing environmental damage, etc. vehicles are necessarily equipped with more and more driver assistant systems, which-in addition to the above-unburden and partially take over the task of the driver. The wide spreading of fully autonomous vehicles will be a determining stage in the development of these systems. Despite the technological progress, occurrence of traffic accidents in the future is unavoidable. Novel causes of accidents are expected in connection to traffic accidents between the manned (driven by a human driver) and autonomous vehicles and between autonomous vehicles. To determine the causes of these types of accidents imposes the novel requirements for accident analysis experts. The development of vehicle systems, especially electronic systems, makes it inevitable to record data related to the operation or malfunctions of those systems, and to make those data accessible for accident analysis experts.

Autonomous vehicles, accident analysis and examination of causes of accidents are the key research areas of our Department.

The aim of this article is to review the current legal and technical situation regarding traffic accidents related data, the expected trend in vehicles development and the EDR systems (Event Data Recorder, also known as the Crash Data Retrieval) and to make a proposal about the data-set necessary for the effective accident analysis related to autonomous vehicles.

2. The development of vehicles, the concept of autonomous vehicles

Nowadays, one of the most important aims of development processes regarding vehicles control is autonomous vehicles. Based on conservative scenarios, the probable value of the ratio of fully autonomous vehicles referring to the number of all vehicles placed on the market as new is 15-20 %, with the assumption that the current economic trends continue and there will be no significant changes in the legal environment.

Based on optimistic scenarios, this rate might even be 25–30 %, assuming more flexible safety and technical specifications, increasing state funding and the emergence of the new, innovative market operators.

The SAE (Society of Automotive Engineers) defined the technological levels, which exist between the non-autonomous and fully-autonomous vehicle-systems [1]. These levels and their attributes can be seen in Figure 1.

Cars which are only equipped with the driver assistance systems like lane departure warning (LDW), frontal collision warning (FCW), etc. cannot be considered as autonomous

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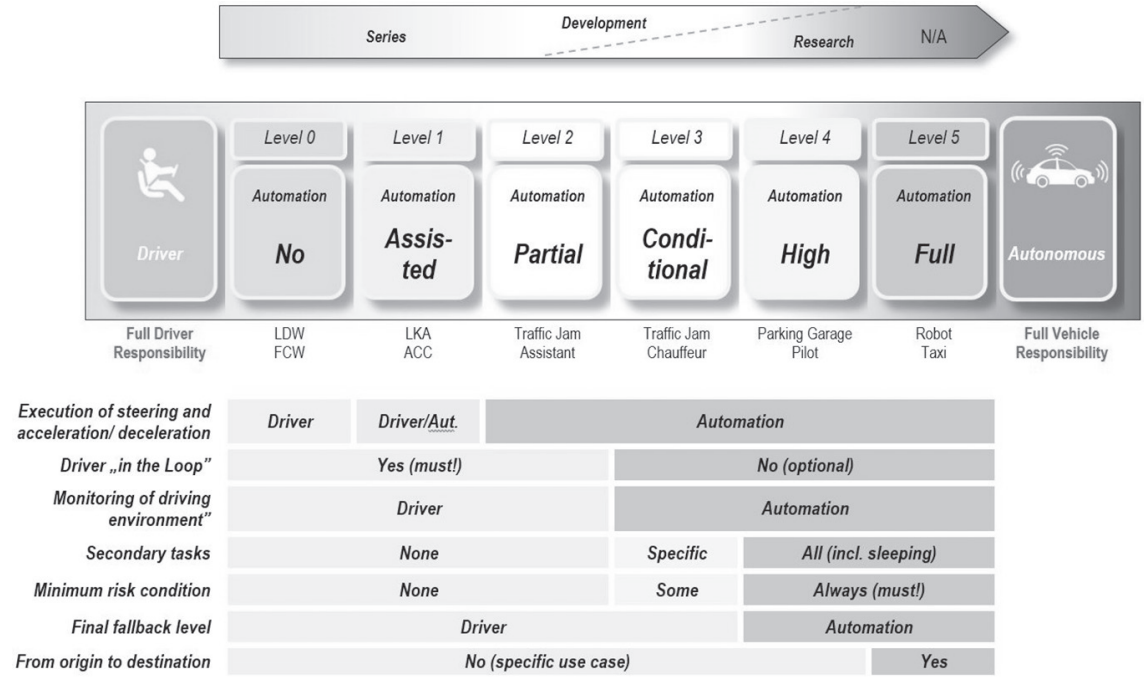

Figure 1 *Development process, levels and attributes of the vehicle control*

vehicles (Level 0). These systems, as their names indicate, only draw the driver's attention to the probable emergency situations, and they cannot intervene in the control of a vehicle.

Systems capable of intervening in the control of vehicles (e.g. by accelerating, braking, steering) only between strictly defined boundary conditions can be found at the first level of automation (Level 1), provided that these systems only proof-correct the parameters set by the driver, in a relatively narrow range. The lane keeping assistant (LKA) and adaptive cruise control (ACC) belong here.

At the second level of automation (Level 2) the vehicle has the ability to control itself-in a relatively small number of situations, between strictly defined boundary conditions-when some accelerating, braking and steering maneuvers are performed by the vehicle itself, for example making one's way along in a traffic jam (Traffic Jam Assistant).

At the levels presented above continuous monitoring and tracking of the traffic environment is the task of the driver and the driver compulsorily takes part in the controlling of the vehicle. Accordingly, in certain traffic conditions the driver has to initiate taking back the control from the vehicle.

At the third level of automation (Level 3) the vehicle can run in fully autonomous mode under conditions nearly identical to the second level. At the same time, when those conditions change, the vehicle initiates to give back control to the driver – in contrast with the automation level at Level 2 (Traffic Jam Chauffeur, Highway Chauffeur).

At the fourth level of automation (Level 4) vehicles can run in fully autonomous mode in broad operating ranges. The control system is always able to take the vehicle into the minimal risk condition in the following cases:

- if the traffic situation justifies it;
- in the case of failure of the autonomous control system of the vehicle;
- when the reaction of the driver is not adequate to the request of the vehicle to intervene (e.g. the driver does not respond to the signs of HMI (Human-Machine Interface), the shaking of the steering wheel).

Nowadays, fourth-level systems include for example the Parking Garage Pilot, which executes parking manoeuvres in fully autonomous mode, or the Highway Pilot, which can run in autonomous mode under highway conditions.

The fundamental difference between the third and fourth level of automation is that while at the third level the final decision regarding the control of the vehicle always has to be taken by the driver in critical operating, at the fourth level this decision is the task of the vehicle.

At the fifth level of automation (Level 5) the vehicle must be able to get from the point of departure to the destination without the intervention of passengers.

In connection to the above, it has to be emphasized that though certain driver assistance systems clearly correspond to certain automation levels, the fact that a vehicle is equipped with a system of a certain level is not sufficient for the whole vehicle to satisfy the requirements of the given level (i.e. the existence of certain assistance systems is a necessary but not sufficient condition for meeting requirements of the given level.)

3. Questions of liability regarding highly automated systems

Nowadays one of the most important aims of development processes regarding vehicles control is autonomous vehicles. Based on conservative scenarios, the probable value of the ratio of fully autonomous vehicles referring to the number of all vehicles placed on the market as new is 15-20%, with the assumption that the current economic trends continue and there will be no significant changes in the legal environment.

With the appearance of highly automated systems, the legal and technical evaluation and assessment of liability require a new approach and interpretation in addition to the usual procedures [2].

The detailed investigation of NHTSA (National Highway Traffic Safety Administration) on an accident that occurred in May 2016 pointed out that even if the ADAS (Advanced driver-assistance systems) system presently available, such as Tesla AEB (Automatic Emergency Braking) and its Autopilot systems in that special case, work properly, the driver's continuous supervision and attention is necessary and indispensable [3].

In this specific case, the investigation concluded that the autonomous driver assistance systems of the vehicle functioned properly and the driver had not performed any preventing manoeuver immediately prior to the accident. This shows that at the present level of automation insufficient emphasis is placed on the fact that the driver must perform continuous and complete supervision over the vehicle and its transport-related environment in every situation (partly due to the aggressive marketing strategy of manufacturers) in addition to the proper functioning of the currently available ADAS systems. A good example for this is the term "Autopilot" system used by Tesla, which clearly implies "the ability to drive itself" function for the users. At the same time, the user's manual of the vehicle also contains indications to the limits of the embedded systems and in the active state of the ADAS system the HMI system of the car reminds the driver in text and picture messages to the necessity of being continuous ready to intervene.

However, the accidents having occurred show that those warnings are ignored by the drivers, which is in part most likely due to the fact that the above mentioned pieces of information with contradictory content are not given the same emphasis. Therefore, when developing the ADAS systems of this kind, one of the key tasks is continuously maintaining the driver's attention, as well as recognizing when driver supervision ceases.

Nevertheless, as it was highlighted in the NHTSA report, the ratio of accidents regarding vehicles that are equipped with the Tesla Autopilot systems has decreased for 38 percent as compared to "traditional" (without Autopilot) vehicles [3].

The results mentioned above support Kenneth Leonard's opinion (Director of the Intelligent Transportation Joint Program Office-U.S. DOT), who claims that "...technology alone has the potential to eliminate 80 percent of the unimpaired collisions" [4].

Safety concerns / Fail-safe concepts	76 %
Liability issues	59 %
Regulatory mandates / Legal restrictions	57 %
Cyber security	51 %
Social acceptance / Critical perception of self-driving vehicles	42 %
Limitations with regards to infrastructure	35 %
HMI driver attention management	22 %

Figure 2 *Expectations of experts from the spread of autonomous driving/vehicles*

This is also confirmed by a survey carried out by the experts in the field in 2017, according to which an increase in transport safety and a decrease in the number of accidents is expected due to the appearance of autonomous vehicles in the first place (76 %) (Figure 2).

Therefore, it can be concluded that the expected wide-spreading of autonomous vehicles can to a great extent contribute to realizing the European Union's ambitious plans regarding the transport safety. They contain the following middle-and long term aims [5]:

- White Book (2001–2010) "The Committee would like to unite the efforts in order to decrease the number of casualties/ deaths for fifty percent during this time period."
- New White Book (2011-2020) "The European Union strives to decrease the number of injuries for fifty percent by 2020"
- Transport 50 (2020–2050): "Decreasing road accident deaths to almost zero by 2050 has to be achieved."

Parallel with the prospective decrease in the number of road-traffic accidents, the new types of accidents appear and therefore the three types of accidents can be identified depending on the automation level of the vehicles involved in the accident:

- accidents between conventional – conventional vehicles;
- accidents between conventional – autonomous vehicles (it can be divided into subtypes depending on the degree of automation);
- accidents between autonomous – autonomous vehicles.

The investigation of these new types of conflicts raises new questions in connection with the investigation of liability in addition to the novel set of expert and technical instruments [6].

When considering a vehicle involved in a road-traffic accident, the impact of the following entities concerned can be examined when investigating the accident liability: vehicle driver, keeper, producer (OEM-Original Equipment Manufacturer), system vendor (TIER1), operator of transport infrastructure [7].

With regard to the above, it has to be taken into consideration that the current basis for the legal regulation of road transport is the 1968 Vienna Convention on Road Traffic. It clearly states that there must be a vehicle driver present in all the moving vehicles

or combination of vehicles, who has to be able to continuously control their vehicle.

Since the Vienna Convention on Road Traffic has not been ratified by each and every country, the current possibilities for testing and operating the self-driving cars vary worldwide.

The differing regulation provides opportunity for the vehicle producers and system vendors to perform road tests already at the current state of the development. At the same time, in the USA, for instance, it was the speaker of the coalition for self-driving cars who indicated that they consider it unfortunate that the individual states regulate the testing and operating conditions of autonomous vehicles on a state level, since a coherent regulation on a federal level would be significantly more efficient.

Until January of 2017, in the US 33 states have introduced autonomous vehicle legislation, and there are some states, where this regulations allow testing self-driving car on public roads, even without human driver on the board. In April 2016 the Amsterdam Declaration has been signed by all 28 EU member states: this declaration is to regulate and unify the implementation of autonomous-driving vehicles on European roads, including to make suitable legal environment for testing the self-driving cars on public roads in Europe. For example, in May 2017, Germany has passed a law that gives auto companies permission to test their self-driving cars on public roads: the most important safety conditions of it is a presence of a human driver behind the wheel at all times with the ability to take over from the car's AI (Artificial Intelligence) when needed, and that all the self-driving cars must have a black box-like device that can record when the AI is in control and when a human is doing the driving. If at the time of the accident-by the data of the EDR-the human was the driver of the car, he or she may be responsible for the accident, in other cases, the car manufacturer will be held responsible for an accident caused by the AI.

Taking into consideration the current regulation regarding conventional vehicles, liability lies mainly with the driver/keeper. However, depending on the degree of automation, liability shifts significantly towards the manufacturer / the system vendor / the operator of traffic infrastructure (Figure 3).

The reasons for these are the following:

- if the vehicle does not have a driver, at the final level of automation, he/she cannot be rendered liable;
- with the appearance of the functions for autonomous vehicles, system vendors supply a complete system, while the car manufacturer "only" a systems integration. In consequence, liability due to the improper operation of the vehicle can be shared between the two parties. It also follows that while regarding conventional vehicles manufacturer liability is only considered in connection with structural defects, regarding autonomous vehicles liability of the logic (= "the driver") controlling the vehicle, i.e. liability of the manufacturer/ vendor can be determinative. In this respect, it is to be investigated whether the programmed decision algorithm complies with the effective legal requirements (perhaps generally accepted moral principles) [8].
- autonomous vehicles can get different pieces of information about the condition of transport infrastructure, or even its elements with their environment sensor systems or during the V2I (Vehicle-to-Infrastructure) communication. If these pieces of information are defective, liability of the systems creating and forwarding the information (its operator) is to be investigated [9].

Regarding the liability questions it is important to emphasize that autonomous vehicles–as their name suggests–are not only capable of executing pre-programmed operations, but under specific circumstances, interacting with their environment, they can also make unpredicted, independent decisions by means of their autonomous functions. In that sense, an autonomous vehicle cannot be clearly considered as a tool in the hands of its manufacturer, owner or user, so the current liability regulations (e.g. product liability) are not completely applicable for dealing with damages caused by operating the vehicle [10]. It is necessary to examine, from a legal point of view, as what kind of an entity (natural, legal, maybe animal or object) an autonomous vehicle, with possible cognitive functions, can be considered or whether it is justifiable to create an independent category for autonomous vehicles and robots. As regards to autonomous vehicles, it causes problems that based on the current legal regulations, it is not possible to identify clearly the person responsible for the damage caused by the vehicle. In that respect, also considering current legal practice, it seems appropriate to apply a kind of objective liability regarding autonomous vehicles.

According to this, it is sufficient to prove only the fact that there is a cause-and-effect relation between the actions of the autonomous vehicle causing damage and the damage suffered by the person harmed. When identifying people with liability and assigning liability, it can be a general approach that the parties' liability has to be proportional to the actual level of the instructions given to the vehicle and the autonomy level of the vehicle.

Finding the answers to the above mentioned questions, which partly arise with the spreading of autonomous vehicles, requires the novel expert tools and methods. When creating those methods, the followings must also be taken into consideration: potential special accident scenarios to be expected in the irregular operation of autonomous vehicles, the elements of intelligent traffic environment. Since it is possible, already at the lower levels of automation that – under specific operational circumstances – the logic controlling the vehicle makes control decisions independently, it is essential to use an event data recorder (EDR). Such data recorders, i.e. data recording functions, are already available in current vehicles, either as manufactured (for passenger cars it is obligatory in the USA since 2014, its data content is recorded in detail by a 49 CFR Part 563 [11] or built in afterwards.

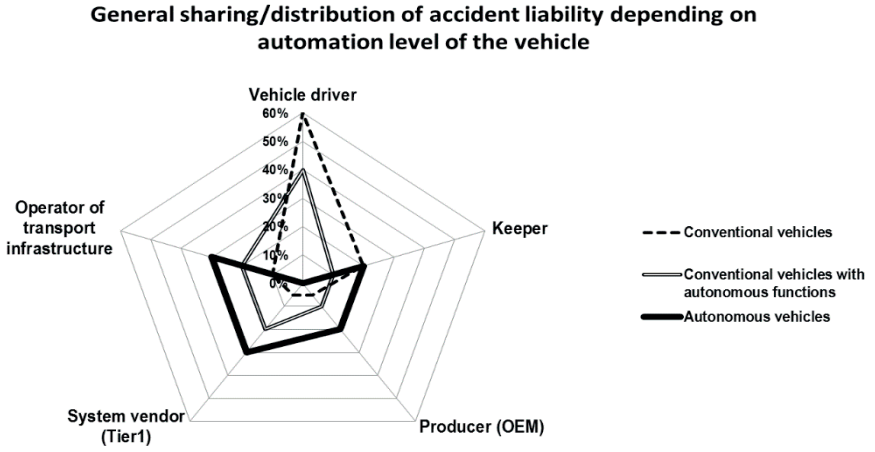

Figure 3 *General sharing/distribution of accident liability depending on automation level of the vehicle*

During the follow-up accident reconstruction, accidents of autonomous vehicles, especially those running without a driver, can be treated similarly to accidents where there is lack of trace. Therefore, in the case of accidents involving autonomous vehicles, the value of operational and environmental parameters, attributes of vehicle dynamics stored prior to, during and following the accident, in the various control units or perhaps dedicated devices of the vehicles involved in the accident, is particularly enhanced, since they can provide objective clues for accident reconstruction.

However, in addition to the data content stored on current event data recorders, it is also necessary to record the following:

- Who was controlling the vehicle at the time of the accident? Was it the control realising the autonomous function or the driver?
- Was the driver watchful prior to the accident: did he monitor the traffic environment? It is necessary to investigate this even if the vehicle was running in a self-driving mode.
- Which systems were operating / intervened in the control of the vehicle at the time of the accident? It is possible, even besides human driving, that a certain active safety system or driver assistance system has come into action immediately preceding the accident.
- Which vehicles or which elements of the traffic infrastructure the vehicle communicated with prior to the accident and what kind of information did it receive from those or transmit to those? [12]
- If the control of the vehicle was given over (from the driver to the vehicle or vice versa) immediately before the accident (approximately in the 3 minutes preceding), in what manner the handover and takeover took place, when exactly it happened compared to the accident and who initiated the handover.

When developing and defining the extended EDR functions, which can be used effectively even in autonomous vehicles, the extent to which the vehicle is autonomous has to be taken into consideration. Accordingly, what functions or sensors supplying information is the vehicle equipped with: it is necessary to record the active/passive status of these systems, or rather those of their sensors, their performance, as well as the signals of the sensors.

4. Conclusion

With the probable appearance of autonomous vehicles, the novel types of accident causes are expected to emerge regarding accidents between the human-driven and autonomous vehicles or between autonomous-autonomous vehicles. The novel accident causes will also result in the novel liability conditions. In connection with the technical and the follow-up enforcement evaluation of those the following are to be expected:

- It becomes necessary to expand the data content of the EDR systems recording certain technical parameters of the process of the accident.
- Depending on the automation degree of the vehicles, liability shifts significantly from the driver / keeper towards manufacturer / system supplier / operator of the traffic infrastructure.
- Co-operation of the legal and technical fields will be needed, not only following the irregular operation of the vehicle, but already during the development of automation functions.

List of Abbreviations

EDR - Event Data Recorder
SAE - Society of Automotive Engineers
LDW - Lane Departure Warning
FCW - Frontal Collision Warning

LKA - Lane Keeping Assistant
HMI - Human-Machine Interface
NHTSA - National Highway Traffic Safety Administration
ADAS - Advanced Driver-Assistance Systems
AEB - Automatic Emergency Braking
OEM - Original Equipment Manufacturer
AI - Artificial Intelligence
V2I - Vehicle-to-Infrastructure

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COMMUNICATIONS

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INTELLIGENT MODELLING WITH ALTERNATIVE APPROACH: APPLICATION OF ADVANCED ARTIFICIAL INTELLIGENCE INTO TRAFFIC MANAGEMENT

The currently existing transport infrastructures are failing due to many problems. This paper deals with presenting a new approach of modelling and forecasting transport processes using artificial intelligence. Firstly, the current state of forecasting transport data is presented; the traditional as well as new artificial intelligence methods, such as artificial neural networks, are discussed and described. After that, a support vector regression prediction model is briefly presented and an empirical analysis is performed. Finally, on the basis of our experiment and performed comparative analysis we state that artificial intelligence (AI) intelligent methods have potential in the transport area as they can improve the efficiency, safety, and environmental compatibility of transport systems.

Keywords: *forecasting, artificial intelligence, intelligent transport system, machine learning, support vector machines, support vector regression, R software, statistical methods*

1. Introduction

The main goal of the transport system is to ensure safe, efficient and reliable transportation while minimizing its negative impact on the environment. However, existing transport infrastructures are failing due to many problems, such as capacity problems, poor safety, unreliability, environmental pollution and inefficiency.

In recent years, artificial intelligence (AI) has attracted big attention of researchers in many different branches from signal processing, pattern recognition, travel time estimations [1], rail vehicle system [2] or time series forecasting [3]. Also in transport, there is a possibility for using artificial intelligence techniques to contribute to the development of new, intelligent modes of operation for existing infrastructures. AI is already deployed in many areas of transport, e.g. intersection control on arterial roads, travel time predictions and vehicle fuel injection systems [4].

Transport problems exhibit several features that allow application of methods and tools of artificial intelligence. Transport systems can often be very difficult to be simulated using the traditional approach, mainly because of interactions between different elements of the transport system. When dealing with transport problems, one often must solve difficult optimisation problems that cannot be fully met by using traditional mathematical programming methods. Artificial intelligence provides a wide range of tools and methods for a solution of transport problems. Methods and tools of artificial intelligence are primarily used to predict the behaviour of transport systems, transport optimisation problems in control systems and clustering, also in the transport planning process, decision making and pattern recognition [5].

Artificial intelligence applications are very efficient on extremely big data sets (gigabytes of data) where classical statistical or econometrical methods could not be used because of computational or time (cost efficiency) reasons [6].

AI techniques are applied in dynamic traffic management including evolutionary algorithms, knowledge-based systems, neural networks and multiagent systems. According to Miles and Walker [4], it is possible to distinguish between:

- direct control (measures using traffic lights, 'smart' barriers and variable message signs (VMS) to allocate traffic priorities in time and space) and
- Indirect control measures like recommendations for drivers which focus on the behaviour of individual vehicles (e.g. radio broadcasts, before-trip information (e.g. via Internet), in-vehicle routing and navigation systems).

Traffic management centres (TMCs) are the building blocks for many other AI applications. Travellers can be kept informed

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of possible problems via a personal information assistant or a car navigation system. The most commonly installed devices are VMS and traffic lights. Incident management is an integral part of transport network management and AI techniques are helping to detect, monitor and respond to accidents quickly [4]. Electronic payment and smart cards are already used for payment of public transport fares and road tolls around the world. AI techniques are already widely employed in smart card technology, for example, to combat fraud. The memory and processing capabilities available on smartcard microchips allow development of flexible and innovative products for paying fares and other transport-related charges. Intelligent navigation systems support individual travellers by providing information about the shortest possible routes, the current traffic situation and alternative routes. AI technologies also address the need for dynamic routing depending on information from TMCs and from other travellers. Artificial intelligence can be used in all these applications: arterial management, freeway management, transit management, incident management, emergence management, electronic payment, traveller information, information management, crash prevention and safety, roadway operations and management, road weather management, commercial vehicle operations, and intermodal freight [7].

Artificial intelligence has also an important role in road transport. As for traffic road, the artificial intelligence is used in intelligent traffic signs, in platooning and when calculating the Green Wave (adaptive traffic signal control based on real-time traffic conditions). Artificial intelligence is also used in the car; primarily for managing the accuracy of stopping, braking the car, control air conditioning in the car, anti-collision system, preventing the driver's drowsiness (analysis of eyelid movement of the driver, analysis of variations in the trajectories), vehicle speed control (based on evaluation of road and weather parameters recommended for the maximum permitted speed), control of frequencies in the car windscreen, optimizing fuel consumption, autonomous vehicle control (in the middle of the traffic flow), vision detection and image recognition systems (identification of fixed obstacles, vulnerable road users using sensors and computer processing). Finally, artificial intelligence is used in the field of tunnels. The means of AI check the lighting and ventilation in the tunnel, traffic density assessment, classification of fire in a tunnel under the heat of fire and the fuzzy logic is used for analysis of environmental data (road moisture, road temperature, visibility range...) [8].

The intelligent transport systems can organise and manage transport systems in such way that they can be used as efficiently and economically as possible [9]. Just implementation of appropriate prognostic methods and planning models allows to determine the planned value of supply and demand by evaluation of time series trend introducing the possible solution to reach stable and long-time results of region and transport enterprise activities and also the application of intelligent transport systems [10].

The goal of this paper is to experimentally show the benefit of using a new AI approach in transport problems by applying advanced artificial intelligence methods for time series forecasting. To fulfil this goal, we use the prediction model based on the theory of support vector machines: we find the optimal kernel function as well as type of regression best suited for such data. Authors then perform optimization of SVR (Support Vector Regression) using Open Source Software R in transport management system with affiliation to further research.

The main hypothesis is as follows: by applying new intelligent methods of artificial intelligence into transport area, we can state that there is a clear benefit of using these methods instead of traditional ones. Our approach is novel in using means of artificial intelligence, i.e. support vector regression into transport problems (instead of using standard methods).

The paper is divided into 5 parts. The second chapter introduces traditional (exponential smoothing, ARIMA models, GARCH) as well as intelligent methods (neural networks, support vector machines) in transport. The third chapter discusses the empirical analysis of the Support vector machines; it then deals with describing the basic theory of the SVM regression which is the default model for our prediction model. The fourth chapter discusses the experiment. Finally, chapter five summarizes the paper.

2. Traditional and intelligent methods in transport

Predicting processes in intelligent transport systems are realized via different approaches. Quantitative approach, which is one of the most used today, is based on statistical methods. Exponential smoothing [11, 12] was one of the first methods for time series modelling. The method is based on weighting data exponentially based on their age. The method is useful for seasonal and trend data. Kalman filtering [13], i.e. Kalman recursive procedures are another time series technique for forecasting. Kalman is used in many areas. One of them is the modelling seasonal data. It consists of estimating the state variables based on structural models. Box-Jenkins models [14], i.e. ARIMA or SARIMA (seasonal autoregressive integrated moving average) models assume of the dependence of the data in one-dimensional time series. According to the type of the process, these may be suitable either for adjusted, or seasonal time series. ARCH, GARCH [15] (generalized autoregressive conditionally heteroscedastic models), or other types of autoregressive conditionally heteroscedastic models are models applicable especially for high frequency data (financial markets), based on failure to meet certain criteria of the autoregressive processes, such as linearity, variance equality and stationarity. Finally, spectral analysis is a time series modelling in the frequency

domain, suitable for seasonal time series. Unlike other methods, several significant periods (frequencies) can enter the model.

In general, artificial intelligence is inspired by biological processes, generally learning from previous experience. Main tasks for artificial intelligence methods are based on learning from experimental data (including learning from patterns) and transferring human knowledge into analytical models [16]. One of the first machine learning techniques were artificial neural networks (ANN). As ANN was a universal approximator, it was believed that these models could perform tasks like pattern recognition, classification or predictions [17, 18]. In recent years, scientists try to incorporate other factors to increase the accuracy of neural networks, such as Evolving RBF (Radial Basis Function) neural networks in which genetic algorithms are implemented [19]. Even though neural networks are not in the centre of attention, their era has not ended yet. People talk about massive renaissance of neural networks [20]-mainly thanks to publications about deep neural networks [20].

However, in recent years, the flagship of artificial intelligence are support vector machines (SVM) [21,22]. In majority of studies the SVM outperformed artificial neural networks. There are many reasons behind this; one of them is that SVM can find and reach a global minimum. SVM are studies to increase their properties. For example, Cao et al. [23, 24] deal with more effective technique for forecasting using self-organizing maps (SOM).

Moreover, there also exists an AI model which is based on transferring human knowledge (experience) into workable systems and uses fuzzy logic (FL) systems such as in [18].

The application of predictive modelling has exceeded the borders of basic statistics long ago thanks to the current software capabilities. Means of artificial intelligence regularly form a part of commercial and open source software packages. As an example, we can mention support vector machines or certain types of neural networks utilized to solve classification and prediction problems in certain areas of engineering, medicine, economic forecasts, management and transport. The choice of an appropriate prediction method is influenced by the properties of the data, namely its actual extent, the structure of the time series, the monitoring frequency and, in case of causal models, the analysis of the relations between specified quantities. A complex solution of modelling the selected time series comprises of various stages, such as specification, quantification, verification and application. Based on the assessment of the present seasonality a certain way of modelling, based on models having a statistically significant seasonal component and models for adjusted data, is chosen. Comparison of the methods, their combination and subsequent optimisation of the solution is the way to improve the output of predictive modelling.

3. Suggested SVR prediction model for seasonal data in transport

Based on the reasons stated in the previous chapter, as well as on base of [25], the authors of this study decided to choose support vector regression as a representative of artificial intelligence technique to test their hypothesis. Another reason why we decided to apply artificial intelligence methods into transport is that artificial intelligence applications are a very efficient method for extremely big data sets (gigabytes of data) where classical statistical or econometrical methods could not be used due to computational or time (cost efficiency) reasons [6]. Finally, we decided to use linearly inseparable model of SVR since linearly inseparable SVR is better choice when forecasting time series instead of cross-sectional data.

3.1 Methodology

The Support Vector Machine [26 and 21] has wide application in classification tasks, as well as in predictions (SV regression). SV regression is based on the fundamental principles of the SVM method. The main idea of the SVM regression [27, 22 and 28] (SVR) lies in the search for the optimal band for the regression function. This band can be characterized as an error of the approximation of the actual data by a regression function, thus being the measure of the regression error. It is denoted by e and calculated as:

$$e = y_t - \hat{y}_t \tag{1}$$

where y_t is the current observed value at the time t and $\hat{y}_t$ is the value estimated by the regression function.

Root mean square error is a statistical measure to selection and optimisation of predicted data:

$$RMSE = \frac{1}{n}\Sigma_{t=1}^{n}(y_t - \hat{y}_t)^2 \tag{2}$$

Details of the theoretical background for SVM, core functions and linear inseparable data can be found in numerous scientific publications [21, 22]. Current solutions of the classification and prediction options support this method when comparing and evaluating the prediction capabilities and accuracy of this method with conventional statistical methods, whether it is the logistic regression or any of the approaches for modelling. Application of the machine learning methods resources is currently supported by the software applications (e.g. modelling in R) and, compared to the "traditional" statistical methods, it often prevails by having the advantage of raw data input, irrespective of the restrictive assumptions of the approach chosen.

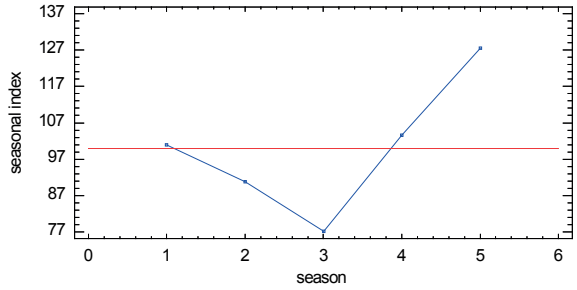

Figure 1 *Seasonal indices for selected time series*

3.2 Experiment

The data we used for our experiments were time series of financial profit of a Slovakian transport company. This company provides the personal bus public transport. The length of the series was 145 weeks. We have chosen to select the optimal (the best) model based on AIC and RMSE, assuming the significance of all model parameters. Therefore, stationarity of time series was not tested. To compare forecasting abilities of two approaches (statistical methods and machine learning methods) we have chosen the daily data of revenues with assumed seasonality. This element was confirmed by the graphical representations of periodogram, autocorrelation and partial autocorrelation function, and season indices which are shown in Figure 1.

As in the text above Figure 1, the presence of seasonality was assessed in several ways. We chose the graphical tools: periodogram, correlograms, and seasonal index chart (Figure 1). For the sake of clarity, this graph has been chosen to show unambiguous fluctuations in the daily work week data (Monday = 1, Friday = 5).

Both approaches were evaluated using seasonal data as well as cleaned unseasonal data (using moving averages) where the combination with seasonal indices is necessary. Statistical methods were processed in Statgraphics and in R. The methods of SV regression were realized in the R software. We selected the best models based on criteria and RMSE.

As stated above, we chose the R software for our SVR experiments. The detailed instructions on how to use R for statistical modelling is stated in [29]. To create a SVR (Support Vector Regression) model with open source R, we need the package e1071 [30, 31]. We used this package to train a support vector machine. It can be used to carry out general regression and classification (of nu and epsilon-type), as well as density-estimation. Code [32] with default settings to make predictions for selected data with SVR can be seen in [33]. As for R modelling, environment R allows the preparation, data processing, quantification and optimisation models based on a combination of selected modelling approaches. R currently offers number of built-in functions in the packages.

This basic SVR setting is not sufficient in many cases, however we can optimize the SVR parameters ("epsilon", "cost") and make further "extensions", such as the choice of kernel function, defining the training and test set. The epsilon parameter reflects the error rate. Valid: if the difference between the actual and estimated value on the regression curve in absolute value is less than or equal to the epsilon, the SVR considers the error to be zero. Constant C penalizes regression function deviations from measured values. To optimize the SVR parameters, we trained more models and then chose the best one.

Based on our R manual [33] we created estimates for selected real-time series. Our SVR models were compared with appropriate statistical models. Table 1 displays some of them.

In our experiments, the centre of attention was at regression models. These models are built on the assumption that there is some sort of dependency in the data. SV regression models bring an appropriate alternative for forecasting seasonal as well as non-seasonal data. The code used to estimate the SVR is as follows

```
datasvr2<-read.csv("c:/csvtrend.csv", sep=";", dec=",")
> model2 = svm(yt2~yt.1, data= datasvr2,  type="eps-regression",
+ kernel="linear",cost=1, epsilon=0.01)
> predictions=predict(model2, datasvr2)
rmse2=sqrt(mean((datasvr2$yt2-predictions)^2))
> rmse2
plot(datasvr2$yt2, type='lines')
lines(predictions, col='red')
> tuneResult <- tune(svm, yt2 ~ yt.1,  data = datasvr2,
+ ranges = list(epsilon = seq(0,1,0.1), cost = 2^(2:9))
+ )
> print(tuneResult)
```

Figure 2 displays the development of real and estimated values of season-free data using the methods of SV regression. The graph of real values is shown in black, the graph of estimated values is red. The parameters of SVR have been already optimized in R. Figure 3 displays the optimisation output with estimated parameters.

The text and graphical outputs display the results of the „tune" function. Based on this, they are optimized (their combination) cost and epsilon. The darkest area on the chart shows the best values. The „tune" function optimizes the model based on the RMSE criterion, calculated on the set of data where the model is trained.

4. Discussion

Inputs into SVR were independent time lags of the same time series, i.e. the lag of 5 days (seasonal data) and lag of day 1 (season-free data). By optimizing the SVR using the function tune, i.e. finding best values of parameters of 'cost' and 'epsilon', we

Table 1 Statistical models for seasonal and seasonally adjusted data (source: own experiment performed in R)

Model - seasonal data	Estimated parameters	RMSE
ARIMA(0, 0, 0)(0, 1, 1)	SMA(1)=0.981	5.470
Seasonal regression model		5.418
Holt - Winter expon. smoothing		6.081
Model - seasonally adjusted data		
ARIMA(1, 0, 5) with constant	AR(1) =0.481; MA(1) = – 0.402; MA(2) = -0.424; MA(3) = – 0.405; MA(4) = – 0.390; MA(5) = 0.560; Mean = 66,300	1.254
ARIMA(0, 0, 5) with constant	MA(1) = – 0.810; MA(2) = – 0.810; MA(3) = – 0.800; MA(4) = – 0.700; MA(5) = 0.170; Mean = 66.300	1.255

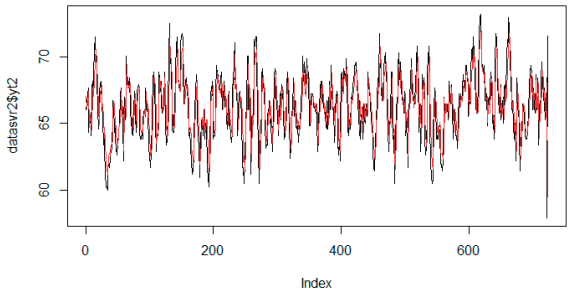

Figure 2 *Actual and estimated values with SVR*
Parameter tuning of 'svm':
- sampling method: 10 - fold cross validation
- best parameters: epsilon cost
0.7 4
- best performance: 2.468643
RMSE=1.571

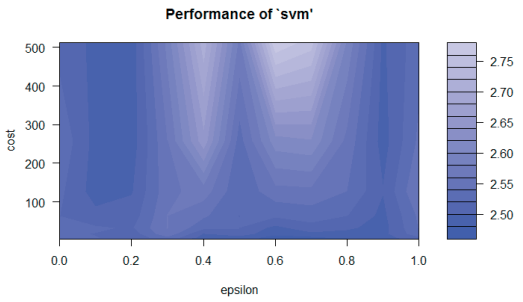

Figure 3 *Optimisation of SVM*

tried to minimize the RMSE error. The best value of RMSE with SVR (season-free data) was RMSE = 1.571 (before optimization the RMSE was equal to1.600).

The lowering of RMSE influences many factors, such as the size of training and validation set, selection of the kernel function (in our experiments we used linear, radial, polynomial kernel functions) and regressors. SVR is a way to go for modelling time series data with a possibility to apply this method in transport management.

5. Conclusion

Artificial intelligence has an important place in transport. It can be used in various fields of transport, especially in traffic management systems, incident management, travel information systems, transport management centres and models. Nonlinear models can be used for predicting traffic demand, predicting the deterioration of transport. In a transport planning process, AI-based decision support systems can be implemented for transport planning. Optimisation problems based on AI in transport can be solved with designing an optimal transit network for a given community, developing an optimal shipping policy for a company, developing an optimal work plan for maintaining and rehabilitating a pavement network, and developing an optimal timing plan for a group of traffic signals. AI can also be used in controlling a system, i.e. signal control of traffic at road intersections, ramp metering on freeways, dynamic route guidance, positive train control on railroads, and air traffic control. Clustering can be used for the identification of specific classes of drivers based on driver behaviour. Computer-Aided Design can be implemented in the geometric design of highways, interchange design, structural design of pavements and bridges, culvert design, retaining walls design, and guardrail design. Decision making can also benefit from techniques of artificial intelligence; deciding whether to build a new road, how much money should be allocated to the maintaining and rehabilitating activities and which road segments or bridges to maintain, and whether to divert traffic to an alternative route in an incident situation.

In this paper, we firstly discussed the current state in forecasting time series in transport; traditional as well as modern

AI methods were briefly discussed. Subsequently, we tested the hypothesis that by applying new intelligent methods of artificial intelligence into transport area, we can state that there is a clear benefit of using these methods instead of traditional ones. To test our hypothesis, we performed the empirical analysis of customized SVR prediction model. In our experiment, we used seasonal data of financial profits in personal transport of selected economic subject. By applying the Support vector regression prediction model optimised to given data and by running a comparative analysis, we found out that using AI techniques have a lot to offer to the field of transportation. The versatility of the tools and their performance are well suited for the complexity and variety of transport systems. AI holds promise for a wide range of transport problems, which have been previously approached using other mathematical frameworks. In transport modelling, they are relatively new, but they seem to be a great alternative to traditional models and methods.

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MOTIVATION LEVEL AND ITS COMPARISON BETWEEN SENIOR MANAGERS AND BLUE-COLLAR WORKERS IN SMALL AND MEDIUM-SIZED TRANSPORT ENTERPRISES

The aim of the article is to compare the motivation level of senior managers and blue-collar workers in Slovak small and medium-sized enterprises providing transport for forestry sector with the focus on the creation of motivation programs. The analysis included 340 senior managers and 262 blue-collar workers. A total of 30 motivation factors were examined. The most important motivation factors were defined. We identified the significant differences between the needs of senior managers and blue-collar workers by using the Student two-sample t-test. Based on the results of our testing we may conclude that in the field of motivation factors in Slovakia it is not possible to establish a uniform motivation program for the analyzed groups of employees. In the future, after meeting the needs of employees, it is possible that motivation may change with the change of requirements.

Keywords: *employee motivation, motivation program, job satisfaction, work position, student two - sample t - test*

1. Introduction

Due to the fact that every business is based on the work of human beings, the main objective of the human resources management is to create conditions for effective implementation of the business concept by maximizing the performance of its employees. Any company may have at its disposal a top-level technology, rich financial resources, and scarce information, but its success and competitiveness only depend on high-quality and qualified employees [1]. Whereas in 1999 the emphasis was laid upon productivity growth, the development of senior management took priority in 2004, while employee satisfaction and motivation have been the center of interest of personnel professionals since 2004 [2, 3]. Currently, human resources are strategically important for each company. If we realize that human resources are the basis of enterprise development, then human resources management is the key to business success [4]. The principal task of human resource management is to ensure positive behavior of employees. Satisfied and positively motivated employees, having their own interest in the prosperity of the company, can guarantee the success of the company the same as systematic motivation and motivational processes support effective work of employees.

In recent years, employee motivation has become a determining factor for the success of any organization. It is, therefore, necessary to actively build and declare the company´s positive relation to employees and employees' relation to the company [5]. Work motivation is more complicated because people have different needs and aspirations. Therefore, they are motivated differently. Employee motivation is linked closely to the human resources as they can affect the company performance. Nedeliakova, et al. [6], Yuanhua, et al. [7] and Wu et al. [8] emphasize that employees are an important asset for any organization. They should be motivated relative to the changing context of the organization in which they work. Work motivation depends on the job, as well as on age, gender, education, job position and other factors which grow in importance particularly at management level. Eskildsen and Nussler [9] found out that the reason for the relatively high level of work motivation could be that highly educated employees were held to higher positions, more diverse and more demanding tasks. The differences are greater when married women and men with dependent children are compared. According to DeMartino and Barbato [10], the percentage difference between these two groups increases by every motivational incentive in their career.

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Employee motivation and engagement has always been a major concern for research [11]. Leete [12] found that nonprofit organizations rely on internally motivated employees unduly. Based on Buelens and Van den Broeck [13], public sector employees are more often motivated intrinsically. Public sector employees are more motivated by workload, personal growth, recognition, individual decision-making, interesting work and an opportunity to learn something new [14]. Hitka and Balazova [15] assume that employees with higher education and a higher level of seniority prefer different motivation factors from employees with lower education and less seniority. Freund's research [16] is based on younger adults, particularly college students who want to acquire new knowledge and skills to enable them to get a degree and get a job. College students are motivated to succeed and seek to optimize their performance. However, it is not known if the emphasis on optimizing is also true for senior employees [17]. According to Moon [18], public sector managers have a lower level of loyalty to the organization than managers of the private sector, especially when it comes to their willingness to make a further effort. Bolfikova et al. [19] confirm that the behavior of the manager depends on the performance, and that flexible and dynamic behavior, management styles and techniques differ from organization to organization. Manager behavior depends on the decision-making process as well. It can have an impact on the motivation level of employees. Based on those arguments, it is clear that work motivation among employees varies. It is likely that adults with higher levels of education are able to work independently and to develop more. Older workers with higher education do not need to spend so much effort on their expertise to achieve the same performance as their younger co-workers with lower education. Thus, acquisition of new knowledge is easier if it is compatible with the existing framework, necessary training, and experience.

The company motivation program is a comprehensive set of measures in the field of human resources management. It is built on management activities, actively influences job performance, and creates or strengthens positive attitudes of all employees. In this respect, the goal is to reinforce the identification of the employees' interests with the interests of the company (loyalty to one's own business) and the formation of employee interest in the development of their own abilities, knowledge, and skills, actively used in the work process [20]. This is based on the assumption that the development of creative abilities of human potential and its engagement in enterprise benefits is the best guarantee for the successful fulfillment of its fundamental objectives and that it survives in the difficult conditions of the market environment. In enterprises, individual or group motivation programs are often used as part of adjustment programs to achieve the required level of employee performance. By their implementation and integration into internal corporate documents, the motivation programs are expected to change the overall approach to the role of employees in an enterprise.

Sumita [21] says that in today's competitive environment, the number of enterprises is increasing. Companies compete with one another. The interest in excellent employees is constantly growing. Therefore, it is inevitable to maintain high employee productivity through rewards. Grazulis and Baziene [22] and Kucharcikova [23] claim that the theory of human capital deals with increasing the economic value of human resources (adding value to human capital) through investment into resources, especially through education. The importance of remuneration may vary depending on the context. Employees who fulfill basic needs prefer financial reward, while others tend to seek reward and recognition in another form. To obtain benefits from the concept of remuneration, it is essential to provide processes in companies that are fair and reasonable to the market.

2. Methodology

The randomly addressed senior managers and blue-collar workers in Slovak small and medium-sized enterprises providing transport for forestry sector were asked to complete the questionnaires. The sampling unit consisted of 340 senior managers and 262 blue-collar workers. To obtain empirical data and to verify the established hypotheses, the questionnaire method was used as the main technique. The questionnaires were distributed via e-mail. For maximum comprehensibility, the questionnaire was created in the uniform format for all categories of employees. The respondents were informed about anonymity in advance. The questionnaire consisted of two parts. The first part focused on obtaining a clearer idea of the personality through gender, work position, age, level of education and seniority in the enterprise. The second part consisted of 30 motivation factors. To avoid influencing the respondents, the motivation factors were arranged in alphabetical order. The respondents defined how important the motivation factors were for them, as well as which of these factors more or less affect their job performance. The respondents were using a five-point rating scale of the significance of each motivation factor (5-very important, 4-important, 3-medium important, 2-less important, 1-unimportant).

The findings were used to process an analysis of employee motivation. Data acquisition covered the period from November 2015 to March 2016. The method of comparative analysis was used to process the experimental results. The data were processed by Statistics 10.0 software [24]. We assumed that there exist significant differences in motivation level between senior managers and blue-collar workers. Based on inductive statistics, we used Student two-sample t-test to determine the statistical significance of differences in average levels of motivation of senior managers) and blue-collar workers $_{BCW}$) at the selected level of significance $\alpha = 0.05$ [25]. The null hypothesis was tested versus the alternative (Equation 1):

$$H_0 : \mu_{SM} = \mu_{BCW} \text{ vs. } H_1 : \mu_{SM} = \mu_{BCW} \quad (1)$$

Table 1 The structure of sampling unit

Work position		Age		Completed education		Seniority	
Senior managers	340	Under 30 years	95	Primary	40	Less than 1 year	30
Blue - collar workers	262	From 31 to 40 years	182	Lower secondary	122	1 - 3 years	62
		From 41 to 50 years	210	Upper secondary	230	4 - 6 years	115
		50 years and more	115	Higher	210	7 - 9 years	140
						10 years or more	255

Table 2 Top motivation factors ordered according to the level of importance

S.N.	Top motivation factor rated by senior managers	Average	S.N.	Top motivation factor rated by blue - collar workers	Average
1.	Job security	4.62	1.	Atmosphere in the workplace	4.69
2.	Fair appraisal system	4.57	2.	Good work team	4.65
3.	Base salary	4.54	3.	Work environment	4.48
4.	Fringe benefits	4.43	4.	Fringe benefits	4.42
5.	Supervisor's approach	4.40	5.	Working hours	4.37
6.	Atmosphere in the workplace	4.34	6.	Relation to the environment	4.37
7.	Good work team	4.28	7.	Fair appraisal system	4.33
8.	Name of the company	4.25	8.	Job performance	4.29
9.	Working hours	4.25	9.	Mental effort	4.29
10.	Communication in the workplace	4.24	10.	Mission of the company	4.29

H_0: we suppose that the importance level of the selected motivation factors of senior managers is equal to the importance level of the selected motivation factors of blue-collar workers.
H_1: we suppose that the importance level of the selected motivation factors of senior managers is not equal to the importance level of the selected motivation factors of blue-collar workers.

3. Results and discussion

In the research, 1.800 questionnaires were distributed. The questionnaire response rate was 33.44 % (602 correctly completed questionnaires). The sampling unit consisted of employees working in small and medium-sized enterprises providing transport for forestry sector operating all over the Slovak Republic. Table 1 shows the sociological overview of 602 respondents (512 men and 90 female) in terms of work position, age, completed education and seniority.

The aim of the research was to compare the motivation level of senior managers and blue-collar workers in Slovak small and medium-sized enterprises providing transport for the forestry sector. Based on the results, we could define the hierarchy of motivation factors for the group of senior managers and the group of blue-collar workers. Table 2 presents 10 motivation factors that acquired the highest values of the selected averages.

Based on the collected data, senior managers considered job security the most important motivation factor. Subsequently, there were motivation factors related to financing (fair appraisal system, base salary, fringe benefits). The motivation of senior managers was affected by supervisor's approach, the atmosphere in the workplace and good work team. Blue-collar workers considered atmosphere in the workplace the most important motivation factor followed by good work team and work environment. Hypothesis testing was evaluated due to the significance of differences of averages according to the importance of individual motivation factors (Table 3). Within the hypothesis, we assumed that there exist differences in the motivation level of senior managers and blue-collar workers.

Table 3 shows the motivation factors with differences considered statistically significant. The significant differences of arithmetic averages of motivation factors at the 5 % significance level are highlighted in bold. Significant differences between senior managers and blue-collar workers were observed when analyzing the atmosphere in the workplace, good work team, job security, mental effort, mission of the company, physical effort at work, stress, supervisor´s approach and work environment.

In the following step, a total of 30 motivation factors were subject to a more detailed analysis. Using statistical methods, it was verified that the work position influences the importance of motivation factors ($p = 0.000$). The *p*-levels are highlighted in bold in Table 4.

Table 3 The assessment of the significant differences in motivation level between senior managers and blue - collar workers

Motivation factor	Average		t - value	p - level	t - value (reduced df)	p - level	F - value	p - level
	Senior managers	Blue - collar workers						
Atmosphere in the workplace	4.34	4.69	-2.60	**0.010**	-2.71	**0.008**	1.80	0.029
Base salary	4.54	4.25	1.68	0.096	1.64	0.104	1.44	0.161
Career advancement	4.07	4.21	-0.82	0.411	-0.80	0.425	1.55	0.092
Communication in the workplace	4.24	4.23	0.03	0.978	0.03	0.978	1.04	0.897
Competences	3.87	4.02	-0.81	0.418	-0.79	0.431	1.53	0.103
Fair appraisal system	4.57	4.33	1.52	0.132	1.47	0.146	1.66	0.051
Free time	4.13	4.21	-0.51	0.608	-0.50	0.616	1.41	0.188
Fringe benefits	4.43	4.42	0.02	0.981	0.02	0.981	1.02	0.935
Good work team	4.28	4.65	-2.51	**0.013**	-2.56	**0.012**	1.36	0.251
Individual decision-making	4.09	4.02	0.41	0.685	0.39	0.696	1.72	0.037
Information about performance result	4.06	4.15	-0.59	0.557	-0.58	0.564	1.29	0.334
Job performance	4.13	4.29	-1.01	0.313	-0.98	0.327	1.55	0.091
Job security	4.62	4.13	3.00	**0.003**	2.82	**0.006**	2.62	0.000
Mental effort	3.90	4.29	-2.30	**0.023**	-2.30	**0.023**	1.04	0.893
Mission of the company	3.91	4.29	-2.31	**0.022**	-2.35	**0.022**	1.26	0.388
Name of the company	4.25	4.06	1.01	0.314	1.00	0.321	1.23	0.417
Opportunity to apply one's own ability	4.13	3.90	1.35	0.181	1.31	0.195	1.56	0.086
Personal growth	4.13	4.02	0.64	0.524	0.62	0.534	1.44	0.157
Physical effort at work	3.50	4.21	-3.63	**0.000**	-3.80	**0.000**	2.01	0.010
Prestige	3.78	4.00	-1.19	0.237	-1.20	0.233	1.14	0.636
Recognition	4.18	4.08	0.68	0.501	0.66	0.512	1.45	0.151
Region's development	3.69	3.96	-1.42	0.159	-1.40	0.164	1.18	0.514
Relation to the environment	4.24	4.37	-0.87	0.388	-0.88	0.381	1.22	0.458
Self - fulfillment	4.04	4.19	-0.90	0.372	-0.88	0.379	1.24	0.409
Social benefits	4.16	4.17	-0.07	0.942	-0.07	0.944	1.52	0.107
Stress	3.78	4.15	-2.16	**0.033**	-2.16	**0.033**	1.01	0.965
Supervisor's approach	4.40	3.96	2.30	**0.023**	2.18	**0.032**	2.37	0.001
Work environment	4.10	4.48	-2.57	**0.011**	-2.58	**0.011**	1.09	0.759
Working hours	4.25	4.37	-0.76	0.451	-0.73	0.464	1.57	0.081
Workload and type of work	4.18	4.21	-0.23	0.818	-0.23	0.821	1.21	0.455

Based on the analysis (Table 4), there is a significant dependence between work position and motivation factors listed in Table 4 (competences, information about performance result, job security, physical effort at work, supervisor´s approach). Due to the independence of the sampling unit, Student two-sample t-test was used to consider the significant differences between the needs of senior managers and blue-collar workers. The null hypothesis vs. the alternative hypothesis was tested at the selected level of significance $\alpha = 0.05$. A total of 602 employees working in Slovak small and medium-sized enterprises providing transport for forestry sector were asked to identify the importance of factors that affect motivation. Senior managers considered job security the most important motivation factor. This factor is motivating in most occupations in Slovakia as researched in Hitka and Stipalova [26] and Zavadsky, et al. [27].

Table 4 The analysis of significant dependence between work position and motivation factors

Motivation factor	Statistical methods	Chi - square test	Degree of freedom	p - level
Competences	Pearson's chi - square test	9.458580	df=4	**p=.051**
	Maximum likelihood chi - square test	9.523136	df=4	p=.049
	Pearson's contingency coefficient	.1669243		
	Cramér´s V.	.1692996		
Information about performance result	Pearson's chi - square test	13.62886	df=4	**p=.009**
	Maximum likelihood chi - square test	14.80124	df=4	p=.005
	Pearson's contingency coefficient	.1991521		
	Cramér´s V.	.2032230		
Job security	Pearson's chi - square test	9.456244	df=4	**p=.051**
	Maximum likelihood chi - square test	11.09171	df=4	p=.026
	Pearson's contingency coefficient	.1669043		
	Cramér´s V.	.1692787		
Physical effort at work	Pearson's chi - square test	17.84001	df=4	**p=.001**
	Maximum likelihood chi - square test	18.19052	df=4	p=.001
	Pearson's contingency coefficient	0.2264685		
	Cramér´s V.	0.2325094		
Supervisor´s approach	Pearson's chi - square test	10.72958	df=4	**p=.030**
	Maximum likelihood chi - square test	11.04578	df=4	p=.026
	Pearson's contingency coefficient	.1774542		
	Cramér´s V.	.1803160		

Blue-collar workers considered the atmosphere in the workplace the most important motivation factor followed by good work team and work environment. Among senior managers, surprisingly, the name of the company was rated in top 10 most important motivation factors. It represents a high level of loyalty status. But, based on the research of Hitka and Balazova [15] and Hitka, et al. [28], this factor was the least preferred in many other areas of the economy of Slovakia. Similar research performed in 2009-2011 pointed out that base salary, job security, fringe benefits, the atmosphere in the workplace and good work team were preferred motivation factors in the Slovak wood industry. The atmosphere in the workplace, good work team, supervisor's approach, job security and base salary were preferred motivation factors by senior managers [27].

Based on the collected data, it can be concluded that significant differences were identified in 9 motivation factors (atmosphere in the workplace, good work team, job security, mental effort, mission of the company, physical effort at work, stress, supervisor´s approach, work environment). In addition, there exists a significant dependence between work position and competences, information about performance result, job security, physical effort at work, supervisor´s approach. Differences of senior managers and blue-collar workers can be caused by the workload and type of work. Senior managers work mostly indoors, while blue-collar workers mostly work physically outdoors. Mental effort and mission of the company influenced senior managers in Slovak small and medium-sized enterprises providing transport for the forestry sector. Blue-collar workers were influenced by the physical effort at work and the supervisor´s approach. Therefore, in the creation of a motivation program focused on each group analyzed, it is necessary to differentiate specific requirements of both groups as well as respect the needs arising at work. The investments in the creation of the motivation program are long-term investments. In terms of time, the motivation level does not change radically. Individualization of the motivation program using motivation factors related to self-fulfillment and personal ambitions of individual employees is another option. However, this method increases costs greatly.

4. Conclusions

Currently, many enterprises do not consider motivation, development, and education of employees important. It is often a question of finance, or employees are not interested in this area. Based on the analysis, a conclusion can be provided. Due to the diversity of work environment in Slovak small and medium-sized enterprises providing transport for the forestry sector, it is not possible to establish a uniform motivation program for the analyzed groups of employees. The motivation program specific

for senior managers should be related to finance as well as to the atmosphere in the workplace, good work team, communication in the workplace and supervisor's approach. Similarly, the motivation program specific for blue-collar workers should be focused on the atmosphere in the workplace, good work team, communication in the workplace, supervisor's approach, as well as on the physical effort at work, occupational safety, job security, workload and type of work, information about performance result, working hours, work environment, job performance, mental effort and stress. It is difficult to define an effective motivation program. Since the motivation of employees may change over time, the company should deal with motivation continually. The motivation program should be continually updated after fulfilling motivation needs. However, costs may be increased by these changes. The motivation program can be concentrated on process management as well as on recognition and communication in the workplace [28].

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COMMUNICATIONS

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HUMAN CAPITAL AS A TOOL FOR PREDICTING DEVELOPMENT OF TRANSPORT AND COMMUNICATIONS SECTOR: THE CZECH REPUBLIC PERSPECTIVE

Human capital as a part of intellectual capital has crucial impact on the overall development of all sectors of national economy. This trend can also be confirmed by the growing number of academic papers dealing with the issue. This paper presents results of a questionnaire survey that investigated the human capital in terms of selected motivational factors and employability prospects as seen by students of high schools programs related to transport and communications. The main objective was to get an insight into the current situation in the sector and its attractiveness as seen by potential future employees. The questionnaire survey was carried out in April 2016 and its respondents were future high school graduates, who can either continue to study transport and communications at university or enter the job market and search for a job in the sector straight away. Results obtained from a series of statistical tests using the Two-way ANOVA method can serve both companies and educational institutions as a basis for implementation of measures that would guarantee sustainable development of human resources in this field.

Keywords: *human capital, transport, communications, employability, motivation, gender*

1. Introduction

Human capital has gained increasing importance over the last few years. This fact is reflected in the growing number of research studies that recognize human capital as one of the key areas that are essential for the development of countries and companies as market players. Human capital is therefore one of the key social constructs which must be analyzed thoroughly in order to ensure effective management of all the processes that lead to increase in a company's value [1-4]. It can be examined in relation to a number of other measurable indicators and once a relationship is found among selected indicators, it is possible to predict future development in this area [5, 6].

Education is one of the main processes, which have fundamental impact on human capital. It is therefore vital to analyze education from the point of view of its participants, i.e. the people who help to create the future of human capital in a given sector of economy. By means of a targeted and long-term research it is possible to search for closer connections between current trends in the process of education and the process of social integration. Similarly to other sections of national economy, education is crucial for further development of transport and communications sector. It is thus necessary to create such conditions that would attract and motivate individuals to work in this sector. Because education shapes its participants, it is useful to analyze the whole process of education, especially from the point of view of the future graduates.

This article presents results of a questionnaire survey that was conducted among students of high schools, which offer study programs related to transport and communications and are associated in *IT, Telecommunications, Postal Services and Logistics High Schools Association* (henceforth, the Association). The ultimate objective is to identify trends of human capital in the sector of transport and communications. The analysis starts with the identification of the two main factors:

a) student's first - intention ("look for a job" or "continue to study"),
b) student's gender (male student or female student).

Students respond to questions related to two main areas:

a) perceived employability,
b) selected motivational factors.

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Table 1 B2C Survey timetable

Date	Activity
	Research design
January - February 2016	Inform the headmistress of the Association about the intented survey
	Formulated hypotheses
	Outline preliminary timetable
	Define desired results
	Determine resources (human, financial, non - financial)
	Consult high school representativnes for respondents' relevance
	Data collection methodology
February	Complete questionnaire and test its pilot version
	Design the electronic questionnaire
March 2016	Pilot testing of the electronic questionnaire
	Send the link to the questionnaire to school representatives
Apr 4 - Apr 22, 2016	Collect data
	Data processing
May 2016	Data entry
	Select the final sample for statistical testing
	Analyze data
June - September 2016	Evaluate data
September - December 2016	Confront results with other works

This research is rather unique as there are currently no studies that would investigate the relationship between human capital and perceived employability and/or motivation to enter this particular sector.

2. Background and methods

First, it is necessary to outline the scientific understanding of the term human capital. The human capital is one of the components of intellectual capital [7, 8]. It came to the forefront of scientific interest in the 1960s when economists and other experts came to realize its importance.

The key role of the human capital in achieving sustainable growth, with emphasis on its society - wide impact (especially in its relation to new social constructs), has been mentioned in the work of Coleman, who claims that building trust and loyalty among members of a particular group is essential for the achievement of the society - whole objectives in any sector. This makes human capital a modern area of concern reflecting the current turbulent situation [9]. The human capital is an area *sui generis*, it is thus necessary to bear in mind any overlaps in the definitions of the human capital as various authors or works define it differently. For the reasons stated above, it is necessary to clearly define the term "human capital" as it is used in this paper. The general paradigm under which the human capital is understood in the present paper is in accordance with Burgess-human capital is a determinant of economic growth. The human capital is being shaped in the process of education and is among the main tools to express the level of social integration of individuals or group of individuals in each company [10, 11].

2.1 Methodology

The first impetus for this research has been raised at the Department of transport management, marketing and logistics at University of Pardubice. The survey was conducted in 2016 at a number of Czech high schools. The Czech education system is a four - tier system of preschool, primary, secondary, and tertiary education. On the secondary level, students can choose between vocational schools (which are completed by a qualification exam), professional high schools and the so - called „grammar schools", which are both completed by a graduation exam. Students of vocational programs must take both qualification and the graduation exams if they wish to continue to study.

After leaving the high school, students of vocational and professional high schools can either start looking for a job or continue to study at higher vocational schools or universities. However, many students also like to take a kind of a „gap year" and attend an intensive language course at a language school before starting university or going to work.

In the planning stage, authors had to take into account time schedules for graduation exams at the participating high schools. Table 1 shows the survey timetable.

The survey focused on two main areas: perceived employability and motivational factors. The term „perceived employability" as used here stands for a student's perception of his or her future employability prospects-whether they consider their knowledge and experience sufficient for their success on the job market.
The following hypotheses were proposed:
Perceived employability:
$H0^1$: Interaction between respondent's first intention „(„look for a job" or „continue to study") and gender („male students" or „female students") does not affect perceived employability.
$H1^1$: Interaction between respondent's first intention („look for a job" or „continue to study") and gender („male student" or „female student") does affect perceived employability.
$H0^2$: No match in terms of gender has been found in evaluations of perceived employability in the group of respondents with the same first intention.

H1[2]: A match in terms of gender has been found in evaluations of perceived employability in the group of respondents with the same first intention.

H0[3]: Respondent's first intention does not affect perceived employability.

H1[3]: Respondent's first intention does affect perceived employability.

Motivational factors:

H0[4]: Interaction between respondent's first intention („look for a job" or „continue to study") and gender („male students" or „female students") does not affect motivational factors.

H1[4]: Interaction between respondent's first intention („look for a job" or „continue to study") and gender („male students" or „female students") does affect motivational factors.

H0[5]: No match in terms of gender has been found in evaluations of motivational factors in the group of respondents with the same first intention.

H1[5]: A match in terms of gender has been found in evaluations of motivational factors in the group of respondents with the same first intention.

H0[6]: Respondent's first intention does not affect motivational factors.

H1[6]: Respondent's first intention does affect motivational factors.

2.2 Data collection methodology

Data were obtained in a primary research initiated by authors of this study. Respondents were all students of study program no. 37-42-M/01 Logistics and financial services at high schools associated in the Association (Stredni odbornaskola logistickych sluzeb, Ucnovska 1/100, Praha; SOS informatiky a spoju a SOU Kolin, Jaselska 826, Kolin; Stredni odbornaskola a Stredni odborne uciliste, namesti Edvarda Benese 2353, Kladno; Strední odbornaskola a Stredni odborne uciliste, Volanovska 243, Trutnov; Stredni odbornaskola logisticka a stredni odborne uciliste Dalovice, Hlavni 114/29, Dalovice; Stredniskola informatiky a financnich sluzeb, Klatovska 200 G, Plzen; Stredniskola informatiky, postovnictvi a financnictvi Brno, Cichnova 982/23, Brno; Stredni prumyslovaskola, Resslova 5, Usti nad Labem; Obchodni akademie a Stredni odbornaskola logisticka, Hany Kvapilove 20, Opava; Stredniskola logistiky a chemie, U Hradiska 29, Olomouc).

They were all in their final year of study, at the end of which they sit for the school - leaving exam. That is why respondents are called „future graduates" - in this paper, the term „graduate" is used to mean a student who has successfully completed his or her high school studies. Respondents were thus approximately 18 years old.

The questionnaire was created in Google Forms and the survey took place from April 4 to April 22 2016. The questionnaire first divided respondents into three main groups according to what their first intention after finishing the high school was: „I want to continue to study", „I want to look for a job" and „I have no idea". If a respondent chose the last option „I have no idea", he or she was redirected to the last part of the questionnaire to respond to questions related to identification analysis:

- „Gender"
- „What high school are you studying?"
- „What is the first foreign language you study at school?"
- „Apart from the compulsory professional hands - on training, did you have any possibility to work, e.g. to have a part - time job or summer job?"

These respondents were not subjected to further investigation and their responses were not included in the sample for statistical testing, while the first two groups of respondents („I want to continue to study" and „I want to look for a job") were redirected to another part of the questionnaire, which dealt with the two main areas of the survey.

2.3 Data processing

A total of 157 completed questionnaires were returned, which represents 79.69 % return rate. For the sake of maximum relevance, Stredni skola informatiky a financnich sluzeb, Klatovska 200 G, Plzen, had to be excluded from the survey[1]. Therefore, data from 102 respondents were processed. The final calculation was done on a sample of 95 respondents because 7 respondents stated they had "no idea" about their first intention. 93.13 % of respondents (95 out of 102 respondents) had a clear idea about their first intention after leaving the school, which is a definitively positive finding.

Data calculation was done in two phases as there are two main areas of interest.

Perceived employability:

In this set of statements (see Appendix A), respondents had to choose one of the options: "strongly agree", "agree", "disagree", "strongly disagree". The following equation was used to express the values:

$$a_j = \frac{1}{n}\sum_{i=1}^{n} a_{ij} \qquad (1)$$

where:

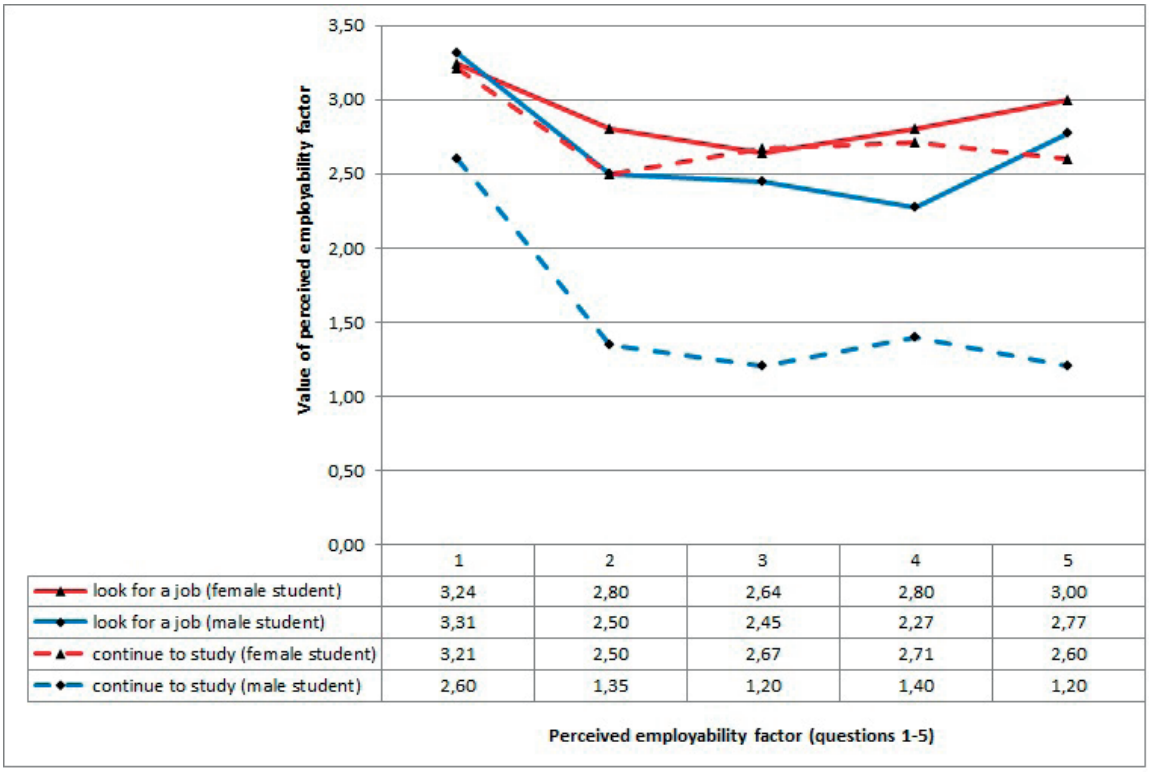
i ... is the sequence number of respondent

j ... is the sequence number of statement (see Appendix A)

a_j ... average score of the j - factor

n ... total number of respondents

[1]The questionnaire was submitted by high school representatives also to students of the vocational program, who cannot continue to study at university immediately after their qualification exams. Because all the obtained data were anonymous, it was not possible to separate these students' responses from the rest. As this would lead to distortion of results, the data from the whole school were excluded from the statistical testing.



	1	2	3	4	5
look for a job (female student)	3,24	2,80	2,64	2,80	3,00
look for a job (male student)	3,31	2,50	2,45	2,27	2,77
continue to study (female student)	3,21	2,50	2,67	2,71	2,60
continue to study (male student)	2,60	1,35	1,20	1,40	1,20

Figure 1 *Value of perceived employability factor*

Motivational factors:

In this set of statements (see Appendix B), respondents had to assign a grade to each factor, ranging from 1 to 6 (1 - rather unimportant factor, 6 - rather important factor). Respondents were free to use the grades as many times they wanted. Therefore it could have happened that respondents used the same grade for all the factors. The following equation was used to express the scores:

$$b_j = \frac{1}{n}\sum_{i=1}^{n} b_{ij} \qquad (2)$$

where:

i ... is the sequence number of respondent
j ... is the sequence number of statement (see Appendix B)
b_j ... average score of the j-factor
n ... total number of respondents

The two-way ANOVA method was used to confirm the above proposed hypotheses. This method was chosen because authors wanted to find any possible differences in values of perceived employability and motivational factors when looking at interaction of both factors, i.e. gender and the first-intention:

- first-intention („continue to study" versus „look for a job"),
- gender (male students versus female students).

3. Results

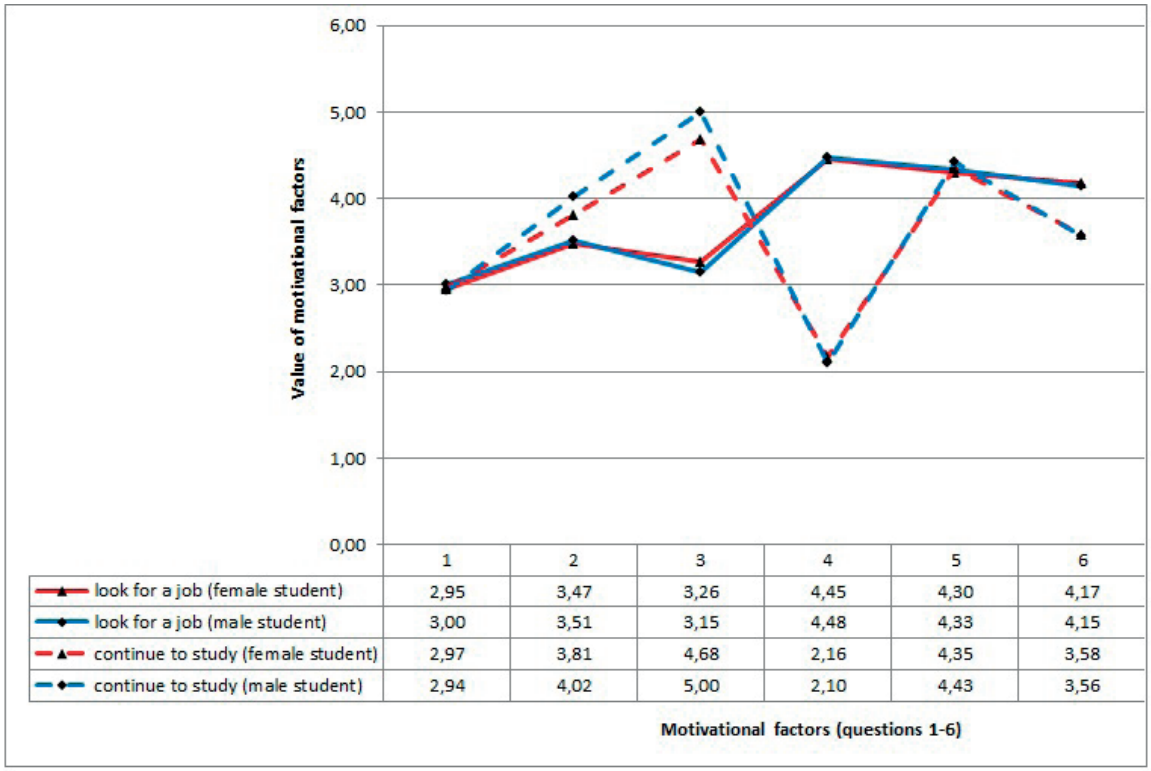
3.1 Perceived employability - results

Figure 1 presents values calculated from respondents' answers to questions related to perceived employability (see Appendix A). Resulting values are differentiated according to:

- student's first-intention („look for a job" or „continue to study""),
- gender (male or female student).

Numbers 1, 2, 3, 4, 5 on the abscissa represent questions from the Perceived employability category. Results were calculated based on the methodology presented in Equation (1). Two - way ANOVA method was used to confirm hypotheses. The results are presented in Table 2.

Results show that in the area of perceived employability, hypothesis H1[2] has been confirmed, meaning that a match in terms of gender has been found in evaluations of perceived employability in the group of respondents with the same first intention.However, significant differences can be observed among responses of respondents whose first-intention is to „continue to study". For example, the average score of question no. 1 in the „look for a job" category is 3.24 for female students and 3.21 for male students, while in the „continue to study" category, the



	1	2	3	4	5	6
look for a job (female student)	2,95	3,47	3,26	4,45	4,30	4,17
look for a job (male student)	3,00	3,51	3,15	4,48	4,33	4,15
continue to study (female student)	2,97	3,81	4,68	2,16	4,35	3,58
continue to study (male student)	2,94	4,02	5,00	2,10	4,43	3,56

Figure 2 *Value of selected motivational factors*

Table 2 Analysis of results: The two - way ANOVA

Source of variation	P value	Sum - of - squares	Mean square	F - test	Results
Interaction	0.9630	0.2255	0.05637	0.1410	H0[1]Accepted
Gender	0.0488	2.010	2.010	5.027	H1[2]Accepted
First intention	0.3450	2.027	0.5068	1.268	H0[3] Accepted
Residual		3.998	0.3998		

Table 3 Analysis results: Two - way ANOVA

Source of variation	P value	Sum - of - squares	Mean square	F - test	Results
Interaction	P<0.0001	8.551	1.710	232.9	H1[4] Accepted
Gender	0.0023	0.1094	0.1094	14.89	H1[5] Accepted
First intention	P<0.0001	5.037	1.007	137.2	H1[6] Accepted
Residual		0.08810	0.007342		

difference is huge: the average score of the same question is 3.21 for female students and 2.60 for male students.

3.2 Motivational factors - results

Figure 2 presents values calculated from respondents' responses to questions related to selected motivational factors (see Appendix B). Resulting values are differentiated according to:

- student's first - intention („look for a job" or „continue to study"),
- gender (male or female student).

Numbers 1, 2, 3, 4, 5, 6 on the horizontal axis represent questions from the motivational factors category. Results were calculated on basis of the methodology presented in Equation (2). Two-way ANOVA method was used to confirm hypotheses. Results are presented in the following Table 3.

The results show that hypotheses $H1^4$, $H1^5$ and $H1^6$ have been confirmed in the area of motivational factors. Namely, it is the following hypotheses:

$H1^4$: Interaction between respondent's first intention („look for a job" or „continue to study") and gender („male students" or „female students") does affect motivational factors.

$H1^5$: A match in terms of gender has been found in evaluations of motivational factors in the group of respondents with the same first intention.

$H1^6$: Respondent's first intention does affect motivational factors.

4. Conclusion

The main objective of this study was to identify the trends of approach to human capital.The statistical testing has proved the dependence between a student's first-intention and gender, and their perceived employability and motivational factors. It has also been found that within the first-intention categories („look for a job" and „continue to study""), a dependence of perceived employability and gender can be observed. It also shows that in the „continue to study" category, the difference in response scores is greater than in the „look for a job" category.

The study brings new insights into the approach to human capital in the field of communications and transport, ever more as several hypotheses have been confirmed.

There is also room for further research. One possible topic for research could be the analysis of responses in both investigated categories, i.e. perceived employability and motivational factors, from the perspective of gender (it would be possible to explain functional relationship in the motivational factors category, where there are practically no differences between male and female students).

The main advantage of this study is in the fact that it draws on current data obtained in a primary research that was conducted in 2016. The study is also rather unique as no such research on this topic has been carried out so far in the Czech Republic.

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Appendix A: Perceived employability

Respondents who stated they wanted to "continue to study" evaluated the following statements:

1) "Graduating from university/higher vocational school/language school will enable me to get a better position once I start looking for a job."
2) "I consider the theoretical knowledge gained at the high school sufficient for finding a job."
3) "The high school in which I study is relatively prestigious in comparison with other high schools (regarding teachers, studies organization, extracurricular activities, etc.)."
4) "I consider the practical skills gained at the high school sufficient for finding a job."
5) "I consider the language competence gained at the high school sufficient for finding a job."

Respondents who stated they wanted to "look for a job" evaluated the following statements:

1) "The acquisition and deepening of practical skills and experience (through working in my country or abroad) right after graduating from high school will enable me to get a better position once I start looking for a job."
2) "I consider the theoretical knowledge gained at the high school sufficient for finding a job."
3) "The high school in which I study is relatively prestigious in comparison with other high schools (regarding teachers, studies organization, extracurricular activities, etc.)."
4) "I consider the practical skills gained at the high school sufficient for finding a job."
5) "I consider the language competence gained at the high school sufficient for finding a job."

Appendix B: Motivational factors

Respondents who stated they wanted to "continue to study" evaluated the following statements:

1) "The university/higher vocational school/language school is within minimum distance from the place where I live (so I don't have to pay for accommodation)."
2) "My partner works/studies near the university/higher vocational school/language school."
3) "I am mainly after getting a university degree."
4) "I am attracted by the high social prestige of the university/higher vocational school/language school."
5) "Higher qualification will be an advantage in the future search for a job."
6) "It will provide me with better chances of earning a higher salary."

Respondents who stated they wanted to "look for a job" evaluated the following statements:

1) "My workplace is within minimum distance from the place where I live (so I don't have to move away)."
2) "My partner studies/works near my potential workplace."
3) "I am mainly after gaining financial independence from my parents."
4) "I am attracted by the high social prestige of the company."
5) "I like the possibility of career advancement in my future job."
6) "I like the possibility to attend further educational programs such as language courses, professional seminars, etc., paid by the employer."

Monika Eisenhammerova - Jan Chocholac*

SEASONAL ANALYSIS OF TOTAL PREMIUMS WRITTEN OF THE MOTOR THIRD PARTY LIABILITY INSURANCE IN THE CZECH REPUBLIC IN YEARS 2000 - 2016 FROM THE MARKETING PERSPECTIVE

The insurance sector is in many ways unique, because insurance companies must use specific marketing tools to satisfy their customers and insurance companies have with customer's long-term relationships. Insurance companies must continuously monitor the insurance market, especially type of demand for insurance products and customer requirements. The number of registered vehicles in the Czech Republic is annually increasing, which causes an increase of total premiums written of the motor third party liability insurance and insurance companies must monitor this insurance product and analyse demand for it. The aim of this article is to analyse the seasonality of total premiums written of motor third party liability insurance in the Czech Republic in years 2000 - 2016.

Keywords: *non-life insurance, motor third party liability insurance, seasonal analysis of time series, Henderson moving average filter*

1. Introduction

The insurance sector is a set of specialized financial activities, otherwise insurance sector has many specifics, for example selling invisible products, high degree of trust between the insurance company and the customer, active approach to the customer and customer relationship management, consulting services for customers and insurance intermediaries have an important role in the insurance sector [1, 2].

The insurance market is influenced by many factors that can be divided into external and internal factors. External factors consist of development and volume of gross domestic product, inflation rate, unemployment rate, demography of the population, average wage, volume of expenditures of households, enterprises and institutions. Internal factors consist of demand for insurance products (the size and type of demand and its variability over time), activities of insurance companies and reinsurance undertakings, regulation of the insurance market, activities of the Czech Insurance Association, mediatory activities of insurance intermediaries etc. [3, 4].

There is a number of studies that emphasize the need to analyse and monitor the demand for insurance products and its variability over time with respect to use of the marketing tools and campaigns [5, 6]. Many businesses find that their working capital is fluctuating over time due to fluctuations in demand and seasonality of demand [7]. Some authors stated that seasonality of demand dictates business and marketing strategy in highly seasonal services such as accounting, tourism, advertising, construction, amusement parks, beauty salons, restaurants, car rentals, cinemas, communications, construction materials, education, public utilities, employment agencies, logistics services and financial services [8 - 11].

Insurance services can be divided from the marketing perspective into life insurance and non-life insurance, where the motor third party liability insurance belongs to the non-life insurance [12]. Nowadays insurance companies use some modern digital marketing tools for getting potential customers (blogging, social media and direct e-mail marketing) [1, 3]. Price is frequently the most important attribute for customers, but in insurance customers buying process are also relevant insurer, bundling strategy and intermediary's recommendation [13].

The motor third party liability insurance is one of the most important lines of insurance business in developed and in developing countries and motor third party liability insurance is a best - selling insurance product in developing countries [14].The number of the road vehicles registered in the Czech Republic is annually increasing and total written premiums of the motor third party liability insurance absolutely increased in years 2000 - 2016 [15].

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2. Methods

The time series represents a chronological sequence of data that are spatially and materially comparable [16]. The financial time series are concerned with the theory and practice of financial market over time [17]. The time series can be modelled using different approaches. The commonly used for modelling the time series is one-dimensional model of real value [18]. The model has the shape of an elementary function of time:

$$Y_t = f(t), t = 1, 2, \ldots, z \tag{1}$$

where z is the length of the series and Y_t denotes the value of the series recorded in time unit t [19].

The model can be created using two basic ways. The first way is to use the Box-Jenkins methodology. This methodology considers the basic element of the construction of the model time series random component, which may be taken as correlated random variables. Another option is to use the classical (formal) model of the time series decomposition into four components of time motion [20]: trend component (T_t), seasonal component (S_t), cyclical component (C_t) and random component (ε_t). Another possibility of expression describes Chan [21] - the time series is decomposed into a time trend part (T_t), seasonal part (S_t) and a microscopic part given by the noise (N_t).

The time series decomposition into individual components can be done by adding the individual components of the time series where components are considered in their actual values. Or, as a result of the individual components of the time series, if it can be considered in the actual value of trend and other components are in relative terms against the trend.

When the seasonal component S_t is present in equation, we can use the methods to determine this seasonality. The seasonal component can be described either by an additive model ($Y_t = T_t + S_t + N_t$) or by a multiplicative model ($Y_t = T_t \times S_t \times N_t$) [21].

For the simple additive model the procedure for calculating of seasonality effects is given as following steps [22]. We calculate Y^*_t for each time point, it is the difference between the original value (Y_t) and the trend Y'_t, see Equation (2). We can determine the trend using the moving averages [23]:

$$Y^*_t = Y_t - Y'_t \tag{2}$$

For each season, in turn, we can find the average of the Y^*_t values - the value I^*_j represents the seasonal factor for each season j (j = 1, ... , n; n represents number of seasons). We can subtract the average seasonal factor:

$$I_j = I^*_j - \frac{I^*_1 + \cdots + I^*_n}{n} \tag{3}$$

The last step is to remove the seasonal component (see Equation (4)), to make seasonal adjustment. Y''_t represents the data without seasonal effects, j represents the season (j = 1, ..., n).

$$Y''_t = Y_t - I_j \tag{4}$$

Seasonal models are often multiplicative rather than additive [24]. For the simple multiplicative model the procedure for calculating is given as following steps [22]. We calculate Y^*_t for each time point, it is the proportion between the original value (Y_t) and the trend Y'_t, see Equation (5). We determine the trend using the moving averages [23].

$$Y^*_t = \frac{Y_t}{Y'_t} \tag{5}$$

For each season, in turn, we find the average of the Y^*_t values - the value I^*_j represents the seasonal factor for each season j (j = 1, ... , n; n represents number of seasons). We can use the average seasonal index (see Equation (6)).

$$I_j = \frac{I^*_j}{\sqrt[n]{I^*_1 \cdot \ldots \cdot I^*_n}} \tag{6}$$

The last step is to remove the seasonal component (see Equation (7)), to make seasonal adjustment. Y''_t represents the data without seasonal effects, j represents the season.

$$Y''_t = \frac{Y_t}{I_j} \tag{7}$$

For a more detailed analysis and description of seasonal component can we use the following steps [25]: identification of the seasonal component, the seasonal component estimate (to quantify it), removing the seasonal component (to adjust the time series).

The first step is to get an idea about the character of the process, which is represented by the time series [26]. The simplest methods include visual analysis using time series graph. The second step is to use elementary statistical characteristics [27, 28].

The first difference characterizes the absolute change (increase or decrease) of the value of indicators point in time t compared to the previous period (t - 1). Indicator t takes values from 2 to n (n is the number of observations). It can be calculated using the following equation:

$$\Delta^{(1)} y_t = y_t - y_{t-1} \tag{8}$$

The second difference (differential of acceleration), is based on the difference of the two adjacent first absolute differences in the time moments (t - 1). Indicator t takes values from 3 to n (n is the number of observations). It can be calculated using the following equation:

$$\Delta^{(2)} y_t = \Delta^{(1)} y_t - \Delta^{(1)} y_{t-1} \quad (9)$$

The rate of growth (chain index number) indicates the percent increase of the time series at time t contrary to the previous time (t - 1). Indicator t takes values from 2 to n (n is the number of observations). It can be calculated using the following equation:

$$k_t = \frac{y_t}{y_{t-1}} \quad (10)$$

It is necessary to identify whether these fluctuations are statistically significant. In some cases the existence of seasonality could be revealed intuitively. In the more complex cases the answer could be obtained by the statistical verification.

To verify the hypothesis of the existence of seasonality in the time series, the existence of seasonality test could be used. The test takes the form of the F - test with (n - 1) and (n - 1).(m - 1) degrees of freedom [29].

The null hypothesis H_0 is tested. The hypothesis assumes that all indices in seasonal time series are zero. The form of hypothesis: $H_0 : S_j = 0 \; for \; j = 1, \ldots, r$ (11)

Null hypothesis is against the alternative hypothesis H_1. H_1 assumes that at least one index in the seasonal time series is non-zero. The form of hypothesis: $H_1 : non \; H_0$ (12)

The test statistics has following form:

$$F = \frac{\frac{m\sum_{j=1}^{n}(\bar{y}_j - \bar{y})^2}{r-1}}{\frac{S_R}{(n-1)\cdot(m-1)}} \quad (13)$$

$$S_R = \sum_{i=1}^{m}\sum_{j=1}^{n}(y_{ij} - \bar{y})^2 - n\sum_{i=1}^{m}(\bar{y}_{i.} - \bar{y})^2 - m\sum_{j=1}^{n}(\bar{y}_{.j} - \bar{y})^2 \quad (14)$$

where:

m the number of time intervals (years),
n the number of incremental time periods (seasons),
$\bar{y}$ the average oftime interval,
$\bar{y}_{.j}$ the average value in the j - th season,
$\bar{y}_{i.}$ the average value in the i - th interval.

Result of the test will be compared to the critical F-value distribution. It the value of the F-test statistics is greater than the critical value, the null hypothesis is rejected. If there is a seasonal time series component, it is necessary to quantify the seasonal variations and describe the seasonal component. The most common technique is the construction of indexes and seasonal differences, or the classical regression approach to the seasonal component.

We can use an additive model [22]; there are two options. If there is a trend in the series and the size of the seasonal effect appears to increase with the mean, then it may be advisable to transform the data so as to make the seasonal effect constant (this concept of seasonality is called the constant seasonality, the concept of constant seasonality can be described either by the linear trend or stepped trend). Or the size of the seasonal effect is said to be multiplicative (this concept of seasonality is called the proportional seasonality) [30, 31].

The model of the constant seasonality and the seasonal differences (b_j) can be described using the following equations: [32]

$$Y_{ij} = T_{ij} + S_{ij} + \varepsilon_{ij} \quad (15)$$

$$S_{ij} = b_j \quad (16)$$

$$\Sigma_{j=1}^{n} b_j = 0 \quad (17)$$

$$\bar{b}_j = \frac{1}{m}\Sigma_{i=1}^{m}(Y_{ij} - T_{ij}) \quad (18)$$

where:

m the number of time intervals (years),
n the number of incremental time periods (seasons),
i the time intervals (year), i = 1, 2, ..., m,
j the time periods (season), i = 1, 2, ..., r,
b_j the seasonal difference,
$\bar{b}_j$ the average seasonal difference.

The model of the proportional seasonality, the seasonal parameters (c_j) and seasonal indexes ($1 + c_j$) can be described using the following equations:

$$Y_{ij} = T_{ij} + S_{ij} + \varepsilon_{ij} \quad (19)$$

$$S_{ij} = c_j \times T_{ij} \quad (20)$$

$$Y_{ij} = (1 + c_j)T_{ij} + \varepsilon_{ij} \quad (21)$$

$$(1 + \hat{c}_j) = \frac{\Sigma_{i=1}^{m} y_{ij} \cdot T_{ij}}{\Sigma_{i=1}^{m} T_{ij}^2} \quad (22)$$

where:

m the number of time intervals (years),
n the number of incremental time periods (seasons),
i the timeintervals (year), i = 1, 2, ..., m,
j the time periods (season), i = 1, 2, ..., r,
$(1 + c_j)$ the seasonal index,
$(1 + \hat{c}_j)$ the estimated seasonal index.

The choice of the model can be confirmed by analysis of the empirical data - the index of determination [33].

The last step is the seasonal adjustment of the time series. Methods of seasonal adjustment are usually based on different types of moving averages. Furthermore, the regression methods or special filters is used. We can use the Equation (4) for the additive model or Equation (7) for the multiplicative model and we can use special filters, as well. We can adjust the time series by a Henderson moving average filter. Filter values for quarterly data are (- 0.073, - 0.294, 0.558, 0.294, - 0.073). We use special filter for the first

Table 1 Total written premiums (CZK)

Year	Quarter			
	I.	II.	III.	IV.
2000	8 238 250 051	1 280 894 987	1 939 802 791	1 302 995 043
2001	8 551 967 975	2 435 886 956	2 429 250 249	2 107 394 158
2002	8 785 018 870	2 635 259 903	2 940 351 869	3 321 244 275
2003	9 017 700 717	3 387 194 231	3 768 388 913	3 525 820 090
2004	8 585 094 323	4 020 838 244	4 204 559 935	4 150 365 492
2005	8 165 886 283	4 315 786 804	4 649 390 901	4 565 761 580
2006	7 533 299 839	4 879 077 613	4 835 398 027	4 859 864 426
2007	7 316 111 159	5 284 682 766	5 131 876 172	5 217 300 715
2008	7 377 390 462	5 528 561 938	5 369 001 117	5 433 909 496
2009	7 304 281 899	5 588 876 693	5 433 887 480	5 447 997 444
2010	6 574 423 103	5 510 400 176	5 089 435 430	5 169 296 336
2011	5 977 322 299	3 468 702 668	4 686 205 694	3 261 509 297
2012	5 433 731 712	4 865 010 097	4 568 434 435	4 604 652 313
2013	5 315 651 506	4 867 612 572	4 466 550 550	3 125 507 531
2014	5 440 668 934	5 065 328 774	4 647 015 809	4 887 662 401
2015	5 423 764 786	5 240 604 470	4 868 146 979	5 034 794 468
2016	5 518 494 871	5 420 106 857	4 933 182 417	5 099 435 130

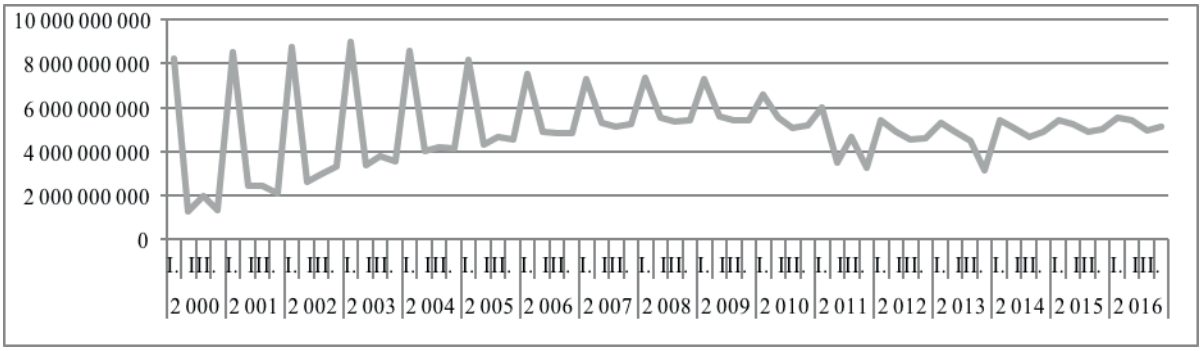

Figure 1 *Total written premiums (CZK)*

adjusted value (Y_1'), the second adjusted value (Y_2'), the last adjusted value (Y_z') and the penultimate adjusted value (Y_{z-1}') : [34]

$$Y_1' = 0.670Y_1 + 0.403Y_2 - 0.073Y_3 \quad (23)$$

$$Y_z' = 0.670Y_n + 0.403Y_{n-1} - 0.073Y_{n-2} \quad (24)$$

$$Y_2' = 0.257Y_1 + 0.522Y_2 + 0.294Y_3 - 0.073Y_4 \quad (25)$$

$$Y_{z-1}' = 0.257Y_n + 0.522Y_{n-1} + 0.294Y_{n-2} - 0.073Y_{n-3} \quad (26)$$

3. Data

The motor third party insurance was required by law until 2000 [35]. An Act No. 168/1999 Coll. - Motor Third Party Liability Insurance act on liability insurance for damage caused by operation of vehicle and on amendments to certain related acts (the Motor Third Party Liability Insurance Act) coming into force in 2000 [36]. The motor third party insurance is mandatory according to the new law. The development of this type of insurance in the period 2000 to 2016 shows the following Table 1. The data in the table are given in Czech crowns and show the trend of total written premiums.

4. Results

Using visual analysis of time series (Figure 1) it can be said that the time series has each year a polynomial character with the effects of seasonality.

By using the elementary statistical analysis of the characteristics, it can be said that the time series recorded increase

Table 2 Seasonal factors and seasonal indexes

Season	Average seasonal factor - simple additive model [CZK]	Average seasonal factor - simple multiplicative model [-]
I.	2 004 576 118	1.4732
II.	- 536 399 222	0.9130
III.	- 634 430 530	0.8878
IV.	- 833 746 366	0.8374

Table 3 Seasonal differences and seasonal indexes

Season	Constant seasonality		Proportional seasonality - seasonal index [-]
	Linear trend - seasonal differences [CZK]	Stepped trend - seasonal differences [CZK]	
I.	2 120 294 316	2 100 087 671	1.3747
II.	- 644 014 018	- 650 749 566	0.8868
III.	- 647 717 290	- 640 981 742	0.8835
IV.	- 828 563 008	- 808 356 364	0.8563

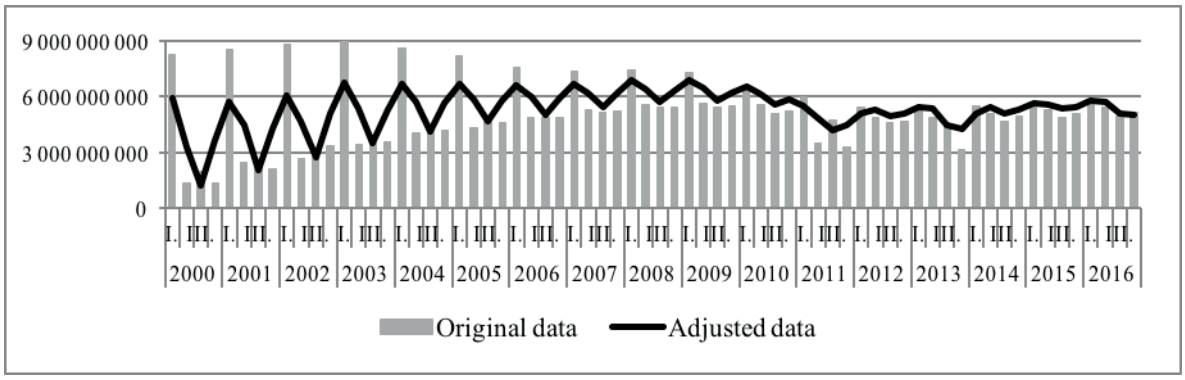

Figure 2 *Adjusted data (CZK)*

in the first quarter of each year, and conversely a decline in the second quarter of each year. This fact points to the same conclusion to be drawn from the analysis of the graph, the time series is affected by seasonal influences. The seasonal component S_t is described using the simple additive model (average seasonal factors) and the simple multiplicative model (average seasonal factor), see Table 2.

Seasonal influences in the time series with a periodicity of less than one year can be found almost always. We used the F-test for statistically significant confirmation. We chose significance level $\alpha = 0.05$, degrees of freedom are 3 and 48. The critical value is equal to 2.7985. The value of the test statistics F was higher than the critical value (26.637), the null hypothesis is rejected since there is a significant seasonality.

We used the concept of constant seasonality (we determined seasonal differences for linear trend and for the stepped trend) and the concept of proportional seasonality (we determined seasonal indexes), see Table 3.

The choice of appropriate model among other options was confirmed by analysis of empirical data-we used index of determination. The value of the index of determination was: 0.52 (the concept of constant seasonality-linear trend), 0.69 (the concept of constant seasonality-stepped trend), 0.92 (the concept of proportional seasonality). The coefficient of determination generally takes values from the interval <0, 1>. The more are functions apposite, the more is the coefficient of determination closer to one. The selected concept (the concept of proportional seasonality) explains 92 % of the values of variables.

The last step was the seasonal adjustment of the time series. We chose adjustment of the time series by a Henderson moving average filter. This method is commonly used in practice. The method allows adjustment of limit values and time series. The following graph shows the results-comparison of original and adjusted values (see Figure 2).

Seasonal adjustment is done because there is a need of continuous comparison of consecutive data. After elimination of the seasonal component, in the model remain the trend component, the cyclical component and a random component (if any).

5. Discussion

The problem of demand variability and seasonality is solved by many experts not only on the theoretical level, because demand seasonality affects some businesses and some sectors daily. There are currently many professional studies that focus on the problem of demand seasonality, especially in services such as accounting, tourism, advertising, construction, restaurants, communications, construction materials, education, public utilities, employment agencies, logistics services and financial services [8 - 11]. However, there is currently no relevant study or sources to analyse demand seasonality in the insurance sector or of the specific insurance product. Otherwise some authors emphasize the need to analyse and monitor the demand for insurance products and its variability over time related not only to the working capital [5 - 7]. Seasonality of demand is a very important parameter for marketing planning in general, especially for planning of marketing campaigns and activities, and for marketing and business strategy [8 - 11]. The seasonality of demand for motor third party liability insurance has been confirmed for the Czech Republic in years 2000 - 2016, based on the research results (Section 4). Insurance companies should reflect the results of research when developing the marketing strategy, preparing marketing campaigns or activities, because it is necessary to implement these activities in accordance with demand for insurance products.

6. Conclusion

The current turbulent market environment is very competitive and insurance companies need information about demand for insurance products, as much as possible. This information can be used to increase the competitiveness of insurance companies and for more efficient planning of marketing activities, especially in the situation where the demand is growing (due to seasonality). If there is a seasonal demand in any given sector, companies need the most accurate information about the seasonality of the demand. The motor third party liability insurance in the Czech Republic in 2000 - 2016 is seasonal, based on the research results, which implies necessity to take this into account when planning any business activities, especially for marketing activities. The combination of an increase of demand (due to seasonality) and application of appropriate marketing strategy can get a better position on the market for insurance company.

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kamunikácie
COMMUNICATIONS

Daria Gunina - Tomas Kincl - Sabina Suldova*

USAGE OF COLORS IN TV COMMERCIALS: CROSS-INDUSTRY ANALYSIS OF MASS MEDIA COMMUNICATIONS

The aim of this study is to analyze the differences in color schemes in TV commercials across different product categories. The study answers the question of whether advertisers in different industries use specific color schemes to promote their company or products in TV commercials and if they follow the general recommendations for using colors in marketing communications. The research sample consists of 200 video adverts proportionally representing the commercials aired in six major product categories in the Czech Republic in 2016. The results indicate there is no statistically significant difference in the usage of colors between the product categories. Nevertheless, the advertisers in the Czech Republic generally follow the color scheme recommendations suggested by the theory.

Keywords: *color content, commercials, television, mass media communication*

1. Introduction

Color plays an important role in marketing communications. It helps to create a company or product identity, enhances brand recognition [1, 2], its memorization [3] and trust [4], attracts consumer attention [5, 6], shapes consumer perception [7] and initiates purchase intentions [3, 8, 9]. As a prominent factor, color also affects advertising effectiveness [10, 6] and recall [11]. Color also influences human emotions [12] and expresses customer personality [13]. To support customer self-expression, most products are offered in various colors [5]. The color subconsciously shapes consumer behavior and induces different motivations [14] – i.e., if the brand is familiar to the customer, they recall their own experience with the brand; however, if the consumer does not know the brand, they recall their associations with the color [5].

Each color has a different significance and consumer color preference also differs in various product categories [5]. The actual color itself can also affect the association of a product with a particular category [1, 15]. There is also a difference in associations triggered by different products with the same color [3]. Therefore, advertisers must carefully select an appropriately assigned color scheme for a particular product category to make the product desirable [16, 17].

In general, cool colors (blue, green and violet) are preferred over warm colors (red, yellow and orange) [11]. Blue and green are recommended functional products needed to solve or prevent problems while red is a good color for sensory-social products used for self-expression, pleasure, and social approval [1]. For example, financial services are often associated with blue and green [1]; health foods with blue, green and yellow; toys with red, yellow, green and blue; cosmetics with pink [16]. Bright and cool colors seem to be habitual for the jewelry industry and bright and warm colors for children's products [9]. Beige is preferable for furniture, carpets, and paint [3]. Electronics are mostly colored black or silver, and gardening products are green [14]. Most cars are sold in black, white, red, blue and gray colors [3]. Red color is often used in the fast-food market to stimulate consumer appetites [9]. Red is also a very popular color in casinos [3], dark and warm colors are popular in night clubs, although dark and cool colors are popular in classy restaurants [9]. The color of food may help consumers to identify the flavor [16] plus the color can influence time perception when waiting [9] or spending time in the store. Gray is considered as neutral [8] and is more appreciated by men, while women prefer pink [18]. White is related to neutrality, cleanliness, and trust and in contrast, black represents modernity, style, and professionalism [19] but is also neutral. Nevertheless, black, brown, and red are sad colors while blue, orange and yellow are happy colors [9]. Brown is associated with nature [5] and environmental quality [19].

However, there is a difference between a customer's response to an individual color itself and to a product of a particular color [6]. The customer's favorite color may also have a different impact when deciding on products with high involvement [3]. For

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products with high involvement – e.g. a car or a furniture – the customers' decision is less influenced by their color preference, but rather by usual or common/expected colors associated with the product. Color combinations also evoke diverse customer reactions than just one isolated color. Therefore, marketers must carefully select the color schemes when promoting company products or the company itself.

The impact of color on various marketing activities has been examined in many previous studies. This paper focuses on the impact of color in advertising. Most developed countries suffer from advertising clutter and mass media proliferation [20, 21]. Even if the digitalization of mass media allowed more precise profiling of TV (television) channels, advertisers still do not fully utilize targeted mass media communication strategies and would rather take an undifferentiated approach [22]. In the cluttered advertising environment where customers are prone to advertising overload, a careful choice of a proper color scheme influences the first impression and eases delivering the marketing message [15]. By using the right color scheme, companies can differentiate from their competitors [16, 9], enhance brand awareness, assign their product to the corresponding product category, and better target their specific audiences [5].

The motivation of this paper is to contribute to this current and resonating debate and to *analyze the differences in color schemes in TV commercials across different product categories*.

2. Research design and methodology

To answer the research question of whether *there is* a *difference in color schemes used in TV commercials across different product categories*, we analyzed the selected TV commercials aired in the Czech Republic in 2016 and used two applications: the Movie Barcode Generator [23] and the Color Extraction app provided by MulticolorEngine [24].

The commercials belong to various product categories (according to the classification NACE – Statistical Classification of Economic Activities in the European Community) – based on the monitoring data provided by Nielsen Admosphere, a. s. Categories that represented over 90 % of commercials aired in the Czech Republic in 2016 are C – Foods, Drinks, D – Textile, Clothing, Leather, Shoes, E – Other Manufacturing Industry, L – Information and Communication Activities, M – Finance and Insurance, and T - Cultural, Amusement and Recreation Activities. The overview of all categories included in the analysis is in Table 1.

To select the video adverts for the analysis, we used stratified sampling where the strata reflected the number of ads in NACE categories in the whole population (ads aired in Czech Republic in 2016). Within each strata, the adverts were randomly selected from the top 20 % of the largest advertisers in each NACE category. The research sample contains 200 video adverts (see Table 1) and all commercials were downloaded from youtube.com in the highest quality available. The list of all analyzed advertisements is included in Appendix A.

Each video of an advert was processed by the Movie Barcode Generator. The software divides the video into 1000 frames. Each frame is represented by a column 1 px wide. The pixels in the column embody the colors included in each frame, divided proportionally (according to the color in each frame) between 500 px. For each video of an advert, the software generates an output image of the size 1000×500 px. The output image was used to analyze the color scheme of the analyzed video.

Each color scheme was subsequently analyzed by the Color Extraction software. The software extracts the color palette of the image (see Figure 1) and calculates the percentage of all colors used. The app also assigns all identified colors to the scale of 11 basic colors [25] – blue, gray, green, brown, red, violet, orange, white, yellow, pink and black. According to Singh [9] and Crowley [11], the colors were also divided into a warm group (red, orange, yellow, pink, brown), a cool group (green, blue, violet) and neutral (gray, black, white).

To compare the frequencies of colors in each category, we utilized the Chi-Square Test of Independence. The research hypothesis was formulated as:

H_0: the representation of colors in different NACE categories are independent variables.

The Findings Chapter provides the results of the analysis; the interpretation and discussion of the results follow in the Discussion Section.

3. Findings

Table 2 shows the color usage in TV commercials across the analyzed NACE categories. In general, the most used colors are neutral (gray, black, and white – 45.29 %). Moreover, the cool colors (blue, green and violet – 31.03 %) are used more than the warm ones (brown, red, yellow, pink, and orange – 23.11 %).

Table 3 shows the most used colors in each of the analyzed categories (each column sorted by the colors according to their usage in video adverts). The most popular colors among all categories were gray, blue, black, brown and green. Such colors accounted for more than 80 % in each category (Category C = 92.76 %, D = 92.7 %, E = 84.7 %, L = 88.12 %, M = 86.46 %, T = 94.59 %). The color ranking is very similar across the categories, even if there are some minor differences. In comparison with other categories where the most used color was gray, in C the most prominent color is brown (over 30 %). Similarly, in T the most protuberant color was blue (35.31 %). D was the only category where white (6.43 %) was in the top 5 most used colors. Otherwise, the color ranking appears to be similar.

To answer the research hypothesis about the independence of colors among categories, the Chi-Square Test of Independence

Table 1 Research sample

Category	Description	Number of ads in 2016	Category % of total number	Number of ads in sample (% of total x 200)
Category C	food and drinks	3 210 452	31.41 %	63
Category D	textile, clothing, leather, shoes	156 143	1.53 %	3
Category E	other manufacturing industry (electrical devices, pharmaceutical products, chemicals and chemical products, motor vehicles, furniture, other products, computers, electronic and optical products)	4 726 769	46.25 %	93
Category L	information and communication activities	977 682	9.57 %	19
Category M	finance and insurance	737 169	7.21 %	14
Category T	cultural, amusement and recreation activities	412 888	4.04 %	8
	Total in C, D, E, L, M, T	10 221 103	100 %	200

Figure 1 *Example of the software transformation: Bepanthen Care's Barcode and Color Map (Source: MulticolorEngine [24])*

was conducted. However, the p-value = 0.967 (Pearson Chi-Square = 33.226; df = 50) indicates that H_0 cannot be rejected. There is no statistically significant difference between the categories in the usage of colors.

Since neutral colors are often used as a background color to emphasize the objects or messages in the foreground, we skipped the neutral colors and conducted the Chi-Square Test of Independence again. However, even with the neutral colors removed, there was no statistically significant difference among the categories in the usage of colors (p-value = 1.000; Pearson Chi-Square = 13.605; df = 35). Therefore, the H_0 cannot be rejected.

Table 4 provides a similar analysis as above; however, it distinguishes only between neutral-cool-warm groups of colors.

Again, in some categories (D, M, L), the neutral colors were the most prominent. The cool colors were the most used only in T, while the warm colors were the predominant only in C. The Chi-Square Test of Independence once more revealed there is no statistically significant difference among categories in the usage of colors (p-value = 0.400; Pearson Chi-Square = 10.478; df = 10). Similarly to the previous analyses, the H_0 cannot be rejected.

4. Discussion

The analysis revealed no statistically significant difference in the usage of colors among the most frequently represented categories of video adverts in the Czech Republic in 2016. However, this does not mean that the advertisers in the Czech Republic do not follow the color theories addressing the color scheme recommendations for different product categories.

The popularity of using neutral colors (esp. gray) can be explained by the fact that the background is usually colored with a neutral color to highlight the object of the communicated message (product, service, or message) [26, 27]. The background is monochrome and represents the largest space of a scene. The results also resonate with previous studies (i.e. [11]) suggesting that cool colors are used more often than the warm ones.

Category C (food and drinks) is the only category which has more than 13% brown (30.74 %). Brown is associated with nature [5] and environmental quality [19]. Other colors associated with healthy food are blue (12.36 %), green (15.34 %) and yellow [16]. Therefore, the colors used to promote companies and their products and services in this category generally follow the recommendations about proper color scheme choice.

Table 2 Color usage in TV commercials

Hue	Gray	Brown	Blue	Green	Black	White	Violet	Red	Yellow	Pink	Orange
Percentage	29.82 %	18.13 %	16.46 %	12.03 %	11.76 %	3.71 %	2.54 %	2.27 %	1.58 %	0.65 %	0.48 %

Table 3 Color share in particular categories

	Category C	Category D	Category E	Category L	Category M	Category T
1.	Brown (30.74 %)	Gray (60.17 %)	Gray (31.05 %)	Gray (34.44 %)	Gray (42.28 %)	Blue (35.31 %)
2.	Gray (24.47 %)	Blue (12.60 %)	Blue (18.48 %)	Blue (16.64 %)	Black (12.77 %)	Black (27.49 %)
3.	Green (15.34 %)	Brown (12.30 %)	Brown (12.93 %)	Black (14.41 %)	Blue (11.32 %)	Gray (13.39 %)
4.	Blue (12.36 %)	White (5.63 %)	Black (11.32 %)	Brown (11.66 %)	Brown (10.47 %)	Brown (10.11 %)
5.	Black (9.85 %)	Green (5.20 %)	Green (10.92 %)	Green (10.97 %)	Green (9.62 %)	Green (8.29 %)
6.	Violet (2.83 %)	Black (2.43 %)	White (6.43 %)	Violet (5.35 %)	White (5.04 %)	Violet (2.86 %)
7.	Yellow (2.08 %)	Violet (1.47 %)	Red (3.09 %)	White (2.36 %)	Red (2.52 %)	Yellow (1.26 %)
8.	Red (1.56 %)	Pink (0.13 %)	Violet (1.98 %)	Yellow (1.83 %)	Yellow (1.98 %)	White (0.98 %)
9.	Orange (0.37 %)	-	Yellow (1.22 %)	Red (1.63 %)	Violet (1.20 %)	Red (0.21 %)
10.	Pink (0.35 %)	-	Pink (1.05 %)	Pink (0.51 %)	Orange (0.98 %)	Pink (0.05 %)
11.	White (0.05 %)	-	Orange (0.63 %)	Orange (0.02 %)	-	-

Surprisingly more than half the share of *Category D* (textile, clothing, leather, shoes) is devoted to one color (60.17 %; gray) and exhibits less basic colors than the other categories (only 8). As clothing is a product of low involvement [3], the reason for using mostly gray may lie in the customers' color preferences. As the individual color preferences play a prominent role in the purchase decision, in this product category it can be hazardous to choose a specific color. There is no universal or generally accepted color for such products; therefore, the advertisers could use a neutral color deliberately. Moreover, cool and warm colors are balanced in this category.

Category E (other manufacturing industry) is also mostly represented by a neutral color (31.05 %; gray), which is probably due to highlighting the object of the communicated message in the foreground. The other most frequently represented colors reflect the nature of the products in this category – blue (18.48 %) and green (10.92 %) are appropriate colors for functional products [1].

The results of *Category L* (information and communication activities) and *Category M* (finance and insurance) are similar to Category E. The prevailing colors are neutral - gray (34.44 % for L, 42.28 % for M), followed by black (14.41 % for L; 12.77 % for M). The neutral colors are followed by blue (16.64 % for L; 11.32 % for M) and green (10.97 % for L, 9.62 % for M), which are typical for functional products [1]. What is quite surprising is the higher share of brown (11.66 % for L; 10.47 % for M). However, information and communication technologies, as well as the financial product, are often shown as contributing to a better environment and the quality of life these days [28, 29]. Again, it can be concluded that the prevailing colors reflect the nature of the products from these categories.

Surprisingly *Category T* (cultural, amusement and recreation activities) is represented by the higher share of blue (and therefore cool) color (35.31 %), followed by black (27.49 %) and gray (13.39 %). Such products were expected to be promoted with bright and warm colors expressing pleasure or social approval [1]. Contrary to this, red (0.21 %), yellow (1.26 %), and violet (2.86 %) represent less than 5 % of the share of colors used in the video adverts. The advertisers do not follow the general recommendations for this category.

5. Conclusion

This study aimed to analyze the differences in color schemes in TV commercials across different product categories. The research sample was 200 video adverts aired in the Czech Republic in 2016. The adverts came from the largest advertisers in the country in product categories representing over 90 % of all aired advertisements. Even if the analysis revealed no statistically significant difference in the usage of colors among the most frequently represented categories, it still provided some interesting conclusions.

Surprisingly, the most used colors are neutral (especially gray and black). The other colors generally reflect the recommendations for using colors in marketing communications

Table 4 Color groups share in particular categories

	Category C	Category D	Category E	Category L	Category M	Category T
Neutral	34.37 %	68.28 %	49.24 %	51.30 %	61.20 %	41.88 %
Cool	30.53 %	19.28 %	31.66 %	33.02 %	22.55 %	46.48 %
Warm	35.10 %	12.44 %	19.09 %	15.68 %	16.25 %	11.64 %

and the psychological properties of colors. The findings are in line with previous empirical studies and contribute to the field by providing additional empirical evidence. Moreover, there are only limited studies in Central Europe area in this field.

Our study also provides some managerial implications. It emphasizes the role of colors in marketing communication in the mass media and provides an overview of the Czech advertising market. The marketers should carefully design their marketing campaigns with respect to consumer color preferences in particular categories [7]. Some studies suggest the color scheme or composition plays an important role in perceiving the gist of the communicated message [30]. On the other hand, a successful marketing strategy also requires to step out of the crowd and not to blindly follow the routine and general color recommendations. The colors preferences, perceptions, or associations are prone to cultural bias [31], even though some studies suggest the color effects operate on universal levels as well [7]. Managers definitely need a deeper insight into the psychological effects of colors in marketing, esp. in the international environment where it remains a challenge to find a balance between establishing and maintaining a product image and reflecting consumers' cultural backgrounds.

There are several limitations of this study. The research sample of 200 commercials accounts for only 0.1 % of the total number (195 306) of all unique commercials broadcast in the Czech Republic in 2016. The results are also biased by the selection (even though it was random) of adverts and an extended study is needed. Color research is also prone to perceptual and cultural bias – i.e. different people have a different perception of colors (according to their physical conditions and limitations), the lighting of the environment influences the color perception, and colors have various meanings in different cultures. Therefore, the conclusions of this study must be considered with respect to its limitations.

The limitations of this study also provide an opportunity for further research. The study could be extended in terms of research sample size (even though the processing of the adverts is being made manually and is time-consuming) and could also cover more product categories. The differences between various national markets also call for a deeper investigation.

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Appendix A – List of Analyzed Advertisements

Category C		
7 Days – Euroleague	Hello – Vybirejte srdcem	Milkana – Chut plna mleka
Ahmad Tea – Ledove caje	HiPP – Nic neni bliz materskemu mleku	Milko – Recke jogurty zimni limitovana edice
Algida – Porce rodinne radosti	Chio Chips – Pritahnou kazdeho	Mlekarna Kunin – President
Aperol Spritz – Naladi po praci	Chocenska mlekarna – Jalapeno Poctive palive	Nestea – Udelej pro sebe neco dobreho
Aquila – Prvni voda AquaBabes	Chupa Chups – Doba ledova 5	Nestle – Cheerios Oats
Babiccina volba – Dortova Velikonoce	Jacobs – Snete s otevrenyma ocima	Orbit – Jezte, pijte, zvykejte
BeBe dobre rano – Namekko Energie na Cele dopoledne	Jupi – Fousate leto	Pedigree – Denta Stix
Becherovka Original – Cim vetsi vasen, tim vetsi radost	Kinder Bueno – Orient Express	Pickwick – Zahreje nejen vase telo, ale i dusi
Bertolli – To nejlepsi z masla a olivoveho oleje	Kofola – Fofola a couvani	Pilsner Urquell – Svetlo Vanoc
Big Corny – Corny to das!	Kostelecke uzeniny – Poctive parky z Kostelce	Prima – Mroz zmrzlina vyrobena s laskou
Big Shock – Sokuj sam sebe	Lays – Pivo chutna lepe s Lays strong	Purina ONE – 3 tydenni test
Bohemia Chips – Soutez o pekacky	Lindt – Lindor Tajemstvi	Rajec – Patentovane prirodou
Bozkov – Bozkov bily	Lucina – Nadychana s okurkou a koprem	Sedlcansky – Soutez nozik
Brit – Let´s bite!	M&Ms – Sam si vlez do misky	Semtex – Odpal to naplno
Coca Cola – Vanoce 2016	Maggi – Extra silny bujon	Staropramen – Jedno nas spojuje
Danone – Activia	Majka – Radost byt spolu	Sunar – Po kom to ma? Po Sunaru.
Dr Oetker – Paula strakaty puding	Mattoni – Pomerancove mambo	Tatra – mlsani, ktere neomrzi
Emco – Mamy dekujeme	Merci – Finest Selection	Tic Tac – Osvezujici chvile
Fanta – Fantasticka zabava	Milka – Kouzlo Vanoc kazdy den	Tuc – Vitejte v zemi moznosti
Frisco – Objevte nove barvy noci s Frisco Night		Vinarske fondy – Na zivot jako vino!
Granko – retro edice		Vitana – Farmarske polevky
Hellmanns – Delikatni tatarska omacka		Zott – Monte Snack

Category D		
Deichmann – jaro leto 2016	Dormeo – Fresh Prima	F&F – leto 2016

Category E		
Airwick – Wax Melt vune domova	Ford – Tuhle jizdu si urcite zaslouzite.	Nicorette – Zbavte se zavislosti na koureni
Albi – iKnow	Garnier – Velka show s Benem Cristovaoem	Nissan – Stvoren pro rodinu.
Ariel – Velka vyzva „Ariel“ cistota	Gorenje – Design by Starck	Nivea – Krasne vlasy diky peci Nivea.
Audi – Q2 #untaggable. Naskok diky technice.	Grand Optical – 3 bryle za cenu 1	Olynth – Uvolnuje, zvlhcuje a regeneruje
Avon – Nutra Effects rozjasnujici krem, krasne pro sebe	Hamleys – Zabava zacina.	Oral-B – Stante se expertem s Oral-B
Balakryl – Voskovy olej	Herbadent – Vychytavky Extra	Oriflame - Oriflame Sweden
Bepanthen Care – ucinna pece proti projevum opruzeni miminek	Honore – Eva Samkova. Zapomen na pochyby.	Oscillococcinum – Preventivne a od prvnich priznaku
Blackfire – Svet her a zabavy.	Huawei – Jaromir Jagr. Make it Possible	Pampers – Tak suche, kam se to vsak podelo?
BMW – Radost z jizdy.	Hugo Boss – The Scent	Paralen – Oblibena klasika na horecku a bolest.
Borotalco – Stop poceni	Hylak Forte – Pro Vase traveni jako nove	Parodontax – Pomaha zastavit a predchazet krvaceni dasni
Bosch – Silent Mixx prislusenstvi	Hyundai – Sebejisty za vsech okolnosti	Persil – Deti kuji pikle
Braun – Jessica Alba	Ibalgin gel – Natrete to bolesti	Peugeot – Nove SUV Peugeot
Buxton – Buxton	Igracek – Jsi cesky original, jsi Igracek.	Pompo – katalog. Sileny profesor.
Calvin Klein – Deep Euphoria	Indulona – vsestranna pece	Priessnitz – Priessnitz
Cannaderm – Mentholka Extra	InSportline – domaci posilovna	Primalex – Vymalujte si zivot
Citroen – Angry Birds	Isana – Sprchovy gel pro zeny nebo pro muze	Rimmel – Neprekonatelna Cara Delevingne.
Clavin – kolo	Kia – Zcela nova Sportage.	Rimmel London.
	Kika – Domov vaseho zivota.	

Coldrex – Silnejsi nez chripka a nachlazeni	Klenoty Aurum – Jaromir Jagr. Sperky nejsou hrich.	Sally Hansen – Sally Hansen
Colgate – Objev ji pro sebe	Lacalut – zubni pasta, ktera ucinkuje	Savo – Bezchlorova rada. Resi temer kazdy problem v domacnosti.
Corega – Jezte, mluvte a smejte se s jistotou!	Lactacyd – Protoze sebeduvera je videt.	Sensodyne – Zubni lekari doporucuji Sensodyne.
Dacia – Zase dalsi ridi Duster	Lancome – Zivot je krasny. Vune stesti	Septabene – v krku vase sila
Dedra – Dedra Innovations primo k Vam.	Lenor – Amy Sedaris Unstoppables	Sikaflex – Stavime na duvere
Dermacol – 16H Lip Colour. Pro lasku jako stvorena.	LG – Nejlepsi televize vsech dob	Somat – Tak ciste. Tak snadne.
Dolgit – pomaha pri artroze a revmatismu	Lioton – Pro Vase zdravi a krasu	Spektrum – Spektrum Gummies
Doliva – rada s olivovym olejem	Listerine – Pocit v sobe silu	Surf – Vune cisteho pradla
Domestos – Sila v kazdem splachnuti	Loreal – Excellence Creme, Vy za to stojite.	Varilux – Dej silu svemu videni.
Dove – Moje vlasy moje volba	Martanci – Vesmirny projektor	Vicks – Od nachlazeni zpet k zivotu.
Durex – Mene casu s displejem vice casu na hrani	Mixa – Cold Cream. I citliva plet si zaslouzi hyckat.	Vichy – Cas leti, ale vy muzete zpomalit.
Espumisan – Simeticonum 40mg	Mobelix – To nejlepsi pouze vyhodneji.	Volkswagen – Dokonalost je jen zacatek.
Festina – Time to live.	MoliMed – O krok dal pro zdravi	Wobenzym – ...proste pomaha
Fiat – Nalad se na X.		Zendium – Podporujte prirozenou obranyschopnost Vasi ustni dutiny.
Fisher Price – Smej se a poznavej!		

Category L

Casopis Epocha – Casopis, ktery Vas vtahne do deje.	Fortuna – Trezor. 100Kc na ruku pro nove hrace.	Muj cas na kaficko – To nejlepsi, co si muzete ke kave dat.
Cedok – Verite nam od roku 1920.	Frekvence 1 – Hraje nase pisnicky.	Muj svet – Zivot, ktery me bavi.
Denik Metro – Vase metropolitni noviny.	Invia – More zajezdu na jednom miste.	Neckermann – Budte drzi.
DIGI - Nova DIGI TV	Mapy – Mobilni aplikace Mapy.cz	O2 - Nadelujeme to nejlepsi z chytre site
E-darling – Seznamka pro narocne.	Moje chvilka pohody – Casopis, co Vas chytne za srdce.	T-mobile – Klinika inovativni pece
Exim Tours – Poradatel cest do exotickych raju	Moje stastna hvezda – Naladte se do pohody.	UPC – Bez zpomalovani a vypadku
		Vodafone – Probudte v sobe to nejlepsi

Category M

Airbank – I banku muzete mit radi.	CSOB – Investice pro kazdeho	Sberbank – Fer pujcka srpen 2016. Vas pribeh, Vase banka.
Allianz – Revoluce v autopojisteni	Equa bank – Repujcka	Unicredit bank – Pro vsechny, kdo neprestavaji chtit vic.
Cetelem – 200 000 Kc za 2700 Kc mesicne	Fio – Ucet pro obcany, podnikatele i firmy bez poplatku a podminek	Zlato.cz – Chytre sporeni s Felixem
Cofidis – Partnerska pujcka. Dik za lasku tvoji zlato.	ING – Podilove fondy. Penize na spravnem miste.	Zonky – Lide pujcuji lidem.
Creditas – Chtejte vic od svych uspor.	Mastercard – Priceless Specials	

Category T

Adademie ved CR – Tyden vedy a techniky.	Cinema City – 1. kvetna 2016	Red Bull – Red Bull Flying Bach
Aqualand Moravia – Nejvetsi zabava pod sluncem	CZECH TEAM – Vsichni jsme jeden tym.	Tipsport – Vstupte do nejvetsi komunity sazkaru
Cine Star – Cool Ticket	Eurojackpot – Pravy duch Vanoc	

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NEW METHODS OF DESIGNING THE BALANCED SCORECARD METHOD FOR MANAGEMENT IN INDUSTRIAL COMPANIES

The Balanced Scorecard (BSC) is a strategic performance measurement system for enterprises, which allows managers of industrial corporations to measure variables that are based on strategic goals of a company. The issue while creating and implementing the BSC system could lay in a mere copying of its traditional forms without incorporating specific needs of a particular enterprise. This article aims to present the research results of a team of authors that was, in cooperation with managers of selected companies in the Moravian-Silesian region, searching for an answer to a question, whether it is possible to simplify the creation process of the BSC without losing the information value of the whole method or of its individual parts. At the same time it was examined whether, in the case of heavy industry, there are different priorities against others.

Keywords: *strategic management, BSC method, industrial companies, managers, competitiveness, consistency analysis, item analysis, focus groups, questioning*

1. Introduction

The on - going processes of the market globalisation and computerization, management's internationalisation and product and technological innovations bring to the market both - opportunities, as well as threats. Early anticipation of these changes and ability to deal with potential problems of a strategic nature, bring to these enterprises certain competitive advantages [1]. The core of successful company management consists of strategic management that cannot be effective without relevant information serving as a basis of manager's knowledge needed for their decision - making processes. In industrial corporations, in particular, well - done implementation and management of innovations play a great role [2].

When forming a strategy one should work with the results of strategic analysis. To do that you need to have an appropriate IT support with all the types of companies: large industrial enterprises [3] or small and medium - sized enterprises [4], or the public sector organizations [5]. Current managers are in need of a complex tool to measure variables derived from strategic goals of a company. A tool that besides financial indicators also focuses on areas of company's operation dealing with external as well as internal customers and consequent innovative activities. And that is exactly what the strategic performance measurement system for enterprises - the Balanced Scorecard (BSC) can provide. In Czech conditions, this system is often implemented from the bottom, i.e. the demand to create the usually structured BSC is requested, as it is a tool used by the largest number of companies. After putting individual factors and indicators to four areas (dimensions) of the BSC, it is then consequently and at regular intervals, verified whether the numerical scales are in this company met or not. However, thus constructed BSCs are not based on the company's strategic goals and represent only a set of figures, not a tool for performance measurement. That is why the authors of this article, in cooperation with managers of selected enterprises, have decided to revise the current approach towards the BSC creation, consisting merely in copying of the usual BSC, and find a new, simpler procedure based on the specific needs of local enterprises.

2. Analysis

2.1 The BSC method

The Balanced Scorecard is a strategic management tool. The abbreviation BSC, which is used for this method, in Czech translation means the system of balanced performance indicators. Performance must be measured so that the management knows

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to what extent are the strategic goals fulfilled and whether the company is competitive. Since the beginning, the BSC was a very successful tool for implementing corporate strategies and gradually it has become the most important concept of strategic management [6]. The BSC method is universal and therefore applicable in all sorts of companies. Its model thus cannot be seen as a formula, but rather as a template. In the case of individual perspectives of the BSC, the authors themselves admit that the number of these perspectives and their structure may differ from business to business. Nevertheless, there are a lot of cases when while implementing the BSC in various companies only the basic structure is copied with its 4 major dimensions (financial, customer, internal processes and training and development). To make the whole system work, individual steps of the strategic management should be in an appropriate sequence, so the mission and vision of the company should be followed by objectives, out of which the strategy is then formed and implemented. To successfully implement the BSC, it is important to link the scale factors of performance in individual perspectives to the strategic goals and not only form them based on a demand focusing on fulfilling certain perspective of the BSC by some controlled indicators. The strategic goals should be based on a relevant strategy, as well [7].

2.2 Creation of the BSC

There are many ways and procedures while creating the BSC; the most frequently implemented are the traditional structures of the BSC, which are then used for criterion selection. In many cases highly sophisticated methods for measurement are used, which may be for many companies unavailable, overly complicated or require cooperation with another subject. For example, Yuksel and Dagdeviren [8] dealt with measuring and evaluating individual dimensions of the BSC of a production company in Turkey. The expert team included authors of the article and managers of different departments of the company. Performance indicators were set based on literature study and finally for their consolidation with the BSC structures, the fuzzy ANP technique was designed. Wu [9] developed a structured evaluation methodology putting the key performance indicators, into a strategic map according to the BSC for banks. The most important key performance indicators synthesized into the dimensions of the BSC were collected by literature review. Subsequently, a list of criteria was made and the DEMATEL method was used to determine causal relations. Wu, et al. [10] used the similar procedure three years before while evaluating the performance of banks. Firstly, they reviewed indices that could be used for evaluating performance of banks out of a literature and then they summarized them in accordance with the 4 dimensions of the BSC method. Furthermore, they used the method of fuzzy analytic hierarchy process to calculate the relative weights of selected evaluation indices. To evaluate the performance of banks, they used three analytical tools of multi - criteria decision - making, namely the WSA, TOPSIS and VIKOR.

The authors of this article consider s the approach of Bentes, Carneiro, da Silva and Kimura [11], towards designing the BSC for a telecommunication branch in Brazil, as essential for their research procedure. For this research, managers of the company set three functional units that were from their point of view, the most important in connection to company's performance. The indicators were determined and selected by various people from the company, specifically employees of functional units, senior managers, supervisors, analysts and directors of financial operations. After conducting the focus groups and several brainstorming sessions, indicators were found and evaluated according to their significance. The individual participants did not set such a significance; it was a result of a discussion with a unified consensus.

3. Methods

3.1 The consistency analysis

To create a comprehensive scale out of a several questions (items) of a questionnaire set, such creation should be meaningful and consistent. There are many possibilities how to verify that, yet the most used one is the consistency analysis with the use of the Cronbach's alpha coefficient [12]. It is based on an assumption that all the items measuring one attribute shall have a positive and sufficiently high correlation between them. The Cronbach's alpha measures reliability as an internal consistency. It may be interpreted as an estimate of the lower confidence limit (reliability) for the summation variable Y, the components of which may not be parallel measurements. To measure the internal consistency of groups *as well as* items ($i = 1, 2, ..., k$), it is necessary to determine the sample variance σ_i^2 of individual k items that will be consequently compared to the variance σ_i^2 of the measured initial file, expressed as the sum of the individual items. The Cronbach's alpha can then be expressed by equation [13]:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\Sigma_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right) \quad (1)$$

where:

k is the estimated number of (free) parameters,
σ_i^2 is the variance component i for the given sample
σ_t^2 is the variance of the measured initial file.

The value of $\alpha = 0$ means extremely inconsistent group of values (entries are not correlated), while $\alpha = 1$ represents 100 % consistency, when all the items in the group are linearly dependent and express the same thing. The Cronbach's alpha

value should be optimally greater than 0.7 for each latent variable, sufficient amount appears to be a value of 0.5. Simultaneously, $\alpha >$ 0.9 represents an unnecessarily large amount of items.

3.2 The item analysis

The item analysis is used to evaluate individual items of the set of questions without regards to which the aggregated indicators they belong to. This way it is the most likely to find the most outstanding views within the set of questions. Additionally, you can determine whether each item of the set was suitably put one after another in the correct order and see whether the respondents do not fill the questionnaire automatically, but they take a minute to think about their answer, or more precisely, put down what is their true evaluation. While searching for the most outstanding opinions, the average score (arithmetic mean) may be determined for individual items. After that you can calculate the strength of the opinion for individual items as a standardized absolute distance *NAD* the average score from the average scale value x_{med}.

$$NAD_i = \frac{2 \cdot |\bar{x}_i - x_{med}|}{R} \quad (2)$$

where:

R is the range of scale (difference between maximum and minimum values).

The standardized absolute distance takes values between 0 and 1, where the higher the value, the stronger the opinion. As a strong opinion may be considered an item for which the $NAD_i >$ 0.5 applies.

4. The primary qualitative research method

The research, which involved the authors of this article, took place in 2015. The primary research procedures were based on a combination of qualitative and quantitative research. The outputs of the qualitative research served as the inputs for the quantitative one. The quantitative research, performed among the managers from Moravian - Silesian Region (MSR) aimed at verifying the accuracy of the outputs of the qualitative research. The following part of the article focuses on the qualitative research method design.

4.1 Preparing the research

Starting points for the research conducted with managers of MSR were established by the explorative research, which used the unstructured interviews with experts and studying of available secondary sources (from the field of the BSC and statistical methods). A revision of the methodology of the BSC for achieving the higher competitiveness of Czech companies was defined as a research problem. The aim of the research was to verify the accuracy of the BSC setting in the conditions of Czech companies, in particular, selected companies operating within the MSR. To that end, in cooperation with selected experts, a research hypothesis was defined and had to be verified by using other research techniques:

Hypothesis: Experts with knowledge of local situation are more important for proper designing of the BSC than the published secondary sources of past experience.

The hypothesis was created as a critical approach to some of the published outputs from the scope of the BSC, when authors of the studies preferred reviews from literature while selecting the input set of factors for constructing the BSC and it was often conducted based on a specially developed systems analysis, instead of seeking the simplest procedures.

4.2 The research organization plan

The qualitative data was obtained from experts in the field of strategic management and from managers of selected companies via the focus groups. The outcome of the interviews in form of a questionnaire was used as the mean for quantitative research. The managers of companies in the MSR filled in the questionnaire by being personally interviewed. The sample size was limited to 100 respondents. Data analysis also compared results in selected groups of respondents with the emphasis on the following groups:

- Main activity (production),
- Sector / core business (industry),
- Scope of business (mining and metallurgy),
- Prevailing customers (B2B),
- Average number of employees - more than 250,
- Average gross annual sales / revenues of more than a billion CZK.

It was suggested that statistical data analysis was carried out using a combination of one and multivariate statistics methods (for example factor, cluster and correspondence analyses). This article further presents the results of consistency analysis.

4.3 The research implementation

The qualitative research data collection was conducted via the focus groups. Those focus groups were hosted several times and consisted of the authors of this article, 8 - 10 experts on strategic management and managers of selected companies of the MSR. The aim of this group was to examine the individual proposals arising during these group debates and discuss them more. Only after all of the participants agreed on the proposal, such could

Table 1 List of questions of the evaluation set of the quantitative questionnaire

	I. Financial perspective
F3	financial planning and budgeting
F4	analysis of financial indicators
F5	cost analysis
F6	risk analysis
F7	financing method
F8	management of current assets
	II. Customer perspective
C10	market analysis, opportunity search
C11	comprehensive offer
C12	customer segmentation
C13	characteristics of customers
C14	Customer Satisfaction Analysis
C15	building customer relationships
	III. Perspective of processes and innovations
I17	implementation of innovations
I18	process management
I19	process analysis
I20	optimization, redesign and reengineering of processes
I21	support of innovation by management of the company
I22	willingness to participate in innovation from the side of employees
	IV. Employee's perspective
E24	planning and prediction of places and work loads
E25	hiring and selection of employees
E26	management and evaluation of employees
E27	employees' carrier management
E28	employee's motivation
E29	safety and working conditions of employees

be approved for further research procedure. The first topic of discussion was whether or not to revise the current state of the BSC structure at all. Participants expressed their opinion that many of the companies have the BSC proposed only because it is a necessity. After they receive it, they either do not know how to use it or they are using it, but its true purpose, importance of its implementation and above all the content of the BSC in connection to strategic goals of a company, are not further communicated nor used, and thus the resulting benefit of the BSC for the company's competitive advantage is again disputable. Another extensive topic was the actual form of the BSC and its content. Participants of the discussion expressed their negative attitude towards automatic acceptance of previously published standards without the knowledge of local market specifics and a number of external and internal factors influencing the particular company. To verify their claims the focus groups participants created their own concept.

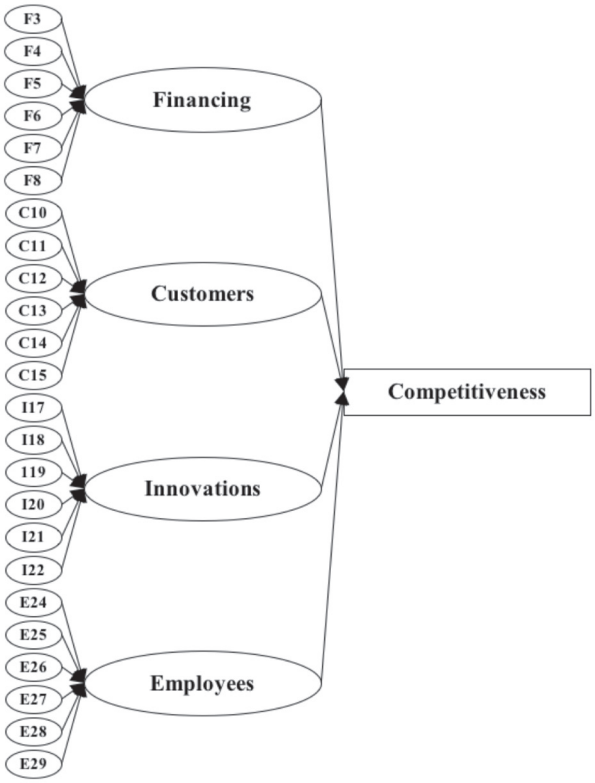

Figure 1 *The conceptual diagram of the three - level model*

5. Results

5.1 Evaluation set

The expert group suggested 50 possible questions out of which 24 evaluating questions were selected. These questions were divided according to where they belong to one of the four basic perspectives/dimensions of the BSC, see Table 1.

During a subsequent questionnaire survey, the respondents evaluated this set of 24 questions on the scale of 0 (zero significance / importance) - 4 (great significance / importance). Altogether 200 companies operating in the MSR were approached. Out of questionnaires that met the conditions of accuracy and completeness 111 were selected as they fulfilled the criteria for maximum/minimum relative frequency of respondents in each category of sorting variables.

5.2 The three - level model

Based on the submitted set of evaluating questions, a three - level model has been created. This model explains competitiveness in four areas of the BSC, whereas each area consists of six evaluating questions (items), see Figure 1. The items use the

Table 2 Degree of consistency and average values for each area of the BSC

Summary indicator	Mean	Cronbach's α
Financing	2.934	0.649
Customers	3.047	0.746
Innovations	2.749	0.882
Employees	2.852	0.807

Likert - type rating scales. The values of the individual items then serve as a basis for the overall value of indicators.

5.3 Consistency of the current model

To measure the internal consistency of the group the Cronbach's α was used. In our three - level model we can measure the influence on each of the BSC area on company's competitiveness by means of 6 items on an integral evaluation scale 0 (no influence) to 4 (significant influence). As a summary indicator the average of 6 items is used, which is the way able to take the (quasi) continuous values from 0 to 4. Table 2 shows the degree of consistency and average values for the individual areas describing the company's competitiveness.

The limit value for the Cronbach's α is 0.5 and ideally it should be greater than 0.7 for each latent variable. It is therefore clear that the given items express all four areas very well. That means that the newly established aggregated variables may now be used in further analyses.

When comparing the results of the model consistency with the answers of the respondents to each question, a clear trend of levelling the importance of all four areas of the BSC can be seen. The obvious difference between evaluating the importance by using the set of evaluating questions (by their aggregated indicator) and stated influence on the competitiveness out of a direct question regarding it, is shown in Table 3, where the line maxima are marked in red and the column maxima in yellow.

While the column maxima of this table form, as expected, the main diagonal matrix (i.e. the same strategies match each other), the line maxima appears only in the second column. That means that the managers quite consistently claim that the greatest influence on competitiveness lay in customer oriented strategies, regardless of which strategy according to the questionnaire they appointed with the greatest importance. If we calculated the consistency between the newly created aggregated variables that correspond to individual strategies, we would get the value of $\alpha = 0.848$, suggesting a high consistency of aggregated variables.

Table 4 Item analysis of the question set

Items of the question set	Mean	NAD
C15 - building customer relationships	3.60	0.799
F3 - financial planning and budgeting	3.31	0.654
C10 - market analysis, opportunity search	3.30	0.650
C11 - comprehensive offer	3.17	0.584
F5 - cost analysis	3.12	0.561
E29 - safety and working conditions of employees	3.11	0.556
E28 - employee's motivation	3.07	0.533
E26 - management and evaluation of employees	3.04	0.519
C14 - Customer Satisfaction Analysis	3.03	0.514
F4 - analysis of financial indicators	3.02	0.509

5.4 The item analysis

If we have more than 50 measured values for each item, we can perform the item analysis for the set of evaluation questions. For the five - value scale with variations of 0 - 4 (zero significance / importance) - 4 (great significance / importance) that was used for the set of 24 evaluation questions, this parameter can be calculated as:

$$NAD_i = \frac{|\bar{x}_i - 2|}{2} \tag{3}$$

Out of the 24 items of the question set, a strong opinion ($NAD_i > 0.5$) is expressed by 10 items, which is app. 42 %, see Table 4. All the set items have a sample mean higher than 2, which means that they represent a positive attitude. Therefore, the managers consider all the items as important and at the same time the order of their responses do not comply with the order of the items in the set of questions, which means that the questions were set correctly.

When carrying out the item analysis of the question set according to selected classifications the largest finding item I17 - implementation of innovations (average evaluation 2.99) was found. It is a factor that together with item I18 - process management - most frequently achieved the biggest differences

Table 3 Relation between the aggregated indicators and stated influence on the competitiveness (in %)

Greatest importance	Stated influence on competitiveness			
	Financing	Customers	Innovations	Employees
Financing	30.58	33.08	19.42	16.92
Customers	23.50	40.17	19.67	16.67
Innovations	24.55	32.73	25.00	17.73
Employees	26.40	34.60	18.40	20.60

in the evaluation of selected groups. Both of these items reached the positions in the top ten according to the measured values for groups of companies, which according to the methodology of the research were crucial for the following:

- Production companies,
- Industrial companies,
- Mining and metallurgy,
- Prevailing B2B customers,
- With more than 100 employees.
- With a turnover of over one billion crowns.

This list agrees with the experts, who during the preparation of the questionnaire considered innovation to be important for achieving competitiveness, especially in large industrial enterprises. In the subsequent statistical analysis of data (mainly exploratory and confirmatory factor analysis and hierarchical cluster analysis) it was confirmed that out of the suggested set of questions, based on the of respondents' answers, a five - factor model may be created. This model would be identical with the usual four perspectives of the BSC.

6. Discussion

The hypothesis of the expert group, expressing a certain level of criticism towards automatic implementation of already existing standards while creating the BSC, as well as unnecessary use of overly sophisticated systems and procedures instead of searching for simpler and functional solution for creating the BSC, was verified by several research procedures and the respondents of the qualitative research (managers of MSR companies) had confirmed it. It may be presumed that for creating the BSC in practice, the best solution would be combining a group of experts from external (experts, academics) environment together with people working in the internal environment of enterprises and companies (owners, management) to create a suitable structure of the BSC. They may use both, their experience with implementing this method in other companies, as well as knowledge of their current surroundings (external participants), and strategic plans that they wish to implement in their company, along with a thorough knowledge of the internal environment of the company (internal participants), which should ensure that the result will comply with the needs of a specific company.

An important factor that influenced other research technique in this work was the decision of the existing members of the expert group that all the outputs of their actions shall be agreed upon by all of the focus groups participants otherwise the result will not be valid. Putting this condition to practice means finding a common approach towards the BSC implementation in the company that would be agreed upon by all the BSC creators. In this way, the BSC should be linked to the strategies and strategic objectives of the firm and consistent communication of the BSC as a tool for management and evaluation of other employees in the company should be ensured (whether while implementing the BSC or during its use within the company). At the same time it has been proven that the respondents of the quantitative research correctly interpreted (understood) given questions and were able to answer them accurately.

7. Conclusion

The Balanced Scorecard method as a useful tool for improving the competitiveness of industrial enterprises became the research content of the authors of this article, who have decided to verify the configuration of the BSC in conditions of selected companies operating within the Moravian - Silesian region. They obtained their feedback, suggestions and help on the matter from managers working in the MSR. The aim was to find out whether the BSC structure might be simplified without losing the information value of the method as a whole or in some of its parts. Secondly they aimed to discover whether in case of industrial companies (especially in the field of mining and metallurgy) the priorities are different in comparison to other companies.

The research method confirmed that the combination of quantitative and qualitative research is suitable for creation and implementation of the BSC. While using the simple procedures when creating the BSC, the results of both researches allow getting feedback from large number of respondents that will have an easier job providing their feedback than in the case of other, overly sophisticated procedures.

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THE ETHICAL ASPECT OF SCIENTIFIC INTEREST IN SELECTED PHYSICAL THEORIES

Mainstream physicists do not form a unified group of scientists sharing the same opinions. It is generally known that their opinions on the dispute regarding the very foundations of quantum mechanics between Einstein and Bohr still differ. Many renowned physicists defend Einstein's standpoint. However, the support of Bohr's assertions regarding quantum mechanics by various grant agencies and foundations is also very significant. The present paper compares the two physical theories. In their case, there is basically no correlation with empirical indicators. The paper points out the robustness of the theory of strings and the theory of physical vacuum. Physicists elaborated both of these theories on a theoretical basis and they both have strong mathematical bases. Moreover, the theory of physical vacuum can be described as remarkably mathematically elegant. Despite the fact that neither of the theories has yielded relevant empirical results they continue to benefit from the lavish support they get. Witten's string theory is widely supported by mainstream institutions which provide funding to research. As Peter Woit points out it is due to the fact that the string theory is the only game in town. It was born in western culture and the richest institutions found many excellent mathematical physicists who studied the same field. The theory of physical vacuum is equally far-reaching. Its highly ambitious plan-geometrisation of the field using Einstein's method aims at developing a theory of field which would unify all hitherto physical interactions. Simultaneously, the theory introduces a new type of physical field, the so called primary torsion field, and extends the principle of the relativity theory. The theory, however, presents several erroneous results. Moreover, there are no empirical correlations and it has failed to achieve the success of theoretical predictions of the string theory. On the other hand, it receives almost no financial support from mainstream agencies and the number of scientists dealing with the theory is considerably lower. If this theory received as much financial support and scientific attention as the string theory, it would probably achieve the same empirical results. Financial resources and support from relevant institutions thus play a significant role in scientific research.

Keywords: *robustness of the theory, support of research, theoretical physics, string theory, physical vacuum theory*

1. Introduction

The issue of validity of scientific theories stands at the centre of attention of epistemology, philosophy of science, ethics of science and sociology of science. Nevertheless, new findings and new methodological approaches, stemming from these new scientific disciplines, are sometimes "difficult to promote because humans prefer the position of 'detached observers' (or, supposedly, 'objective scientists') to that of 'engaged participants' who, by their own attitudes and actions, influence the very process of knowing and thus the results of their scrutiny" [1, p. 25]. The neglect on the side of scientists of sociology of science and scientific ethics has resulted in inadequate methodologies, faulty data analyses, non - objective discriminatory practices, and even cases of fraud. This ethical conundrum, involving a preferential treatment of certain theories over others by scientific institutions as well as media would lead (if unchecked), as Soren Kierkegaard (1813 - 1855) prophesized over 150 years ago, to a societal decline [2 - 6]. Currently, natural sciences and predominantly physics give preference to particular groups of scientists who share common standpoints. Contemporary mainstream physics is, however, differentiated. It is no secret that opinions of physicists on the dispute between Bohr and Einstein regarding the foundations of quantum mechanics differ significantly. In this case, there is no winner. Both Bohr and Einstein have their adherents. However, there are certain lobbying interest groups which favour physicists who in this dispute defend standpoints close to Bohr´s [7].

The present paper provides a critical analysis of two theories present in current physics and attempts to evaluate them from the viewpoint of general scientific criteria. The two theories are the

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theory of strings and the theory of physical vacuum. The paper also analyses the position of the two theories in contemporary science *in correlation with relevant features of serious scientific theories.*

The reasons behind the search for a more unified and fundamental theory were the low ability of the general relativity theory to make predictions in micro space and the incompatibility of quantum theory with general relativity theory. "They were both successfully verified experimentally although each of them separately. They both deliver relatively precise adequate results and explain many new processes and phenomena. Nevertheless, both of them are incomplete and limited with respect to universe as a dynamic system" [8, p. 507]. Neither the standard model nor quantum mechanics can become a comprehensive physical description of the world.

2. The results of string theory

The string theory has been postulated this way since the 1970s. The new theory has an ambitious goal to unify all three independently existing interactions - electroweak, strong and gravitational. The theory of superstrings was originally formulated in twenty - six - dimensional space and it introduced physical particles tachyons. It was a very interesting phenomenon. Tachyons exceed the speed of light which is in contradiction to special relativity theory. In the mid - 1980s scientists worked with five different string theories. Then Edward Witten formulated the so - called M - theory. The aim of his ambitious attempt was to unify the existing string theories - I, II A, II B, heterotic O type and heterotic E type. The M - theory formulated by Witten is considered the mother theory [9].

One theory united the five then known string theories into one. String theory II A includes closed superstrings and I SO (32) includes open superstrings. The two theories are connected through string dualities. They are the S - duality and T - duality. One of the unified theories assumes that there are gravitinos which are supersymmetric particles to gravitons. Reduction of the ten - dimensional string theory to a six - dimensional variety is the way to achieve four - dimensional space - time. It is a six - dimensional Calabi - Yau variety. Physicists defending the string theory believe that the same process can be observed in nature too.

String theoreticians think that the robustness and explanatory power of the string theory rests in the fact that it can explain the variety of particles of the standard model on the basis of transformations of vibrating points [10]. Mathematical unification of the string theory is truly remarkable. It exceeds the standard model and unifies the three interactions in accordance with Comte´s or Laudan´s dream (compare [11]). The string theory helps explain the invariant for the black hole entropy. "Deriving the thermos - dynamic features of black holes from the string theory persuaded many indecisive physicists that the theory of strings is on the right path to understanding the quantum aspects of gravity" [12, p. 285]. P - gateways formulated by string theoreticians helped construct the black hole model while deriving of a formula for calculating the black hole entropy is compatible with mathematical calculations of the string theory. This is an undisputable success of the explanatory aspect of the string theory.

Strings are very interesting and from the explanatory viewpoint also highly successful theories. However, the same cannot be said about the empirical correlation of theory and results. There are basically no empirical confirmations of the string theory. In comparison with the standard model the string theory loses because in the case of the standard model there are clear correlations between experiment and prognosis. Projecting of perturbation theories was relatively successful; nevertheless, they often seem divergent. Perturbation theories are not controversial; however, their divergence prevents their ability to predict.

The question whether it is possible to empirically verify or falsify the string theory represents a serious problem. String theoreticians often argue that the length of their theoretical objects is almost identical with the Planck length and therefore it is not possible to observe these objects with currently available technology. It is a strong argument. On the other hand, however, it makes the entire theory empirically unverifiable. Based on the aforementioned Rudolf Carnap who was a radical logical empiricist declared the theory scientifically meaningless. The present paper does not share his radicalism. Principally, it is not an unverifiable theory. Arguments speaking of the beauty of unification of the general relativity theory and standard model can be considered shallow. The elegance of the solution according to which one - dimensional strings vibrate with different energies, which explains the variety of particles in the standard model, is not a real argument. One cannot speak of the existence of string equations because there are no such equations. Mathematical background of the theory is questionable. Transfer of the eleven - dimensional space of the M - theory to four - dimensional space - time represents a problem.

The real problem is relativisation of space - time which has gone beyond the relativisation of the general relativity theory. In general relativity theory space - time is of the Pseudo - Riemannian variety. Its relativisation has certain boundaries, it cannot be perforated or pierced and it cannot have bizarre features. The string theory enables hitherto unimaginable operations with space - time. "The string theory knows space - time rupture, perforation, ripping and sewing up etc., the so - called flops" [13, p. 702]. It is interesting that in the string theory space - time has a substantial not relational character, which brings the theory closer to Newton than to Einstein. Changes of space - time happen in dynamic reality. The strings can be even reeled up.

What is the M - theory? It is very difficult to obtain a consistent answer to this question. The answer should

unify all five superstring theories. M - theory tries to explain spontaneous disruption of symmetry as well as eliminate faulty development from partial theories. Its correct formulation is thus problematic. The string theory has provided some predictions regarding hypothetical particles and new types of symmetries. However, they are just theoretical constructs since none of the abovementioned has been observed. Within the boundaries of empirical correlation, the explanatory power of the theory is very low. Fault theory is very approximate. As stated above the only thing the string theory has really explained is the construction of black holes by means of p - gateways.

If the string theory depicts its objects one dimensionally, it comes close to point images of the standard model. No new particles predicted by the string theory have been detected yet. The relatively promising explanatory successes of the theory have not been supported by any observation. It can be said that scientists have not confirmed any direct connection between empirical data and predictions of the string theory. From the viewpoint of physics, it is important to add that verification of the theory's predictions is actually possible. However, nothing has been confirmed yet. Therefore, we speak of unconfirmed and not meaningless theory. Although the string theory has been known for more than thirty years, physicists have not presented a single significant empirical correlation of this theory. Against the string theory is also the fact that there can be so many of them [14], and their number can grow to a really large figure [15, p. 3].

So how can a theory with such poor empirical successes keep its position in mainstream physics? The famous physicist Peter Woit explains it by his statement that it is the "only game in town" [16]. It is absolutely clear that it is sociology rather than physical arguments which can explain these reasons. Perhaps it could be said that the predictive power of the M - theory is weaker than we expected [15, p. 56]. In our opinion this theory is only influential due to sociological factors and has achieved only partial success in the field of theoretical physics. However, one cannot speak of any success in the field of experimental physics. The string theory owes its success to the interest of many renowned physicists followed by the support of relevant institutions and lobbying groups. Currently, the world of science is more and more aware of the theory´s weaknesses, its inability to predict observed phenomena and verify predictions.

The future needs to bring further relevant experiments which can or cannot refute the theory whereas the latter would mean its temporary verification. However, considering the hitherto empirical indicators and enormous possibilities regarding string theory variety this scenario is quite improbable.

3. The results of the theory of physical vacuum

Another well - developed theory which aims at becoming a physical theory of everything is the theory of physical vacuum. The fathers of this Russian physical theory are the physicists A. E. Akimov and G. I. Shipov. The - well known physicist academician Pomeranchuk said that the future belongs to the physics of the vacuum. G. I. Shipov developed physics of the vacuum to be in accordance with the theory of physical vacuum. He considers physical vacuum the basis of physics claiming that "it was proven on the levels of vacuum that compliance of central basic levels of physics is done in accordance with them" [17, p. 18]. For Shipov the excited state of physical vacuum is a special state of emptiness. He tries to formulate a unified theory of the field by means of geometrisation of equations of the electromagnetic field. The basis of this geometrisation is application of geometry of absolute parallelism which is connected with rotating systems and Weizenbeck geometry.

Shipov introduced a new type of field - primary torsion field. "In special scientific meaning the category of field shall mean its representation in the conceptual system of physical sciences, it is the category which expresses mutual influence of material physical objects" [18, p. 757]. It is Weizenbeck geometry which describes both a space curved in a non - Euclidian manner and the rotation of the space. Space in which the physical vacuum is described by the abovementioned geometry has ten dimensions. Initial active vortexes cause the space to bend whereas material sources are reduced. What remains active is the excited vacuum. The core of the scientific programme of G. I. Shipov and his colleagues is the geometrisation of space. Shipov explains the emergence of physical reality as changes of space curves and space rotation.

The theory of physical vacuum structures physical reality into several levels. The first level is the level of absolute nothingness. Nothing concrete can be said about this level, and yet it has enormous creative possibilities. This level is mathematically described by a system of equations where the Riemann curve turns to zero [17, p. 82]. It resembles Hegel´s Pure Nothing from his work Science of Logic. The second level is the primary torsion field which originates from the first level. This field resembles Parmenidean full existence which *a priori* excludes the existence of non - being. It is subtle matter reality. Primary torsion field is present everywhere because its energy and impulse equal zero. Other levels are connected with plasma, gas, liquid and solid states of matter. The state of matter depends on the tempo of quantum vibration.

The theory of physical vacuum also includes tachyons, i.e. particles which exceed the speed of light. The theory also mentions the existence of particles with reverse time run, mass and anti - mass which emerge from polarised torsion field. The theory also presents the category of imaginary rest mass. It is also necessary to mention Terlecky's quadrigas and Akimov's fitons. These micro particles predicted by the theory of physical vacuum should resemble de Broglie´s corpuscular wave dualism. In accordance with the conclusions of the EPR paradox our theory

claims that speed of information transmission can be immediate and can thus exceed the speed of light.

The theory´s plan is to become the physical theory of everything by elaborating a theoretical basis for unification of all interactions. The field of inertia can include all forms of matter. Naturally this would mean the unification of the quantum theory with the general relativity theory. Physical vacuum theoreticians often try to apply the principle of correspondence in the field of quantum theory whereas they deem basic physical equations to be special cases of equations of the torsion field. The adherents of the theory believe that the deductive theory of the field means further development of the quantum theory in accordance with Einstein´s ideas. Comprehensive wave function and Schrödinger´s equation comply. The newly introduced "quantum constant (an analogy to the Planck constant *h*) seems to be an arbitrary constant the value of which is (probably) determined by studying the geometrical parameters of the observed system" [17, p. 173]. In Shipov's opinion the theory has a deterministic character.

A critical review of the theory of physical vacuum reveals several problems. Adherents of the theory claim that it is supported by experiments which confirm it [19, 20]. Critics of the theory state that explanation of the experiments is incorrect. V. A. Rubakov says that the results can be explained by Newtonian mechanics and Maxwell´s electrodynamics. Shipov, however, "offers an "experimental proof" of not preserving the impulse in mechanics and then draws a picture of motion on a new transport with "torsion motion"" [21, p. 351]. He similarly criticises the origination of Terlecky's quadrigas. They originate as a result of uniting particles with positive and negative weight which in Rubakov's opinion is in contradiction to all hitherto experiments. Shipov sees new potential of electromagnetic field in equations of geometrised electrodynamics. Rubakov criticises Shipov's three basic equations. Shipov believes they are the basis of physics whereas Rubakov describes them as mathematically elegant theories with no relation to physical reality. On the other hand, it is necessary to say that the existence of torsion fields was thought possible before the occurrence of the theory of physical vacuum. If they do exist, most physicists believe that their manifestations are very weak. Now scientists face a question whether it is possible to experimentally verify the core of the theory which is the existence of primary torsion field. Facts show that "with current level of experiments it is not possible to register torsion fields" [22, p. 35]. Akimov's assertion that it is possible to generate energy from vacuum has not been confirmed either. The theory of physical vacuum presents several erroneous conclusions. Declared correlations with experiments can be explained with the help of established physical theories. It is necessary to emphasise the fact that currently there are no means which could confirm or refute the existence of primary torsion field. Applying the philosophy of science of W. V. O. Quine [23], one must say that at present it is not possible to falsify statements attacking the core of the theory of physical vacuum.

The string theory eliminates discontinuity of points because the size of a string is limited. From the viewpoint of ontology of science, it is a step forward that first bases actually receive more concrete attributes than idealised monads resembling point objects studied by mathematics of the standard model. While the string theory is, in a way, based on Newtonian´ principles of paradigm (substantial nature of space - time, inertial frame of reference), Shipov, in the theory of physical vacuum, refers also to Descartes [24] when he says that all movement is rotation. Twisting of space in accordance with Riemann - Cartan geometry is accepted by string theoreticians, however, these effects cannot be studied by currently available technologies. Nevertheless, torsion effects predicted by geometry of absolute parallelism have no recorded experimental results either. Conclusions of experiments quoted by Akimov and Shipov can be deduced from other physical principles. The other possibility is that invariant real results of experiments do not exist at all.

The mathematical background of the string theory is very strong and can explain theoretically better - known facts. The five string theories can be considered consistent. They do not contradict known physical facts and they probably do not contain mistakes that the critics identified in the theory of physical vacuum. On the other hand, however, there are far more physicists studying the string theory than those studying the theory of physical vacuum. What is missing, however, are the real correlations with physical reality supported by experiments. Again, one cannot speak of anything else than of a physical theory ungrounded by facts.

As Mrozek said, mathematical elegance cannot be the only criterion determining the success of physical theory [25]. First of all, it is necessary to find out whether experiments comply with predictions and mathematically described theory. Preserving the causality principle is also necessary. It is assumed that advancing technologies will enable falsification or verification of the compared theories and that it will be possible to reliably confirm or falsify the predicted objects in the future. These objects are not considered unverifiable. However, it is believed that our civilisation does not have the necessary means to do so.

4. Conclusion

Comparison of the success rates of the physical vacuum theory and the string theory slightly favours the string theory. The cores of both theories are consistent and have solid mathematical foundations; however, currently it is not possible to falsify them experimentally. With respect to certain theoretical results and higher level of consistency with established physical theories the string theory emerges as slightly more successful. The relationship between the two theories is apparently contradictory and so too is the *tertium non datur* situation in the case of their future falsification or verification. It is quite possible that eventually

both theories will be falsified and a new ontological basis having the attributes of fundamental ontological entities will appear on the scene. The sociology of science reacts with a counterargument pointing at totally uneven support for the two theories on the part of mainstream agencies, institutions, scientific committees of prestigious journals, etc. There is a striking difference in the number of scientists dealing with these two physical theories. We dare to say that the string theory, as the better known "only game in town", owes its success to sociological factors, support of scientific institutions and renowned scientific publishing houses as well as to enormous financial support. We believe that with equal share of attention, amount of scientific work and financial resources and particularly with involvement of an equivalent number of renowned physicists the theory of physical vacuum could achieve more or less the same scientific results. The fact that the results achieved are still quite poor and lack connection to experimental measuring is the problem of sociology of science and scientific ethics. Any support of scientific research that has no real experimental results is not only bizarre but potentially detrimental for further research and collaboration among scientists. The selectiveness of this support determined by other than strictly epistemological reasons is a strange aspect of scientific life which often steers declared freedom of scientific research towards Hegelian understanding of freedom as recognition of necessity. In this case it can also be noted, that change can be understood as a new impulse that will provide an opportunity for a genuine creativity, provide more space for application of ideas, and even those not following only mainstream wave [26]. Enabling full freedom of scientific research supported by the interest and funding of responsible institutions could thus acquire a more realistic direction.

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COMMUNICATIONS

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SCIENTIFIC ETHICS AND THE PENDULUM OF DEHUMANIZATION

The article contends that science is forsaking its core purpose, which is to meet human beings' intrinsic epistemological need to understand the world, know it and explain it fully for specific purposes. On the one hand are the pure scientists, overly concerned with solving their research problems but indifferent to the uses to which their work might be put. Another question is the system itself-companies, corporations and governments-which takes advantage of this negligence or indifference and develops applications or technologies for its own economic or political benefit, instead of meeting real needs of individuals or social groups. Finally, there are the students of science, who are not necessarily afforded a well-rounded humanistic education that might make them feel ethically linked to their environment and accountable before society for their scientific work. This combination of elements has led to a loss of meaning and a growing dehumanization as a corollary to the increasingly rapid, chaotic and disconcerting surge of new technology.

Keywords: *science, technology, ethics, development, humanities*

1. Introduction

Using a very simple explanatory criterion, the essay looks first at the characteristics, limits and scope of theoretical models for understanding and systematizing knowledge, and defines their diachronic criterion and the relativity of the scientific philosophical foundation. Next, it calibrates the isolation from the natural world in which contemporary society lives, including scientists, and considers the implications of this alienation for basic research and for subjection of the process of technological innovation to the values of productivity, growing monopolization, and control by governments and transnational corporations. Finally, it examines the aspects of disconnection, proposing formulas for integrating the ethical and humanistic formation of researchers and for reorienting and reversing the negative, distorting effects of scientific and technological developments.

2. The fragility of theoretical constructs

The critical element of all structures is rooted in a very simple proposition: that all objects of knowledge are subject to explanation by way of models. It would then make sense to start out by asking: what exactly is a model? It would seem that the object sitting before my eyes is not the same as trying to make a model of it. A photograph, for example, can be a model, but it is not necessarily one. If we set out to make a photographic model of a human being by taking the picture from the back, it is not hard to see that we are doomed to failure, because the photo will leave out the eyes, nose, mouth, ears (etc.), parts that we consider indispensable for characterizing that individual. It would be absurd to present that photo as an integral reflection of the person, because we *know* that model in *person*; we are sure of her physical appearance and evolution. Any sensible observer would take one look at the photograph and dismiss it. In this case, we all *know* that the representative Model of the human species as set forth in that photograph neither is nor ever could be emblematic or representative of that reality.

This leads us directly, and with simple words, not only to the ontological dimension of the object, but to the dimension of its probative (epistemological) intelligibility, as well as to human beings' potential to validate, to dismiss or, why not, to peer into what it means to generate new models. What then does a model do to reality? Could Science also be another point of view of reality? Inductivists thought that science starts by gathering observations or data, and then proceeds to infer laws and finally makes predictions on the basis of this information. Deductivists took the opposite view, contending that a person cannot observe anything without a theoretical underpinning [1]. What is the point of this? The point is that a theory, as an expression of

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scientific knowledge, is also a model [2], that can range from simple to enormously complex and that, in spite of its potential to complement or contradict other models, is necessarily limited and partial, because it comes from a fixed position that constitutes one viewpoint [3, p. 168], one that is situated in a certain moment and in specific circumstances.

The basic objects of research are simple systems. For the cognitive and practical assimilation of simple systems, it is enough to believe that the overall properties of their parts exhaustively define the properties of the whole. The part (element) is thought to have the same properties within or outside the whole. The relationship between the thing and the process is Representations of external events interpreted in a particular way: the thing (the body) is viewed as something primary in relation to process, and process is treated as the effect of one thing on another [3, p. 169].

In the stage of *non - classic* rationality, on the other hand, the main objectives of research are more complex, because it is self - regulating systems that are being examined. These systems are differentiated by relatively autonomous subsystems in which a wide range of stochastic interactions of elements takes place. According to Vyacheslav, the integrity of the system assumes the existence of a special control entity that ties the subsystems together both backward and forward [4], "Large systems are homeostatic. By necessity, they have a program of functioning that defines the control commands and adjusts system behavior based on feedback" [3, p. 171]. When it comes to complex self - regulated systems, the categories of the part and the whole take on new features. "The whole is no longer confined to the properties of its parts; it is necessary to take the systemic quality of the whole into account. The part has different properties within the whole or outside it. Organs and individual cells in multicellular organisms are specialized and, in that capacity, they exist only in respect to the whole" [3, p. 172].

What has all of this brought us to in the field of science? To a realization that there was nothing absolute in the empirical grounding of objective science and that some theoreticians would have to acknowledge that science does not rest on bedrock. It brings us to a sober realization that scientists must resist the "delusions of 'scientism'" and treat "science for what it actually is: a specific, distinct culture with its own methodology, presupposition, and values," since science, much like ethics, "takes place within a complex human tradition" [5, p. 26].

3. The separation of the human being and the specialization of the scientist

The critique of the Western proposal undertaken in the 20th century by incisive thinkers from a wide range of disciplines (ethnologists, historians, sociologists and psychologists, among others) has laid the groundwork for a different approach, by shedding light on the increasingly erratic trajectory of the *modern* project and the need to reintegrate it at its true natural scale.

Man is a natural being. Being part of the whole, he is part of Nature. Individuals may realize that nothing is alien to Nature, or they may be ignorant of the fact, but that makes no difference. Their knowledge, their awareness in the final analysis is irrelevant, as the inexorability of the link is radical [6, p. 1].

It is not hard to see that human beings and their theoretical models, their scientific approaches, no matter how complex they are, reveal an almost inescapable separation from the cosmos, nature [7] and the world they were born into [8].

Inasmuch as the subjects *who do science* detach or distance themselves from this natural matrix or setting, the disorientation becomes a grave issue, almost insurmountable. Why? On the one hand, hard scientists' self - absorption and excessive concentration on miniscule aspects of reality only deepen the rift between the object of their activity, their cognitive interests and the relation or meaning that such close study of a particular point has with the larger context; this of course leads to a kind of science that rushes headlong toward inordinate specialization.

As we have seen, the act of explaining why things are as they are (what we call science) is intrinsically linked to the act of determining what is good and, in particular, of how human beings should make their life consistent with this purpose. In other words, it is linked to two essential domains of philosophy—Axiology and Teleology—also known as the theory of values and the study of the purposes of human endeavor, respectively.

In this sense, it would first be necessary to take a deeper look at the deterministic transcendence of the other option: the one exacerbated by the contemporary world's accelerated rate of change in the technological field. What is absurd about Western civilization is that it produces a plethora of inventions and technology that are good for nothing. It usually develops them without understanding. This is what makes us Westerners slaves of technology. Everything that people make ends up being technology. Thus, technology must be regarded as the extension of one or more of our senses, which, once developed, modify what human beings apprehend: their world [6].

As many observers have pointed out in recent decades, technology has driven changes that profoundly alter the conditions on which the life of humanity depends. Aside from these transformations, "environmental stimuli and demands have taken on an unprecedented pace and acceleration; no one can doubt that people's psyche, particularly their way of feeling, perceiving, imagining and wanting, have been impacted by the pressure, so rich and varied, of their transformed setting" [9, p. 43] and by the incessant need to react [10] to that pressure [11, p. 72 - 73], [12, p. 27].

Unfortunately, the surge of new technology does not come free of charge, as we insinuated above. It is coming faster and faster, causing ever more chaos and apprehension [13, p. 188]. "There are no filters to stop its emergence when it clearly harms

people, because it is usually released onto the market by the people who stand to profit the most from its acceptance" [13, p. 188]. As Eizaguirre contends on the basis of his study Social Values, Science and Technology" (*Eurobarometer 225*),

People do not feel any urgency to take part in scientific activity, while at the same time they feel underrepresented in decision - making about scientific policy; there is an increasing ambivalence and awareness regarding the protection of nature as opposed to "human well - being" (happiness, health) and–above all–regarding the "development of humanity" (innovation, growth); risk and benefit analysis is the standard that people put forth when it comes to evaluating technology, but guided at all times by the rule that scientists propose; the values and principles of action, such as the protection of nature and participation in decision-making, are seen as the most relevant for the immediate future; human health and the natural environment stand out as the areas where new technologies should be applied [11, p. 71 - 72].

Over time, the voice of alarm dies out; technologies are recombined, giving rise to a new generation of machines, which makes them almost impossible to dismantle, even if society were inclined to do so... We continue to see (technologies, *SIC*) as if they were separated, as if they were discrete systems, when that is not the case at all [13, p. 188].

4. Scientists' disjointed vision and education

In the final analysis, what piece is missing? What would be the best way to overcome these ruptures, and to rein in run - away science and technology, with all the risks and nonsense that they involve? The answer is not simple. On the one hand, the current state of affairs does not help. For example, science students do not receive a solid humanistic formation that would make them feel ethically linked to their surroundings and to themselves, not to mention accountable to society for their scientific work.

This is a glaring shortcoming that just happens to be *convenient* for a system that has helped to aggravate this vicious cycle. A combination of elements that has triggered a loss of meaning, a growing monopolization and manipulation of knowledge by powerful governments, international financial institutions, universities and specialized research institutes, and transnational corporations. In addition, dehumanization as a corollary of the ever more unbridled, chaotic and disturbing surge of new technology. Andoni Eizagirre wonders whether it is true that the ways of understanding, analyzing and assessing risks are really value - free [11, p. 71].

As Vyacheslav points out, it is indisputable today that the ideal for justifying or substantiating scientific knowledge must include an ethical assessment as an essential component. The understanding of scientific knowledge as a special component of culture and social life that determines their basic values represents the most solid epistemological justification for all of these transformations of the ideals and standards of science. For this reason, in the first place, "the researcher has to solve a number of ethical problems when defining the boundaries of possible changes to the system. Under these conditions, the internal ethics of science, while stimulating the search for truth and focus on the augmentation of new knowledge, is constantly associated with general humanist principles and values" [3, p. 177 - 178].

Furthermore, as Vyacheslav made clear at the beginning of this analysis, natural science is starting to incorporate another field of dynamic knowledge that comes from the social sciences and humanities: the ideal of historical reconstruction [14], which today represents a special kind of theoretical knowledge that is more and more widespread:

Among the historically developing systems of contemporary science, pride of place goes to the natural and social systems in which the human being himself is a component. Examples of such "human - dimensional" complexes might include medical and biomedical objects, objects of ecology, including the biosphere as a whole (global ecology), nanoscience objects, biotechnology (primarily genetic engineering), "human-machine" systems (including complex informational systems and artificial intelligence), and so forth [3, p. 177 - 178].

In the study of "human - dimensional" objects, the search for truth is related to the definition of the strategy and the possible ways to transform the object, which has a direct impact on humanistic values. One cannot freely experiment with such systems. The knowledge of the prohibition of certain interaction strategies that involve potentially catastrophic consequences for humanity plays a central role in the process of the research and practical assimilation of these systems.

Let us look again at the case of Physics. During the second half of the 20th century, even this field of knowledge would implement a significant shift in its diachronic focus. On the one hand, the development of contemporary cosmology to which we alluded briefly (General Relativity, the Big Bang, and Quantum Theory) led to the idea of the formation of different kinds of physical objects and their interactions. This in turn led to the concept of different types of elementary particles and emerging interactions during the evolutionary process as a result of the decomposition of some kind of initial interaction and its subsequent differentiation. On the other hand, the idea of evolutionary objects would be actively discussed in the thermodynamics of non - equilibrium processes (Ilya Prigozhin) and in synergetics. The mutual influence of these two lines of research would incorporate a notion of self - regulation and development in the system of physical knowledge [3, p. 175].

Aside from the considerations expressed up to this point, one final, but no less important, suggestion can be made to assure the indispensable counterpoint or counterweight. In addition to humanistic formation of science students, there is also a need for science and technology to be understood by the general public,

to form part of their scientific culture [15]. This would help to democratize scientific and technological development, offering a certain guarantee that it will benefit society at all levels, without excluding the majority of the population [16]. The development of new technologies and the furthering of scientific research must go hand in hand with the cultivation of character integrity, engendering thereby "a new quality of human mutuality, in which the human individual will cease to be a mere instrument on the path of other's success. Individuals are thus more clearly seen as genuinely irreducible to the political (totalitarian, or not) order" [17, p. 106].

5. Conclusions

As we have discussed, all objects of knowledge are susceptible to being explained through models, which present reality according to specific viewpoints, contexts and times. This ontological dimension of the object and its probative intelligibility is also an expression of theories or models of scientific knowledge, which can be very simple or enormously complex, depending on whether they deal with simple objects or systems, self - regulating systems, or objects of systemic integrality in transition toward other self - regulating systems. Notwithstanding, the empirical basis of objective science is not absolute in the least; it is partial and in a certain sense static.

The critique of the Western project as undertaken in the 20th century highlighted the almost inescapable separation of human beings from the cosmos, nature and the world they were born into. This discordance tended to be axiomatic in the case of hard science as well. Why? For many reasons, especially those related to scientists' scant humanistic formation. The subjects who actually do science, from this perspective, detach or distance themselves from their natural matrix or setting and concentrate their analytical focus on ever smaller fragments, untethered from reality. This inconvenience or rupture becomes a serious issue when researchers are not aware of their effort to demonstrate the conditions in which they claim to be stating their truth. This is a totally false obsession that manifests a banal intention to dominate *Natura*.

On the other hand, the act of explaining why things are the way they are (which we call science) cannot do without ethical and teleological considerations, linked to the humble willingness of the inquiring subject, and that belong to two essential areas of Philosophy: the theory of values and the study of the purposes of human behavior. These areas or sub - disciplines were relegated to the fringes of scientific work by the positivistic vision of science in the 17th century, and even today sometimes represent marginal concerns for certain discoverers, scientists or inventors [18].

Indeed, technology is imposing changes that profoundly modify human beings' life - support conditions and psyche. Transformations, stimuli, and environmental demands coming at an unprecedented and accelerating pace give rise to a *dyssynchrony* [19]. This combination of elements has led to disorientation, loss of meaning, and a growing monopolization and manipulation of knowledge by governments, financial institutions, universities and, obviously, transnational corporations [19].

So, what mechanism needs to be put into place? What would be the best way to repair these ruptures, to avoid scientific - technological risks and mistaken purposes? The answer is not simple. Aside from renewing the *vita contemplative,* hope would seem to lie in the changes in approach that have gradually been undertaken in recent years, enhancing the humanistic foundation and vision of the exact sciences by including ethical assessment as an essential component, and the historical reconstruction of phenomena and developments. Understanding scientific knowledge as a special component of culture, social life and the Humanities represents the epistemological foundation *par excellence* of all of these transformations of the ideals and standards of science.

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[15] Although efforts have been made in many countries to foment scientific and technological literacy and communication, they are still insufficient. As Martha Vergara and Ramón Rueda Koyama contend, "bringing science closer to the general public is a high - priority goal that involves States, the scientific community and communicators. Citizens have yet to develop forms of group organization or participation mechanisms to take their place alongside experts and government representatives in identifying issues or opportunities related to science and technology, in defining the parameters that delimit the issues, in selecting alternatives for solution and in following up on the application of these alternatives" [16].

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COMMUNICATIONS

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NEUROMARKETING - AN OPPORTUNITY OR A THREAT?

The reason of neuromarketing use lies in an attempt to understand consumer behaviour and motivation to make a purchase of certain product. This method is based on the assumption that the purchase decisions is largely influenced by emotions. The paper explains the essence of neuromarketing and selected neuromarketing technologies, such as Functional magnetic resonance imaging (FMRI), Electroencephalography (EEG) and Eye tracking. In this way, as a literature review, it provides a comparison of the views of several experts on the issue. An important part of the paper is to analyse the perception of neuromarketing by the professional and general public, which points to the advantages and disadvantages of its application. Accordingly, it is possible to summarize the benefits of using the results of neuromarketing research for companies that includes better understanding of customers, their loyalty, in order to strengthen their image and brand value.

Keywords: *neuromarketing, neuromarketing technologies, neuromarketing research, consumer behaviour, purchase decisions*

1. Introduction

An appropriately chosen and targeted marketing communication is an important source of competitive advantage. Traditional approaches to marketing communications are based on the rational consumer behaviour, but this does not always lead to the desired results. The findings of recent years indicate that a significant proportion of consumer purchase decisions is made on the basis of emotions evoked by a particular communication means. This gives the scope for use of the new tool to better understand consumer behaviour - neuromarketing.

The use of neuromarketing technologies uncovers real attitudes and opinions of consumers that failed to be detected by the traditional marketing research, respectively they were hidden for any reason, modified etc. Ultimately, the results of neuromarketing research should have positive impact not only on the company but even on customers.

The article as a literature review provides an overview and comparison of the views of several experts on the issue of neuromarketing and its usage in practice.

One of the most important part of marketing research is the measuring of the response to advertising stimuli [1]. Older researches have been focused on traditional qualitative and quantitative methods for identifying the impact of advertising on sales, awareness, consumer preferences and the like. However, people are routinely exposed to a large number of advertising messages and, of course, they are able to respond only to a negligible percentage of this number. So the response to advertising message is reduced significantly. Therefore marketing professionals are looking for new and unconventional ways that would lead to understanding the functioning principles of advertising and increase the efficiency of their operations [2].

According to Lindstrom [3], marketing professionals should not be focused on what respondents say about themselves in quantitative or qualitative research, because in fact they may think otherwise. The difference between what people think and what they say about themselves, is formed by the action of the algorithm functioning of their neural network that proved them during the life as the most expedient. Especially the female brain (although unconsciously) always unconsciously calculates what is for it the best at a given moment.

Scheier [4] argues that a consumer behaves consciously only in 5 % of cases. Thanks to this new approach, which links knowledge of neuropsychology, cognitive psychology and neuroscience to marketing decision - making environment, scientists can determine why consumers make certain decisions and which part of the brain "tells" them to do so, respectively what motivators are activated.

Follows from the above, in most cases a consumer remembers only what fits into his mental patterns and he selects especially those data that support his views. Psychological findings say that consumer, in general, attaches the greatest importance to information relating to his own person. The aim of marketers is therefore to place the advertising message into consumer's

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long - term memory. In fact, this could be the way for gradually changing consumer's views and attitudes leading to the desired kind of behaviour, change of a lifestyle, preference of promoted brand and so on [5, 6].

2. The essence of neuromarketing

Neuromarketing is based on neuroscience, which can be defined as the branch of science that deals with exploration of the nervous system.

Its aim is to understand the functioning of human behaviour, even by interdisciplinary fields, which are [7]:

- Neuroanatomy - explains the anatomical structure of the nervous system;
- Neuropsychology - deals with the relationship between brain function and human behaviour, analyses impact of the brain disorders to psychical processes and examines the activities and impact of the neurons on performed tasks;
- Neuroendocrinology - explores links between nervous and hormonal system;
- Neurology - deals with the study of the nervous system and treatment of its disease;
- Cognitive neuroscience - deals with the research of the relationship between brain processes and human mind;
- Neuroeconomics and neurofinance - deals with the decision - making processes of economic subjects with regard to impact of emotional, cognitive and social factors on economic behaviour of an individual.

The term neuromarketing was coined by Professor Ale Smidts from Rotterdam School of Management, Erasmus University Rotterdam (the winner of the Nobel Price for Economy in 2002) and it describes a new field of marketing research that aims to study consumer's cognitive and emotional responses to marketing stimuli [7].

Currently, the neuromarketing is seen as commercial exploitation of neuroscience knowledge and tools that enable companies to better understand consumer reaction to the communication efforts of companies, related to different types of brands, products and services [8].

The consumer neuroscience combines scientific studies on the psychology and the consumer behaviour that are more focused on the ways in which customers respond to the activities of companies. The consumer neuroscience is as such closely linked to the decision neuroscience and neuroeconomics in which researchers try to understand how decisions were performed and what may cause consumer decisions and choices [8].

According to Ariely and Berns [9], companies have two important reasons for using neuromarketing technologies:

1. Marketers hope that neuroimaging will provide a more efficient trade - off between costs and benefits. This hope is based on the assumptions that people cannot fully articulate their preferences when asked to express them explicitly, and that consumers' brains contain hidden information about their true preferences. Such hidden information could, in theory, be used to influence their buying behaviour, so that the cost of performing neuroimaging studies would be outweighed by the benefit of improved product design and increased sales. In theory, at least, brain imaging could illuminate not only what people like, but also what they will buy. Thus far, this approach to neuromarketing has focused on this post - design application, in particular on measuring the effectiveness of advertising campaigns. The general approach has been to show participants a product advertisement, either in the form of a print advertisement or a commercial, and measure the brain's response in the form of a blood oxygenation level - dependent (BOLD) measurement, which is taken as a proxy for neural activation.
2. Marketers hope that it will provide an accurate marketing research method that can be implemented even before a product exists. The assumption is that neuroimaging data would give a more accurate indication of the underlying preferences than data from standard market research studies and would remain insensitive to the types of biases that are often a hallmark of subjective approaches to valuations. If this is indeed the case, product concepts could be tested rapidly, and those that are not promising eliminated early in the process. This would allow more efficient allocation of resources to develop only the promising products.

Neuromarketing can enter into product cycle in two places:

- As a part in the proposal of a product - based on the detected reactions it can be used to improve the product before its launch,
- As a feedback to the proposed product - it can be used for measuring the consumer responses to marketing campaigns.

3. Neuromarketing technologies

Methods of neuromarketing research allow to penetrate into the unsuspected layers of the human psyche. This opens up new, previously unknown horizons in marketing research. Experiences of agencies show that neuromarketing technologies of research are especially suitable for those projects in which it is necessary to analyse in more detail the emotions associated with the subject of the research. Neuromarketing research provides useful information especially about which emotional areas of the brain were affected by tested product or brand. However, these need to be supplemented about the interpretation and diagnosis of the causes, which is not easy [10].

There are three neuromarketing technologies:

1. Functional magnetic resonance imaging (FMRI),
2. Electroencephalography (EEG),
3. Eye tracking.

Functional magnetic resonance imaging (FMRI) is an advanced technique that is used in research of brain functions using the three - dimensional image of the brain. The most important advantage of the device FMRI is exactly that it is non - invasive, because it does not operate on the basis of radiation. It also includes the ability to accumulate large amounts of information and the ability to create image of deep brain structures, especially when it comes to the emotional reactions. The disadvantages include the financial and space requirements, the need of professional service and deliverables with a few second delay [11].

Electroencephalography (EEG) is an examination method which records bioelectrical changes (rhythms) in the brain tissue. The EEG method can be used for monitoring the brain responses to marketing stimuli. The result of these observations are answers to questions about the consumer's attention, his ability to remember products (advertising) or emotional aspects of their purchasing behaviour. The advantage of electroencephalography is that the EEG devices are relatively easily portable and the realization of research is thus easier than by the MRI. However, some experts criticize this method because it cannot show the activity of neurons in deeper brain areas very well, such as the limbic region, which is the key object of neuromarketing research. However, it is possible to infer the activity in the limbic part from the activity of the frontal lobe, because these two areas are interrelated [12].

Eye tracking is a device that allows scientists to track the movement of the human eye. The result of such research is an image of the object with color - coded areas that represent where, how long and with what intensity is looking at the observed subject. It is very suitable to combine this research method with the EEG method. The monitoring of human visual attention becomes indispensable aid in detailed analysis of the websites or promotional material used in marketing communications, because people perceive visually about 83 % of information [13].

4. Neuromarketing and its perception by the public

Since its inception, the neuromarketing has induced turbulent discussion both in neuroscience and marketing circles. Many times not only research methods are called into question (starting from criticisms on their financial demands, the need for professional service, to the difficulty of interpreting the results), but also the reliability and accuracy of the data thus obtained. Supporters of this new phenomenon in marketing, on the contrary emphasize the uniqueness of this research, because it allows an insight into the mind of the customer and thus provide reliable and unique results about customer purchasing behaviour, his preference for a particular product or brand, as well as views on marketing campaigns [12].

Lay and professional public begins to more and more deal with ethical aspects of neuromarketing. Especially in the USA we may see fears of civil associations such as Consumer Alert. It draws attention to the ability of marketers to get into the people's heads, reveal how their purchasing behaviour works and thus create the irresistible marketing strategies and campaigns.

They also appeal on the invasion of respondent's privacy, subliminal influencing and handling, which may occur as a result of such a research. They also highlight the problems whether it is correct to use clinical instruments in research for multinational corporations.

Ariely and Berns [9] explain the additional concerns about the ethics in neuromarketing, namely:

- Reading the mind of consumers - fears about privacy of consumer's ideas and arousing preferences without his knowledge. These concerns can be minimized by transparency of research; people need to know what they support by participating in such research and data must be used only for the purposes for which they were acquired;
- Misuse of information obtained by neuromarketing research, search for the "biological" weaknesses of consumer;
- Generalization of the results obtained from a small research sample;
- Results of neuromarketing research carried out for commercial companies often remain hidden;
- Publication of the results in unprofessional prints can lead to distortion and panic among consumers;
- Fear of insufficient regulation of the industry by the government, consumer associations and the like;
- The use of the neuromarketing research, which is not in the interests of consumers.

5. Discussion

Proponents of neuromarketing say that companies using neuromarketing technologies do not seek to control and manipulate customers. People will always have full control over their decisions. They also express the positive opinion of efforts to create the effective communication towards the customers. This means that results of neuromarketing research can help to better understand consumer behaviour, and thus create marketing communication which the public would enjoy. It includes identification of the aspects, which should be avoided during the communication.

The large number of researchers also reject the idea about searching the „buy button", which may force the customer to purchase a product. They argue that neuromarketing technologies only help to monitor brain activity and they do not affect it directly. Current researches concerning the existence of a "buy button", suggest that cognitive processes associated with the purchase decision are multifactorial, and therefore it is not possible to limit them to one particular area.

According to Petr Milacek (former director of strategic planning Media Agency PHD, which began to use MRI to create optimal media plans in the Czech Republic), "*neuromarketing in its own way represents a really great insight into the consumer - the researcher can see what the consumer does not realize. On the other hand, it is true that no marketing research has not established a successful advertising campaign yet. While researchers did not find the "buy button" in the brain forcing people to buy something, in my opinion this would not be an ethical issue*" [14].

The question of ethics in neuromarketing is not closed and raises endless discussions between enthusiastic promoters of revolutionary research methods of the human mind and outraged opponents. However, generally it is believed that if the neuromarketing as a tool for learning and discovery is in the right hands, we will have no reason to worry at current levels of human knowledge of this issue.

So how do we, consumers, and also companies perceive neuromarketing? Is it an opportunity for us to better communicate with each other, or rather a threat?

As mentioned, many people believe that neuromarketing is an area aimed at influencing people to buy products they do not need at all, what is a big mistake. Neuromarketing is just a new way of measuring whether and how the marketing works. Marketers are aware that a consumer has "his own brain" and free will and in any case it is not possible to force him to buy any product [15].

Based on the above, we can conclude that neuromarketing is a science that reveals the secrets of the human mind and answers the question of why consumers prefer one product over another. Among other things, neuromarketing is a step ahead over other research methods and due to this fact it can analyse the requests from the consumer and provides a much more accurate results.

It is difficult to prevent the misuse of this science, especially in the area of ethics. Neuromarketing can be a way of understanding or manipulating human thinking [16]. There is only a very thin line between the two.

Neuromarketing is as mysterious science as the human thinking alone. It has a great future in research and thanks to it we can reach many interesting discoveries. It depends on how we treat this fragile method.

6. Conclusion

If the company wants to be successful and exceed its competition, it will have to know its customers and their preferences, purchasing habits, and at last also customer emotions during purchasing process or reaction of the brain to the means of communication. This information can be obtained thanks to a new approach to examining and measuring the effectiveness of marketing communications - neuromarketing. The exploitation of the neuromarketing research results is therefore advantageous for the company, as well as for its customers.

Fears of possible manipulation or misuse of the information obtained are resulted mainly from a lack of awareness on this issue and the fear of the unknown is then reflected in the unwillingness to participate in neuromarketing research.

Although the neuromarketing in the Slovak Republic is in its beginning, the main cause is not the lack of experts in the field and indifference on the part of business, but especially significant financial difficulty of technologies necessary for the implementation of quality research.

It is not necessary to strictly regulate the use of neuromarketing in Slovakia by legislative, but there are some identified areas where it is appropriate to uncompromisingly prohibit the neuromarketing research that is aimed to enhance the effectiveness of the campaign, such as promotion of alcoholic beverages, tobacco and tobacco products, unhealthy food and beverages and the promotion of political, religious or other ideologies, leading to the acquisition and consolidation of power and so on.

Results of conducted neuromarketing research have definitely many benefits to companies. Whether it is an increase in sales volume and revenues thanks to precisely targeted advertising or qualitative effects, such as increasing the loyalty of existing customers and attracting new customers, a proposal of the most suitable marketing strategy, strengthening the market position of the company, improving the quality of products and services based on identified customer reactions, raising public awareness about the company or brand and building a positive corporate image.

List of Abbreviations

BOLD - Blood Oxygenation Level-Dependent
FMRI - Functional Magnetic Resonance Imaging
EEG - Electroencephalography
MRI - Magnetic Resonance Imaging

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COMMUNICATION IN FRENCH FOREIGN LANGUAGE LEARNING BY IMPLEMENTING THE ASPECTS OF INTERCULTURALITY

This research paper examines the case study and the weak sides of the implementation of intercultural education in a FLT class, and then examines how such teaching could be effective. The didactic intervention through which the native teacher was reflexive was done in two stages in order to recover all the didactic aspects necessary for a successful implementation in the future.

Keywords: *interculturality, aspects, french, teaching, process, communication*

1. Introduction

In this paper, we deal with teaching French by the aid of selected aspects of interculturality, promoting intercultural approach in multicultural foreign language education. In the European Centre for Modern Languages in Graz (Institution of the Council of Europe), the intercultural approach belongs among pluralistic approaches and is described in the FREPA - Framework of reference for Pluralistic Approaches [1, 2]. During the research phase, we proceeded by means of the content qualitative pre - analysis and by the aid of the indirect observation (video records and analysis of students and teacher's talk observation sheet. Pluralistic approaches to teaching languages and cultures are new didactic trends in language policy. The general aim of the pluralistic approaches implemented into the school subjects is to create and develop language and cultural consciousness in order to construct and enrich self - plurilingual intercultural competence. Students need to communicate [3, 4], to live and to socialise in multicultural and multilingual contexts [5, 6]. Within the learning process, learners are to develop their plurilingual and pluricultural knowledge, skills and attitudes through designed pluralistic approaches described in the mentioned document. Globalization and integration process opens new opportunities, types and forms of communication, the existence of which is impossible without mutual understanding between different cultures [7]. Global changes in the information, communication, professional and other spheres have determined qualitatively new areas of the education system [8].

This paper examines the disadvantages, risks and weak sides of the implementation of intercultural education in a FLT class, and then examines how such teaching could be effective. The didactic intervention through which the native teacher was reflexive [9] was done in two stages in order to recover all the didactic aspects necessary for a successful implementation in the future. For the similar methodology procedures or teaching theories see as well [10 - 22].

2. Research procedure

Initially, the native teacher EVG prepared an interesting course on the subject of discrimination. The chosen song with which he planned to work is called "The Difference" from the performer Salif Keita. The song considered a hymn to love for peace and tolerance is part of the album bearing the same name of Salif Keïta released on November 16, 2009 at Emarcy. In 2010, the album whose song is dedicated to the evocation in Africa of its albino condition was rewarded with a Victory of the music during the ceremony of the Victories of the music 2010 in the category "Album of world music of the Year ". The teacher prepared a work with the words of the song adapted for teaching purposes. By means of a sheet, the pupils had to identify the missing words while reflecting on their understanding of the words of the song.. The teacher then prepared a list of questions concerning racism in Africa and in general. According to the didactic intervention and the analyses of the course, it is obvious that this ambitious objective was not reached during the course. And that is the

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objective of this paper - to present negative points in order to avoid them in future implementations and in order to make students communicate more in foreign language.

Educational Objectives: Recognizing Discrimination, Responding to Racism

Cognitive linguistic objectives: recognize the words in the song, express attitudes towards the discussed subject

Number of students: 16

Location: Piarist grammar school, Slovakia

Material: text of the song, teacher brainstorming questions

Instructions and support: see annexe A

2.1 Research methods

To verify the effectiveness, we used qualitative content analysis method as well as indirect observation method (video analysis) as well as a quantitative method for counting teacher's talk and students' talk.

3. Results

3.1 Qualitative content pre - analysis of the lesson objectives by means of the descriptors FREPA[1]

These FREPA descriptors were assigned to evaluate the class and lesson objectives:

Knowledge:

K 2.6 Has knowledge about historical facts (linked to relations between nations or people, resettlements of people) which have influenced or do influence the appearance or development of certain languages

K 4.3 Possesses knowledge about the history of languages (e.g. the origin of some languages, some lexical and phonological evolutions, etc.)

K 6.7 Knows that words may be constructed differently in different languages

K 8.6 Knows that each culture determines or organises at least partly the perception of the world or way of thinking of its members

K 8.6.1 Knows that facts, behaviours or speech may be perceived or understood differently by members of different cultures

K 8.6.2 Is familiar with some schemes of interpretation specific to certain cultures as far as knowledge of the world is concerned (e.g. numbering, methods of measurement, ways of telling time, etc.)

K 8.7 Knows that cultures influence behaviours, social practices or personal evaluations (of oneself or of others)

K 8.7.1 Is familiar with some social practices or customs from different cultures

[1] http://frepa.ecml.at

K 8.7.1.1 Is familiar with some social practices or customs from neighbouring cultures

K 8.7.2 Is familiar with some specificities of one's own culture in relation to certain social practices or customs from other cultures

K 9 Knows that cultural diversity and social diversity are closely linked

K 9.1 Knows that a culture is always complex and is itself made up of (more or less) different conflicting or convergent subcultures

K 9.2 Knows that within the same culture there exist cultural subgroups corresponding to social, regional or generational sub - populations

K 9.2.1 Knows some examples of the variation of cultural practices according to social, regional or generational groupings

K 9.2.2 Knows (in one's own culture or in other cultures) some norms related to social practices and which are specific to certain social, regional or generational groupings

K 10 Knows the role of culture in intercultural relations and communication

K 10.1 Knows that uses, norms or values specific to each culture make behaviour or personal decisions complex within a context of cultural diversity

K 10.3 Knows that cultural differences may underlie verbal or non - verbal communication or interaction

K 10.3.1 Knows that difficulties in communication caused by cultural differences may result in cultural shock or cultural fatigue

K 10.4 Knows that intercultural relations and communication are influenced by knowledge or representations one has of other cultures and those that others have of one's own culture

K 10.4.1 Knows that knowledge one has of cultures often includes stereotypes (i.e. a simplified and sometimes useful way of grasping one aspect of reality, liable to lead to oversimplification and generalisation)

K 10.4.2 Knows some stereotypes of cultural origin which may affect intercultural relations and communication

K 10.4.3 Is aware of the existence of cultural prejudice

K 10.4.3.1 Knows some examples of prejudice or misunderstandings of cultural origin (especially in the case of the cultures of those communities whose language one is learning)

K 11.1.3 Knows that history or geography often offer one the opportunity to understand or explain certain cultural practices or values

K 11.1.3.1 Knows certain historical facts (linked to relations between nations or people, to migrations, etc.) or geographical facts which have influenced or influence the creation or evolution of certain cultures

K 12 Knows several phenomena relative to the diversity of cultures

K 12.1 Knows that there is (still) a great multiplicity of cultures all over the world

K 12.5 Knows that the diversity of cultures does not imply superiority or inferiority of any one in relation to the others

K 12.5.1 Knows that relations between countries are often unequal or hierarchised

K 12.5.2 Knows that hierarchies established arbitrarily between cultures change with time
K 13.2.3 Knows some resemblances or differences between the cultures of different social, generational or regional groups
K 14.1 Knows that identity is constructed on different levels (e.g. social, national, supranational, etc.)

Attitudes:
A 2 Sensitivity to the existence of other languages, cultures or persons or to the existence of linguistic, cultural or human diversity
A 2.1 Sensitivity towards one's own language or culture and other languages or cultures
A 2.2 Sensitivity to linguistic or cultural differences
A 2.2.1 Being aware of different aspects of language or culture which may vary from language to language or from culture to culture
A 2.4 Being sensitive both to differences and to similarities between different languages or cultures
A 2.5.1 Being sensitive to (or aware of) the linguistic or cultural diversity of society
A 4 Positive acceptance of linguistic or cultural diversity, of others or of what is different
A 4.2 Accepting the fact that another language or culture may function differently from one's language or culture
A 4.5 Acceptance (or recognition) of the importance of all languages or cultures and the different places they occupy
A 5.1 Empathy with (openness to) alterity or otherness
A 5.3.3 Openness towards the unfamiliar (linguistic or cultural)
A 5.3.3.1 Being open (and mastering one's own eventual resistances) to what seems incomprehensible and different
A 6 Respect or regard for "foreign" or "different" languages, cultures or persons; for the linguistic, cultural or human diversity of the environment; for linguistic, cultural or human diversity as such (in general)
A 6.1 Respect for differences and diversity (in a plurilingual and pluricultural environment)
A 6.2 Valuing (or appreciating) linguistic or cultural contacts
A 6.4 Considering all languages as equal in dignity
A 6.5 Having respect for human dignity and equality of human rights for everybody
A 6.5.1 Respecting (or valuing) each individual's language and culture
A 6.5.2 Considering each language or culture as a means of human development, of social inclusion and as an indispensable condition in the exercise of citizenship
A 7 Disposition or motivation with respect to linguistic or cultural diversity or plurality
A 7.3.4 Readiness to experience a threat to one's identity (or to feel loss of individuality)
A 7.3.5 Readiness to be considered as an outsider
A 7.5 Motivation to study or compare the functioning of different languages (e.g. structures, vocabulary, systems of writing, etc.) or cultures
A 8 A wish or a will to be involved or to act in connection with linguistic or cultural diversity or plurality or in a plurilingual or pluricultural environment
A 8.1 Determination to take up the challenge of linguistic or cultural diversity (going beyond simple tolerance, towards deeper levels of understanding and respect, towards acceptance)
A 8.5 A wish to discover other languages, cultures or peoples
A 8.5.1 A wish to encounter other languages, cultures or peoples linked to the personal or family history of persons one knows
A 8.6.2 The will to try to understand the differences in behaviour, in values or in attitudes of members of the receiving culture
A 8.8 The will to learn from others (their language or their culture)
A 11.2 Disposition to suspend judgement about one's own culture or other cultures
A 11.3 The will to combat (deconstruct or overcome) one's prejudices towards other languages or cultures and their speakers or members
A 11.3.1 Being attentive to one's own negative reactions towards cultural or linguistic differences (e.g. fears, contempt, disgust, superiority, etc.)
A 11.3.2 Being ready to adopt attitudes to diversity which conform to knowledge one may acquire or may have acquired from it
A 12 Disposition to starting a process of linguistic or cultural decentring or relativising
A 12.4 Disposition to reflect on the differences between languages or cultures and on the relative nature of one's own linguistic or cultural system
A 19.1 Disposition to modify one's own knowledge or representations of the learning of languages when these appear to be unfavourable to learning (negative prejudice)

Skills:
S 1.8 Can analyse the cultural origins of certain behaviours
S 1.9 Can analyse specific social phenomena as being the consequence of cultural difference
S 1.10 Can develop a system of interpretation which enables one to perceive the particular characteristics of a culture (e.g. meanings, beliefs, cultural practices, etc.)
S 2.9 Can identify (or recognise) communicative variations engendered by cultural differences
S 2.10 Can identify (or recognise) specific forms of behaviour linked to cultural differences
S 2.11 Can identify (or recognise) cultural prejudice
S 3.2.4 Can compare languages aurally
S 3.3 Can perceive proximity or distance between graphic forms
S 3.10.2 Can perceive differences or similarities in different aspects of social life (e.g. living conditions, working life, participation in activities of charities, respect for the environment, etc.)

Table 1 A who - talks references

Who talks	Σ
Tt	ΣTt 14 minutes 15
St	ΣSt 11 minutes 49 out of which:
El 1	0'01+0'08+0'14 =0'25 + 0'48 de prière + 4'05 of listening activities = 5'18
El 2	0'02+0'02=0'04+ 0'48 de prière + 4'05 of listening activities = 4'57
El 3	0'04+ 0'48 de prière + 4'05 of listening activities = 4'57
El 4	0'01+0'07=0'08+ 0'48 de prière + 4'05 of listening activities = 5'01
El 5	0'19+ 0'48 de prière + 4'05 of listening activities = 5'12
El 6	0'12+ 0'48 de prière + 4'05 of listennig activities = 5'05
El 7	0'06+0'03+0'09+0'05=0'23+ 0'48 praying + 4'05 of listening activities = 5'16
El 8	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 9	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 10	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 11	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 12	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 13	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 14	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 15	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53
El 16	0'00+ 0'48 de prière + 4'05 of listening activities = 4'53

S 3.10.3 Can compare meanings or connotations corresponding to cultural features (e.g. a comparison of the concept of time, etc.)
S 3.10.4 Can compare different cultural practices
S 7.7 Can manage one's own learning in a reflective manner.

It is assumed that the activity develops several sub - competencies of the intercultural plurilingual competence described in the Framework of reference for pluralistic approaches document. It is up to the teacher to conduct his course in order to develop the listed knowledge, attitudes, and skills.

3.2 Analysis of the filmed class sequences

The effectiveness of the FLT class and of the students' performance (communication) centred on the implementation of intercultural aspects into the FLT class (by the aid of the concept called discrimination) was counted by the equation:
ΣTt : ΣSt

The following abbreviations were used:
- teacher (native speaker - French): EVG
- Slovak teacher (observer): EJS
- student/s: El/s.

It means that

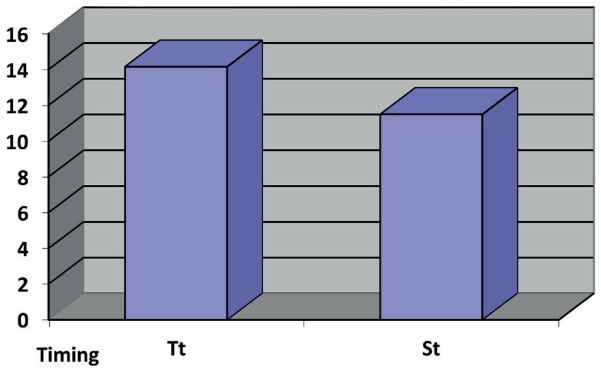

Figure 1 *Proportion of talks*

ΣTt : ΣSt
Σ14'15 : Σ11'49
Tt > St

- the class is effective if Tt < St
- the class is a little effective or not effective if Tt ≥ St.

The Tt is the teacher's talk (speech of professor) and the St is the student's talk or students' talk. Thus it is possible to summarize all the statements of the teacher, all the statements of a chosen student, but also all the statements of all the students together. We sum up a total number of seconds of talk (see Table 1).

To count the teacher's talk and the students' talk in minutes (30 minutes of class), this means that:
- the class is not effective if Tt ≥ 15 minutes (a half of class)
- the class is a little effective if Tt = 8 up to 15 minutes
- the class is effective if Tt ≤ 8 minutes.

3.3 Research results

The very first results during the research procedure occurred when measuring the time of students' individual talk and the talk of the teacher. The total students' talk was 11 minutes 49 seconds which was counted on the base of summarizing partial - individual students' talk. The teacher's talk was higher than students' talk. The following graph was made up from the measured values.

The graph on the proportion of talks

Total minutes of the Educational Discourse Tt versus total minutes activities and student talk St is shown in Figure 1.

The class was a little effective.

The graph of the timing of student activities and talk during the class shows in Figure 2.

Five students performed weakly and the last 5 ones were even weaker.

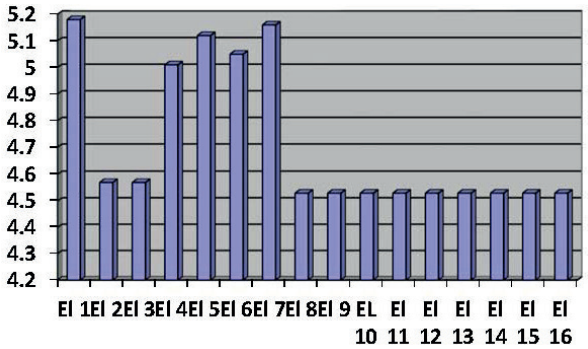

Figure 2 *Students' talk and activity proportion*

4. Discussion and conclusions

As first, the teacher's techniques were observed. EVG prepared a beautiful song that deals with an important phenomenon but little known in the country of Slovakia: the Albino theme in Africa. The teacher could have first presented the theme or done an icebreaker activity related to racism. The song, itself very important for the theme of racism, did not meet with the understanding among the young Slovak public on any level - educational, cultural or linguistic one. The teacher could have distributed a support material to each student in the class in order to facilitate the listening activity as the class lasted only 30 minutes. The song lasted itself about 5 minutes (that is a fifth of the course to pass the song) is considered as not much effective. Similarly, the fact that at the end, the song followed in a completely unknown language did not increase the students' interest or motivation.

In terms of lesson management, the teacher asks the students if they hear well. He acts in this way during the listening phase and so disturbs them during their comprehension activity. He then moves the computer and places it in front of the first student sitting in the first row. Loud sound was only available for students in the first row and the second row, the others were without the possibility to listen to the song properly. As a consequence, they talked.

Two other listening exercises that the teacher develops prove to be little effective. He only passes them halfway because he sees that the class would soon finish. During the post - listening activity, he discovers that most of the students did not fill in the blanks in the material distributed by the teacher. The teacher avoids these students and stops at the student who filled an item in a wrong way saying:

Video Excerpt 1:
« Eh, non, c'est l'opposé. Je suis dans noir. » (line 33, 34 of Indirect observation sheet)

In the teacher's talk that follows, the teacher concentrates mainly on the grammatical items:

Video Excerpt 2 :
« Et le deuxième mot, tu l'as peut - être aussi... Ma peau est » (line 36 of Indirect observation sheet)
Reply of the student 2 - El 2 : « Blanc » (line 37 of Indirect observation sheet)
« Mais au féminin ? Qui a le blanc au féminin ? Blanc au féminin ? Blanc. Blanche. (lines 38, 39 of Indirect observation sheet)
Reply of the student 1 - El 1 : « Blanche » (line 40 of Indirect observation sheet)

Video Excerpt 3 :
« C'est la différence qui est jolie. Et comment tu écris « joli » à la fin ? « joli » (lines 54, 55 of Indirect observation sheet)
« Eh non. Eh, le féminin c'est juste le - e. le masculin c'est juste joli. (EVG writes on the blackboard « joli » and « M » which means « masculin » and « F » which means « féminin ».) C>est masculin... donc, ca s'écrit avec un - e a la fin parceque c'est féminin et au masculin, c'est juste - i. (lines 58 - 62 of Indirect observation sheet)

The teacher only explains two grammatical rules which third grade students already tackled during their first - year courses. These explanations are very undeveloped and do not serve to encourage students to work deeper. The teacher could have prepared a series of exercises or activities in order to satisfy the linguistic or communication need of the students. No work has been done there.

Concerning the oral production or expression of opinions by the students or the taking of the position vis - a - vis racism, we find in the class one sentence expressed and repeated by two students.

Video Excerpt 4 :
« Ce n'est pas bien. » (lines 120, 121 of Indirect observation sheet)

The majority of the class had problems with the song comprehension. This was true in relation to the theme and in relation to the change of the codes (French and Banbarras) without knowing what the albino means. A large part of the class, students read the same text by stopping a few parts to illuminate the spelling. The activities of the students during the FFT intercultural class entitled "Discrimination" consist of reading the song, passively listening to the song and repeating the prayer at the beginning of the course (Catholic High School). This leads to the conclusion that students have not been exposed to a productive language activity. Most of the students did not understand the tasks of the course.

In summary, according to the mathematical analyses of the total pedagogical discourse and the totality of the students' talk

and students' activities and according to the qualitative analyses of these discourses, we sum up that the class was ineffective.

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Annexe A
Dans la chanson retrouvez les mots lacunaires.

La Différence	D finai bai
Je suis un noir	D djl
Ma peau est 1	D kagni
Et moi j'aime 2.....	D magni
C'est La Différence qui est jolie	O bai y couleur kaon ka gnyoro dafa
Je suis un blanc	(Refrain)
Mon sang est noir	Ny y bai n fai
Et moi j'adore a	Y y n ka fima fai
C'est La Différence qui est 3	Fima bai n fai
	N fin d
Je voudrais	
Que nous nous entendions dans l'amour	Ny y bai n fai
Que nous nous comprenions dans l'amour et dans la paix	Y y n ka djmai fai
	Djmain bai n fai
(Refrain) x2:	N djl do
La vie sera belle x3	
Chacun a son tour aura son amour	Ny fina
	A li yr kai bachi y
La vie sera belle x3	Allah y fima dai
Chacun dans l'honneur	Djma dai kan ka gnorota kan ka gnoro dafa
Aura son 4	(Refrain) x3
La vie sera belle	*Clé* : *1 blanche, 2 bien, 3 jolie, 4 bonheur*

Annexe B
Indirect observation class sheet

Timing	Line	Who talks/ who performs	Interactions
00'24	1	EJS	Este raz vas poprosim. Veci - odlozte si vsetko. Pero, zosit (class management)
	2		
	3	El 1	Ja tam sedim.
	4	EJS	Aj tak vies, daj si to von na chodbu.
	5	El 6	Dam si to do tasky. Take mam mokre gate.
	6	EJS	Tam si ich daj, neboj ja ti ich budem strazit. Lubosko, len pero si zober.
	7		
	8	El 4	Jasne, idem. A zosit treba?
	9	EJS	Dole si daj tu tasku.
01'05	10	EJS	Bonjour à tous. Comme habituellement, debout s'il vous plait.
	11		
02'02	12	Els	Au nom du père et du fils. Notre père... (students praying)
02'50	13	EJS	C'est Vincent qui va travailler avec vous aujourd'hui.
	14	EVG	Vous aimez la chanson, non? Vous aimez chanter? On va faire une petite chanson à l'ordi. Eh, vous avez...
	15		
	16		Ça sera juste des paroles. Vous écoutez d'abord et (EVG passes the song). Vous entendez là ?
	17		
	18	El 4	Plus volume

	19		(EVG changes the place of computer, computer is now installed in front of the student in the first row. Students listen to the song without lyrics.)
	20		
	21		
07'07	22	EVG	Vous avez compris un peu la chanson ? Non ? La fin de la chanson c'est normal, c'est en africain. C'est en banbarras, une langue du Mali. Donc la fin de la chanson, c'est normal que vous avez pas compris. Le début c'est en francais. Quelques mots vous avez compris? Ou l'ensemble est... qui a compris un petit peu, la chanson? (students whisper) Personne? Eh, on va la réécouter et je vais vous donner le texte qu'il faudra compléter. Les paroles. (EVG distributes to students the lyrics adapted for the class work) ...
	23		
	24		
	25		
	26		
	27		
	28		Vous complétez les paroles, vous allez entendre ... (students fill in the gaps.)
	29		
	30		
	31		
	32		
10'25	33	EVG	(EVG controls what students fill in) Eh, non, c'est l'opposé. Je suis dans noir.
	34		
	35	El 2	Noir
10'47	36	EVG	Et le deuxième mot, tu l'as peut - être aussi... Ma peau est
10'49	37	El 2	Blanc
10'50	38	EVG	Mais au féminin? Qui a le blanc au féminin? Blanc au féminin? Blanc. (students whisper) Blanche.
	39		
11'12	40	El 1	Blanche.
11'22	41	EVG	Qui veut lire après? Je suis un noir, ma peau est blanche. Et moi, ... qui veut lire? Oliver? La troisième ligne...
	42		
11'40	43	El 1	Et moi, j'aime bien ça. C'est la différence qui est jolie.
11'52	44	EVG	Quelqu'un a les mots qui suivent après ? (EVG passes the song for the third time.) Vous réécoutez une autre fois... (El 3 sneezes.)
	45		
	46		
13'29	47	Els	Na zdravie.
14'14	48	EVG	Est - ce que vous avez réussi à trouver d'autres mots? Je suis un blanc et mon sang est ...
	49		
14'21	50	Élèves	Noir
14'22	51	EVG	Parfait
14'26	52	EVG	Qui veut lire la suite? Qui veut lire?
14'30	53	El 3	Et moi, j'adore ça. C'est la différence, c'est qui est jolie.
14'34	54	EVG	C'est la différence qui est jolie. Et comment tu écris « joli » à la fin? « joli »
	55		
14'42	56	El 5	Chod to napisat, ako si to napisala. (El 3 writes on the blackboard « joliee », EVG corrects.)
	57		
15'01	58	EVG	Eh non. Eh, le féminin c'est juste le - e. le masculin c'est juste joli. (EVG writes on the blackboard « joli » et « M » which means « masculin » and « F » which means « féminin ».) C'est masculin... donc, ça s'écrit avec un - e a la fin parce que c'est féminin et au masculin, c'est juste - i. Qui veut lire le quatrième paragraphe? Je voudrais... qui veut le lire?
	59		
	60		
	61		
	62		
	63		
15'36	64	El 6	(El 6 reads the text.) Je voudrais que nous nous entendions dans l'amour, que nous nous comprenions dans l'amour et dans la paix.
	65		
	66		
15'48	67	EVG	Et qui veut lire le cinquième paragraphe, le dernier?

15'50	68	El 7	La vie est belle, chacun à son tour aura son amour, la vie sera belle. (Elève 7 reads the song paragraph.)
	69		
15'56	70	EVG	Et maintenant est - ce que vous comprenez toute la chanson? Est - ce que vous connaissez Salif Keita? C'est un chanteur malien. (EVG works on computer, shows a photo of an Albino.) Si vous savez, ceci est un Albinos. C'est lui. (EVG shows it to the students sitting on the first row.) Il est Albinos. Vous savez qu'est - ce que c'est pour les animaux? Par exemple un ours albinos. C'est une maladie de la peau, par exemple. Les ours voilà. Ils sont blancs. Et lui, il est noir et sa peau est noire. (EVG shows the phenomenon of Albinos to other students.)
	71		
	72		
	73		
	74		
	75		
	76		
	77		
	78		
	79		
	80		
17'28	81		(EVG shows the photo of the singer Salif Keita; students sitting on the first and second row are able to see the photo, not others.)
	82		
	83		
17'48	84	EVG	Et est - ce que vous savez pourquoi il chante cette chanson - là ? Est - ce que vous savez pourquoi il chante cette chanson - là, le titre de la chanson c'est La différence. Le titre de la chanson c'est La différence, est - ce que vous savez pourquoi il chante cette chanson - là? Est - ce que vous avez vu déjà beaucoup des albinos? (élèves chuchotent). Et les Africains blancs?
	85		
	86		
	87		
	88		
	89		
	90		
18'34	91	EJS	Tu as déjà vu?
18'36	92	El 7	Non. Je n'ai vu pas.
18'41	93	EJS	Je n'ai jamais vu. Et, est - ce que tu penses qu'il y en a beaucoup? Ou non?
	94		
18'49	95	El 7	Ze Ci si myslim, ze ich je vela? (El 7 asks in Slovak). Non. Je ne pense pas qu'ils sont beaucoup.
	96		
18'58	97	EVG	Non ils sont pas beaucoup. Au Mali, ils doivent etre 1000 à - peu - près. Une mille au Mali à - peu - près et euh, il doit avoir 6 - 7 millions d'habitants. Si c'est, je pense, si c'est 6 - 7 millions d'habitants, ils doivent être mille sur l'ensemble de la population. Donc, ils sont rejetés. Est - ce que tu sais ce que c'est « rejetés » ? Racisme, le racisme. Ils sont vicimes de racismes. (Some students get bored and talk.) ... noire, puisqu'ils sont blancs. Donc le racisme n'est pas comme en France' les blancs envers les noirs. Vous avez compris ? (students sitting without performing anything.) Qu'est - ce que tu n'as pas compris? Vsetko? (El 2 laughs.) eh, le racisme, c'est souvent les blancs, une personne blanche envers les noirs, ou les gypses avec blancs envers les gypses. Alors que en Afrique c'est souvent le noir
	98		
	99		
	100		
	101		
	102		
	103		
	104		
	105		
	106		
	107		
	108		
	109		
	110		
20'16	111	El 1	On sa nafarbi.
	112	EVG	Hm? En francais
	113	El 1	Ehm. (students laugh)
20'29	114	EVG	En Afrique c'est l'inverse qu'en Europe, les racistes ils sont surtout noirs. Ils n'aiment pas les personnes blanches. (EJS explains.)
	115		
	116		

20'48	117	El 1	Vincent!
21'05	118	EVG	Qu'est - ce que vous pensez du racisme? C'est bien? C'est mauvais? Qu'est - ce que vous en pensez?
	119		
	120	El 7	Ce n'est pas bien.
	121	El 4	Ce n'est pas bien.

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COMMUNICATIONS

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FORENSICS AWARE LOSSLESS COMPRESSION OF CAN TRAFFIC LOGS

In this paper, we propose a compression method that allows for the efficient storage of large amounts of CAN traffic data, which is needed for the forensic investigations of accidents caused by the cyber-attacks on vehicles. Compression of recorded CAN traffic also reduces the time (or bandwidth) needed to off-load that data from the vehicle. In addition, our compression method allows analysts to perform log analysis on the compressed data. It is shown that the proposed compression format is a powerful tool to find traces of a cyber-attack. We achieve this by performing semantic compression on the CAN traffic logs, rather than the simple syntactic compression. Our compression method is lossless, thus preserving all information for later analysis. Besides all the above advantages, the compression ratio that we achieve is better than the compression ratio of the state-of-the-art syntactic compression methods, such as zip.

Keywords: *CAN, network traffic capture, semantic compression, forensic analysis*

1. Introduction

Modern vehicles have multiple embedded controllers, called ECUs (Electronic Control Units), connected together by internal communication networks such as the CAN bus (Controller Area Network). The ECUs are programmable devices, and many of the vehicles' functions now rely on software running on them, as well as on protocols for exchanging information between the ECUs via the CAN buses. Often, vehicles also have interfaces, such as the OBD (On-board Diagnostic) port and various wireless interfaces that make it possible to access certain parts of the vehicle's internal network from the outside. Such access may be needed for diagnostic and maintenance purposes, for connecting the mobile consumer devices to the entertainment unit of the vehicle, or allowing for the transfer of various sensor data in and out of the vehicle. The concept of *connected cars* goes even further by introducing short range wireless connections between vehicles and to the Internet infrastructure, enabling new types of safety and infotainment applications.

All this development means that modern vehicles should be considered as the cyber-physical systems, in which special purpose computers control physical processes, and those computers are no longer isolated from the cyber space out there. This introduces an entirely new domain of problems for vehicles, and road safety in general: the domain of *cyber security*. Indeed, the ECUs in vehicles can be compromised in similar ways as computers are compromised on the Internet (e.g., exploiting a buffer overflow vulnerability in their software), and due to the increasing level of connectedness, such attacks are now possible to be carried out remotely (i.e., without requiring physical access to the vehicle). The feasibility of such remote attacks has been demonstrated by various research groups recently, showing also their potentially catastrophic consequences [1- 3].

The possibility of remote cyber-attacks on vehicles generated a lot of interest in developing protection measures that either prevent or detect such attacks. One of the proposed approaches is to perform the log analysis on recorded CAN traffic and identify intrusions either in real-time or in an off-line manner. While real-time intrusion detection seems to be the ultimate goal, off-line analysis of the logged CAN traffic would still be required for better understanding of how an attack worked and for forensic purposes in the case that the attack caused some physical damage.

Being able to detect and analyze cyber-attacks on vehicles requires continuous collection and recording of the CAN traffic. This can potentially lead to a large amount of data that need to be stored in the vehicle. In this paper, we propose a compression method that allows for the lossless, yet efficient storage of that large amount of data. Compression of the CAN traffic logs has

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other notable advantages: it helps to shorten the time required to off-load the data from the vehicle. Moreover, the large amount of data is not only a problem for storage and communication; it also makes forensic analysis hard, resource intensive and time consuming. Our compression method allows analysts to perform the log analysis on the compressed data, therefore, it contributes to reduced analysis time and effort. We achieve this by performing *the semantic compression* on the CAN traffic logs, rather than simple syntactic compression. Besides all these advantages, the compression ratio that we achieve is better than the compression ratio of the state-of-the-art syntactic compression methods, such as zip.

The syntactic compression methods operate on the low level byte stream representation of the data. In contrast to this, the semantic compression methods interpret the data being compressed and take advantage of its semantic understanding. The semantic compression has generated considerable interest in the recent years. It has been successfully applied in different fields such as general database compression [4], video compression [5] and virtual machine memory compression [6]. What we propose in this paper is a new application area for it.

The rest of the paper is organized as follows: In Section 2, we give an overview on crash data recorders and show that they are not appropriate for supporting forensic analysis of cyber-attacks. In Section 3, we provide background information on the CAN technology. We describe our new semantic compression algorithm in Section 4, and we evaluate its performance in Section 5. In Section 6, we show that the proposed format is a useful approach to find traces of an attack. Finally, in Section 7, we conclude the paper.

2. Crash data recorder devices

Data recording devices that can capture information continuously or triggered by an event have existed in the transportation industry for decades. The best known such devices are probably the "black boxes" used in aviation to record data that can be used by investigators to reconstruct some of the circumstances of an airplane crash. Such recording devices now also exist in road vehicles: since September 2014, the so-called Event Data Recorder (EDR) is mandatory for every new passenger car and new light commercial vehicle (LCV) in the US. The purpose of the EDR devices is to collect data about the vehicle dynamics and the vehicle status that enable better accident reconstruction. It helps in validating insurance claims, encourages safer driving behavior and extends the scientific knowledge about real accidents, thus, resulting in safer vehicle design.

The European answer to EDR is the so called eCALL system that will be introduced in all new cars as of April 2018 in the EU. The major difference between the two systems is that EDR devices are offline systems, requiring a later data retrieval, while the eCALL is an online system that immediately calls the ambulance (dials 112) in the case of emergency.

The importance of an EDR-like "black box" increases with the deployment of highly automated functions in road vehicles, as there must be some objective evidence proving who was in charge of control in the vehicle in a critical situation. Due to the previously mentioned properties, the EDR devices in their current form are inappropriate for supporting forensic investigations related to cyber-attacks. The European eCALL system does not even record CAN data, so it clearly cannot be used in the case of cyber incidents.

There exist data recording devices, such as tachographs, that perform continuous data collection in vehicles. Tachographs are mainly used on heavy trucks, buses, and emergency vehicles to continuously record certain parameters of the vehicle such as its speed, its engine RPM and odometer values. Yet, the main purpose of tachographs is to monitor the duty status of the drivers of commercial vehicles and they are not designed to record the raw CAN traffic. They usually record only a few vehicle parameters with a certain recording frequency and they are not available on all kinds of road vehicles. Hence, similar to the EDRs, tachographs in their current form cannot really be used in investigations of cyber incidents affecting vehicles.

Hence, we can conclude that, although they have seemingly similar goals, existing data recording devices in road vehicles actually address a problem different from the one that we address in this paper and they are not appropriate for cyber incident investigations.

3. Background – the CAN protocol

The CAN protocol was designed to be simple, causing only a small overhead in the communication. None of the messages contain any authentication information. This nature of the protocol makes it very easy to spoof CAN messages, which, in turn, can lead to numerous other attacks based on the injection of arbitrary messages into the CAN traffic. Understanding the CAN messages, however, is a more complex problem, because it requires a priory knowledge of the network and the communicating parties.

In vehicles, the ECUs communicate with each other mostly periodically. While the communication is event based, regular repetition times enable a quite accurate prediction of the upcoming pattern of messages. Another main property of the traffic is that the content of messages is often repeating.

We confirmed these properties via capturing traffic in real vehicles. Our test vehicles, however, were not premium category vehicles. In premium category vehicles, there are more ECUs, which results in a higher variety of the CAN message types and message contents. Also, the same high variety is expected in autonomous vehicles. Yet, we believe that even in those cases,

1481492674.734327	0x260	8	000000000000006a
1481492674.736055	0x2c4	8	05c8000f0000923c
1481492674.738092	0x2c1	8	080335016ad9004f
1481492674.754306	0x260	8	000000000000006a
1481492674.759605	0x2c4	8	05c8000f0000923c
1481492674.769823	0x2c1	8	0803390170d90059
1481492674.774302	0x260	8	000000000000006a
1481492674.783129	0x2c4	8	05c2000f00009236
1481492674.794246	0x260	8	000000000000006a
1481492674.801541	0x2c1	8	08033b0174d9005f
1481492674.806689	0x2c4	8	05c2000f00009236
1481492674.814227	0x260	8	000000000000006a
1481492674.83034	0x2c4	8	05c5000f00009239
1481492674.833283	0x2c1	8	08033b0174d9005f
1481492674.834316	0x260	8	000000000000006a
1481492674.853767	0x2c4	8	05c8000f0000923c

Figure 1 *Simplified CAN traffic log*

```
0x260
start_time:1481492674.734327
period:19984
00 00 00 00 00 00 00 6a:        0#0,1#-5,1#12,1#-40,
0x2c4
start_time:1481492674736055
period:23540
05 c8 00 0f 00 00 92 3c:        0#0,1#10
05 c2 00 0f 00 00 92 36:        1#-16, 1#20
05 c5 00 0f 00 00 92 39:        1#111
05 c8 00 0f 00 00 92 3c:        1#-113, 1#-22
0x2c1
start_time:1481492674738092
period:31728
08 03 35 01 6a d9 00 4f:                0#0
08 03 39 01 70 d9 00 59:                1#3
08 03 3b 01 74 d9 00 5f:                1#440, 1#14
```

Figure 2 *A compressed message flow example*

the CAN traffic is rather regular and exhibits features that can be exploited for its efficient compression.

4. The compression algorithm

The usage of the semantic compression and syntactic compression helps to achieve different goals. A clever combination of the two approaches could benefit from the advantages of both: the semantic compression reduces the file size while maintaining accessibility to the data, whereas the syntactic compression achieves the smallest possible file size.

To exploit the benefit of both approaches we propose to apply both methods at different operational phases. During the data collection, an on-the-fly semantic compression could reduce file sizes while keeping data available for immediate processing. The compressed data format allows a fast analysis of data flows because they are stored in blocks one after the other, whereas investigation of causality relations is more computing-intensive.

An optional long-term storage or cloud transfer of network logs requires the smallest file size, while the importance of immediate data accessibility is reduced. This implies the use of the syntactic compression at this phase.

We propose a compression algorithm that takes advantage of the largely periodic nature of the CAN traffic. The high-level approach of our algorithm is to separate the traffic into message flows, containing only messages that have the same ID, and then, compressing each message flow separately leveraging the previously identified properties.

The first step is done by filtering messages based on the ID field of the protocol. This step generates separate lists of messages where the only remaining information for each message to be stored is its timestamp in the log and the data content of the message. Storing a complete and separate timestamp for each message in a flow would be a waste of storage. Our more efficient approach takes advantage of the periodicity of messages. Theoretically, a new message with the same ID should come at an exactly predictable time point based on the inter-arrival time of this message type. However, this behavior can be changed by a higher priority message on the CAN bus. If the two messages are sent at the same time, then only the one with the higher priority will be sent, shifting the inter-arrival time of the messages with the lower priority. From this point on, this complete message flow will be shifted.

An efficient way to store the timestamp of a message is to store the number of periods (specific for that flow) passed since the last message of the same type and an additional offset value that is induced by either priority causes or measurement distortions. For each message flow, there are some additional metadata to be stored: the message ID, the first appearance of the flow in the log and the characteristic period length of the flow. These flow specific metadata should be followed by the message data and then the compressed timestamp for each message. An example of this compressed format can be seen in Figure 3, where the # sign separates the period number and the offset value in each compressed timestamp.

The operation of our semantic compression can be effectively demonstrated in Figure 1 that shows a simplified CAN traffic log. It has been truncated and reduced to only contain messages from three different ID types. Other than that, it is a real life traffic log.

In the first step the algorithm reads the messages separating them into groups with the same ID. In this case, it would result in 3 groups: 0x260, 0x2c4 and 0x2c1. The following step is the same for each group; that is compressing messages inside a group.

An efficient way to find repeated messages is to build a hash map of the messages using the message data as a key. At this point, the only remaining information to be stored is the arrival time of the message.

For a more efficient compression the timestamps are stored in a coded way taking advantage of the CAN traffic properties. The

Table 1 The semantic compression

Test case	Original trace file size	Text format	Binary format	Compression ratio for text	Compression ratio for binary
1	10095971	1710920	1090757	16.94 %	10.80 %
2	7040165	1334902	835539	18.96 %	11.86 %
3	19143383	3747229	2307146	19.57 %	12.05 %
4	21936245	4233994	2601354	19.30 %	11.85 %

Table 2 The semantic and Syntactic compressions combined

	Original trace file size	Original file compressed	Text format compressed	Binary format compressed	Compression ratio for text	Compression ratio for binary
1	10095971	1291315	546725	499998	5.41 %	4.95 %
2	7040165	937319	429234	390467	6.09 %	5.54 %
3	19143383	2569118	1194758	1092183	6.24 %	5.70 %
4	21936245	2895039	1332585	1223677	6.07 %	5.57 %

inter-arrival times of the messages can be calculated, based on the stamps, requiring only to store the small difference between the predicted and the actual arrival times.

It is possible, that a message data appears in the traffic from time to time. This also has an impact on the compression, i.e. we need to store the elapsed number of periods in every case, as well. This number usually has the value of 1 but for a recurring data this may vary.

The final result of the compression of this log can be seen on Figure 2. For storing the compressed timestamp the number of cycles and the arrival shifts are separated with a # sign.

We defined two equally lossless output formats for our algorithm. One is a text base (ASCII) representation of the traffic log, while the other is a binary format.

5. The compression evaluation

We evaluated our algorithm in terms of performance and efficiency. As the most important performance metric, we calculated the compression ratio and as for efficiency, we also measured the speed of our implementation. We performed our measurements multiple times with different datasets originating from different vehicles. We used vehicles of three different brands all belonging to the low mid-level category built between 2005 and 2010.

We captured traffic with a Raspberry Pi based CAN interpreter. It allowed us to access the raw information on the CAN bus, and we saved every CAN message with a timestamp. We performed traffic captures through the OBD interface where the design of the vehicle allowed for an uninterrupted access to the powertrain CAN bus traffic through this connection. We were able to gather traffic logs of multiple hours in all three types of vehicles. The algorithm was capable of efficiently compressing data gathered during the test scenarios in every single case at least a magnitude faster that the incoming speed, as shown in Table on the Semantic compression. This speed makes our algorithm a good candidate for an on-board data compression for local usage of the information or as a preparation for a remote transmission.

The measured compression ratios show significant progress in the data sizes (Table 1 and Table 2). We were able to achieve the compression ratios of less than 20 % using an ASCII representation of the output of our algorithm. The binary representation shows an even more efficient compression with the results being around 10 % of the original file size.

If we applied the additional syntactic compression to our semantic compression it resulted in the smallest file sizes we were able to achieve. In the ASCII representation scenario, the combined result shows an approximate 6 % compression ratio while the binary case shows an approximate 5 % compression ratio.

This result can be considered as another proof that it is worth applying the semantic compression before the syntactic one, because with this combination the additional efficiency can be gained.

We validated the lossless property of our algorithm by checking that the SHA-256 hash of the original data matches that of the data that we restored after de-compression.

6. The forensic use of the compressed format

In the recent years several articles have been published about the vehicle security. Perhaps the largest impact was achieved by the papers of Koscher at al. [1] and Miller et al. [7]. These papers described a series of attacks against the vehicle CAN busses using different attack approaches. Their attacks on a network level can be divided into two categories: sending already known messages with a frequency different from the usual frequency and inserting messages with a previously unused message ID. Based on our

```
id:0110
start_time:1483093132166605
period:9994
0200000000270000:3#-392,1#426,
0200000000260000:1#-348,1#-47,1#-22,1#369,1#-37,1#-301,1#44,1#299,1#-209,1#-81,1#-97,
027d000000200000:2149#-3321,0#999,0#999,0#999,0#999,0#999,0#999,0#999,
    0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,
    0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,
    0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999,0#999
```

Figure 3 *The compressed attack traffic log*

research, our proposed CAN compression format can also be helpful to find attacks described in these works.

The first type of the CAN attack inserts new messages with a known message ID. The purpose of this attack is to flood the CAN bus with a modified message data suppressing the information sent in the original messages. This approach was used, for example, to modify information displayed to the driver. The appearance of the original message on the CAN bus cannot be prevented leaving the only option of sending the crafted messages with a much higher frequency (up to 10-20 times the original value).

The second type of the CAN attack inserts completely new, previously unseen messages into the traffic. In the presented works, those new messages were diagnostic messages. The goal of those messages was to trigger functionalities of the car that would otherwise be turned off. As an example, it is possible to use the park assistant feature of certain cars during the normal driving circumstances to change position of the driving wheel.

Both of these attacks produce a very specific pattern in the CAN traffic that can be easily identified in the compressed format proposed in this work.

One of the properties of the CAN traffic, also utilized by our compression, is the highly regular arrival times. This property is harmed when a higher frequency flooding attack is inserted into the CAN communication. The proposed format represents arrival times in an "elapsed cycles # offset" format. During the normal operation, the value of elapsed cycles is the most probably 1 and the offset is a relatively small number. This behavior changes notably when a log file that includes a flooding attack is compressed. In this case, the value of the elapsed cycles is always 0 because the time between attacking messages is around 1/10 - 1/20 of the normal inter-message time. This also results in an offset field with a greater value than the offset values in the normal case. An example of a compressed attack traffic log can be seen in Figure 3.

Using messages, as part of an attack, with completely new IDs generates an entirely new section in the compressed format. The first step of the compression is to separate messages into discrete groups of messages with the same ID. This step makes it very easy to find attacks using new message IDs. The easiest way to find this discrepancy is to compare multiple compressed traffic logs originating from the same vehicle. This allows the analyzer to significantly reduce analysis time.

Finding anomalies in the compressed format relies on the fact that the properties of the traffic are determined based on a benign traffic period. This can be rather easily achieved because only a very short time frame is required to calculate this information. This calculation can be repeated periodically and the result should be the same every time. If that was not the case, that could also be an indicator that probably an attack happened in that time frame.

7. Conclusion

In this paper, we presented an efficient way to perform lossless compression of the CAN traffic logs. Based on our observations of the periodic properties of the CAN traffic, we designed a semantic compression algorithm for the CAN traffic. With the use of our algorithm, storage efficiency and communication costs can be significantly improved, while keeping the possibility to perform analysis on the compressed data.

As part of our future work, we plan to further optimize the file formats. Our current byte level approach could still be refined if we could represent the number of cycles and offset information in a more condensed way. Another possible follow up is to define a loss compression algorithm where every information is dismissed that is not important for a later forensic analysis. This approach could result in a dramatic reduction in file size.

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COMMUNICATIONS

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UNIQUE POLICE TRAINING POLYGON IN TERMS OF ACTIVITY AND TRAINING IMPROVEMENT OF THE INTERVENTION UNITS OF THE POLICE OF THE CZECH REPUBLIC

The report describes project works and the purpose of a special training polygon designated for police officers of intervention units of the Police of the Czech Republic. It is a completely unique training facility newly built for the law enforcement officers. It concerns the outstanding project in conditions of the Police of the Czech Republic, which contains extreme situations and conditions which police officers of intervention and special units can meet in their practical performance of service. In the limited extend this applies also for the training of tactics for members of firstly coming patrols and emergency units.

Keywords: *police, training polygon, intervention units, layout*

1. Introduction

The Police of the Czech Republic has never had this type of training area or any similar one. Police officers of special units trained in improvised conditions or travelled abroad after the consent of foreign police bodies in order to train intervention in the most realistic conditions and occasionally compare abilities and training methods with those of special units of foreign law enforcement bodies (e.g. in Lest in Slovakia). The below described training facility is an area especially designated for special units trainings of the Police of the Czech Republic (e.g. Rapid Response Unit, Intervention Units of Regional Police Directorates, Prague Emergency Mobile Unit, Special Public Order Police Units, Regional Public Order Police Units, etc.) and by prior agreement also for members of Emergency Fire Brigade of the Czech Republic, Special Military Forces of the Army of the Czech Republic, Intelligence Services of the Czech Republic etc. The Public Order Police Service Directorate guarantees, administrates and operates the project and is in charge of the registration system [1]. The directorate has issued an operational order for the area and it has provided staff responsible for the communication with the supplier of new windows which are necessary to replace those damaged during the training, then for preparation of situations concerning circumstances of the intervention, operational issues, professional supervision over group of trainees, efficiency of this facility and remedy of possible faults.

2. Project finances for the modern training polygon development

This project deals with a construction of a special training polygon, which will be used for the training of intervention units. It is located in Zbiroh in Western Bohemia. In December 2013, the Swiss approved to change the technology of the polygon to a high - rise building complex (Figure 1). Switzerland is represented in the project by the Swiss embassy in Prague.

The total amount exceeds CZK 13 million. The project realisation team was established according to the Police President Order No. 131/2013 [1]. The Project is currently operating at full capacity and it was ceremonially opened in February 2016 with the attendance of the police president and the director of Emergency Fire Brigade. The Project was approved based on a long - standing request of police officers from intervention units for a special simulator, which would enable them to train situations in the most realistic conditions that could occur day by day during their police work. The lack of such a polygon in the Czech Republic was evident, as members of the intervention units had to train on provisional simulators and in situations realised within shooting range areas. The need to fire at targets

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Figure 1 *Design of the final image of the training simulator according to the project*

(armed perpetrators, etc.) and not to fire after the recognition of other individuals (hostage, non - aligned persons, etc.) in different situations and areas emphasizes the need to continue building these special polygons also in other localitites in the Czech Republic, each with a different layout of the polygon.

Members of the intervention units will be able to train the following activities at one place [2]:

- reconnaissance of the object before the intervention,
- tactics of entering the building,
- technique of entering the building (from the ground, from the air),
- securing protection for the police officers after they enter the building (in the building, from the area outside the building),
- movement of police officers in the building,
- specific situations and their assessment (offender/hostage),
- reaction to shooting in the building,
- radio operation,
- communication,
- command during the intervention,
- target shooting (rifles, short fire arms, over ballistic shield on a regular basis in the ballistic vest and helmet), overcharge, shooting during the daytime, dusk and in the dark, shooting with the use of collimators, milivizors,
- descent from a model pod of a helicopter,
- other tactical and characteristic methods of an intervention.

The project was time consuming due to a demanding communication with the foreign partner (Swiss partner) and a large amount of correspondence, including its detailed translation to English language. Selection procedures resulting in a decision about the construction company followed. The location of the building was chosen by the guarantor of the Project - the Public Order Police Directorate of the Police Presidium of the Czech Republic, because the directorate is the main methodological guarantee of activities of intervention units as it is an organisational part subordinated to the first deputy police president - in the area of a basic unit of the General Directorate of the Emergency Fire Brigade in Zbiroh, thanks to an excellent cooperation among basic units of the above mentioned bodies of the integrated emergency system and the possibility to create a multifunctional area in this location. Representatives of all parties and all heads

Figure 2 *The cornerstone laying ceremony was held on the occasion of the construction commencement of the simulator of the Public Order Police Directorate for the police officers of Intervention Units, 18. 2. 2015 [3] (photo by the Police of the Czech Republic)*

of intervention units from the whole country solemnly tapped on the cornerstone in February 2015 (see Figure 2).

3. Location and situation in the rooms of the simulator

From a technical point of view, it is a high - rise building complex providing a necessary simulation of the environment. The traverse steel construction is installed on the roof, allowing this construction to sufficiently simulate a real usage of a helicopter, as well as to train any necessary techniques.

The ground floor of the simulator building is in a form of a rectangle 27.35 m x 14.05 m and it is designed as a five - floor building, approx. 14 m high, without any basement. Bigger part of this facility is roofed from the second floor, where the steps are located. It has an elevator shaft and a training shaft with imitations of installations (see Figure 3). The northern part of the building above the flats is roofed over the fourth floor. The roof above the flats is accessible from the staircase of the fifth floor which extends over the roof area.

The main entrance to the building - behind the spacious covered approach there is a glassed - in entry hall enabling the access to other premises downstairs. There are also rooms imitating the premises of a restaurant and a bar including their back rooms, a shop, and a store.

The control room is part of the first floor. It is the only room that is heat cladded from the inner side and it is provided with the direct heating devices (see Figure 4). All floors are connected vertically by two areas of steps with a prefabricated staircase located in opposite corners of the building. The one - armed

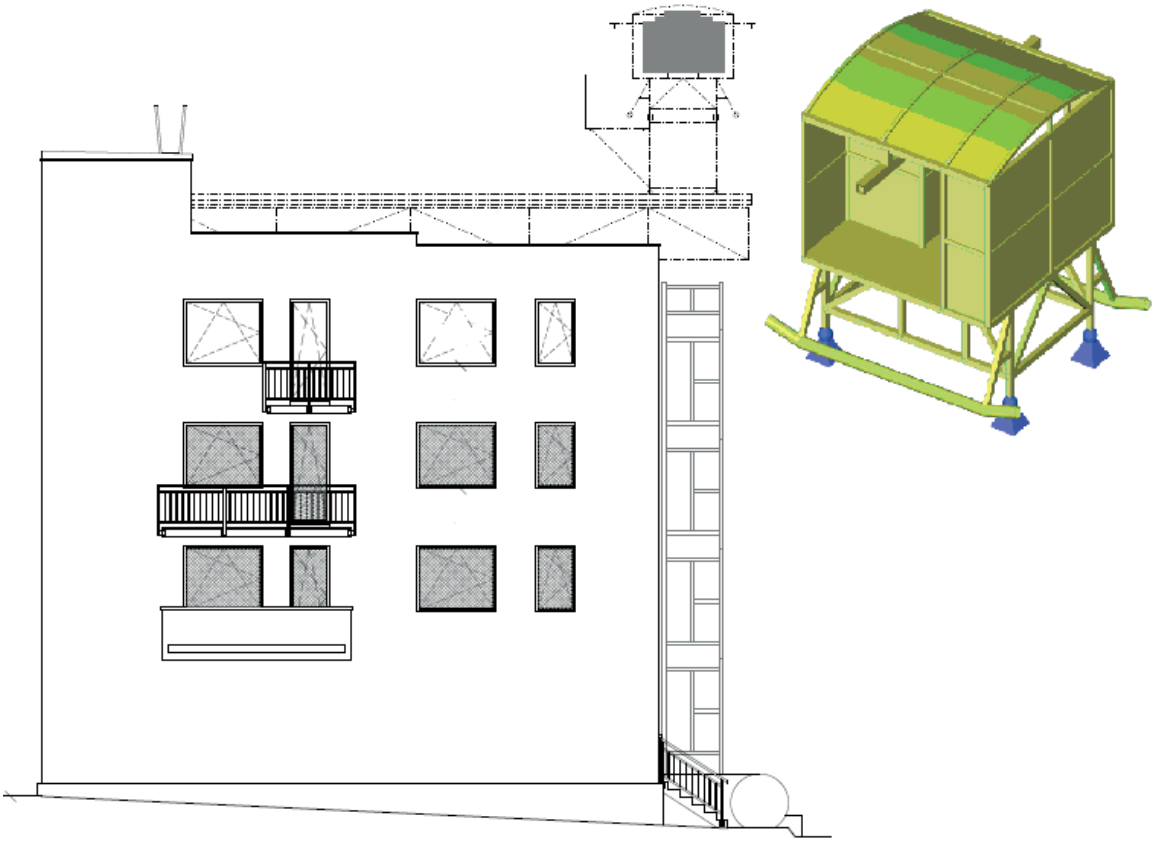

Figure 3 *Model of a helicopter board and a location of the building*

staircase in the north of the main entrance is accessible by separate entrance from the covered entrance to the building. On the opposite end of the building there is a two - armed staircase with an imitation of an elevator shaft and an opened space 4 floors high with an imitation of a rising conduction of a technical infrastructure, including a steel ladder anchored in the wall of the room. The premises of the restaurant and the bar are also accessible from the outside. Imitations of wells DN 1200 and 1500 mm are designed to be located on the premises of the store for training reasons. They lead up to the roof over the second floor and they are connected horizontally downstairs with concrete pipe conduit DN 1000 mm passing through the encircling wall outside, where this pipe continues further as an imitation of a sewage pipe approx. 10 m long, leading to both sides along the western side of the building.

The second floor is the most variable one. There are two tactical premises in the size of two flats (2 rooms + a small kitchen and 2 rooms +1 normal kitchen). It is possible to go outside to a loggia and a balcony from one of these tactical premises (see Figure 5). There are cellar cubicles on one part of this floor, which are formed of flexible and movable crossbar elements. This floor includes a labyrinth accessible from circular passages that are imitations of wells. It is possible to enter the open space by a climbing pipe as well as to enter the cellar part.

The third floor is divided by the flat roof over the second floor with a partial attic. It is divided into two parts of towers of the area 6.3 x 5.6 m with a two - armed staircase, an elevator shaft and an open space with a climbing pipe and a part imitating block of flats with a one - armed staircase and two flats (see Figure 6). The bigger flat with a loggia and a balcony is a duplex flat type vertically connected with a steel circular staircase. On the roof, there is a movable construction of a saddle roof with eaves and a dormer - window. The roof is latched in three positions, i.e. at the end of the roof and in the middle, where the western end of the roof is latched without an attic and it also covers the open construction of the imitations of wells. The vertical steel lattice construction is fixed into the construction of the roof over the second floor. This part of the steel constructions set is designated for hanging and rolling during various intervention tactics trainings of special units.

The space of the tower is dispositionally resolved on the fourth floor in the same fashion as on the third floor and it is ended with a flat roof without an attic. The steel lattice construction is fixed into this roof with rails and supporting function for the mobile lattice construction - a footbridge. In the northern part of this

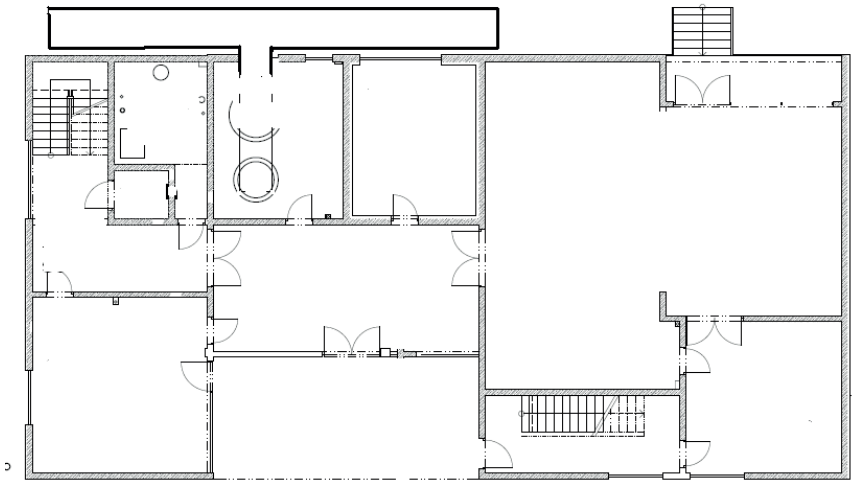

Figure 4 *The First floor*

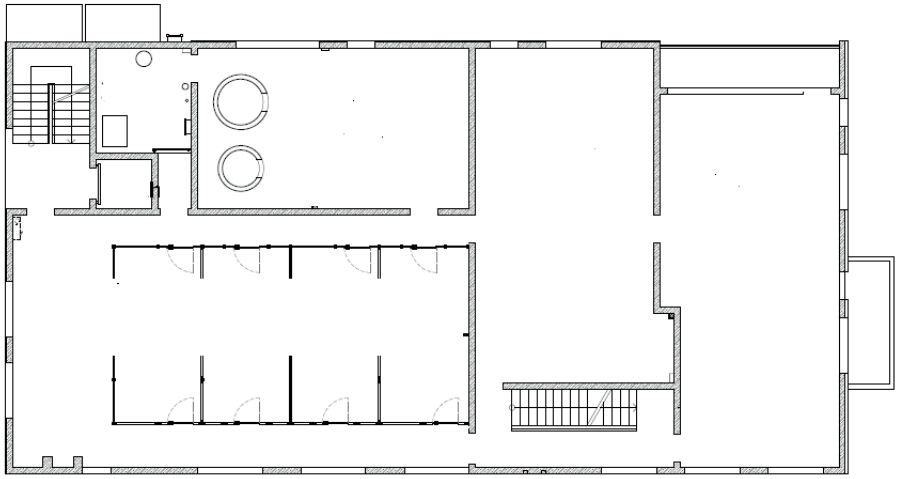

Figure 5 *The Second floor*

facility there is again a flat with two rooms and a kitchen located as well as the second floor of the duplex with an unconventionally formed gallery connected with the loggia and the small balcony (see Figure 7).

The staircase area containing a one - armed staircase only leads to the fifth floor. From this floor, admission to the roof is possible. The roof has following heights of attics: 0, 300 and 600 mm and the attic high as one floor borders one part of the eastern front face of the building. Sparings for gripping during roping down are made in this peripheral wall in a stripe of approx. 1.6 m wide. The flat roof over the staircase is without any attics and it leads to the centre of the building. The second lattice steel construction with rails and a supporting function for the mobile lattice construction - a footbridge with a mobile platform imitating a helicopter board is fixed to the roof over flats (see Figure 8). The roofs of various heights is accessible not only from the towers' doors and from the staircase in the northern part, but also by steel ladders fixed into encircling walls and by industrial lattice constructions. In some places roof edges will be equipped with a low banister to provide additional gripping when going down the rope.

The facade of the building is provided with a variety of surface treatments and colourings because of training purposes. The eastern facade is painted on ferroconcrete, the northern one is faced with wooden oak boards and the western and southern walls are provided with the contact heat cladding with the use of a facade polystyrene of 50 mm + the silicate plaster of the RAL 2012 colour (salmon orange - see Figure 9).

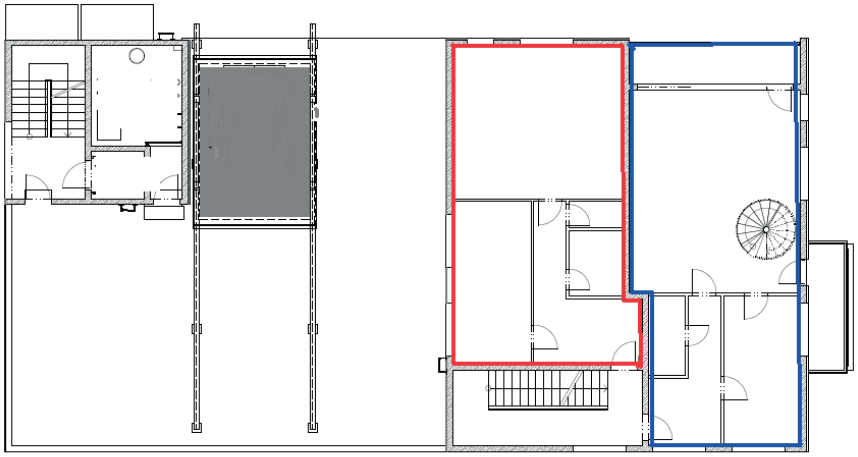

Figure 6 *The third floor*

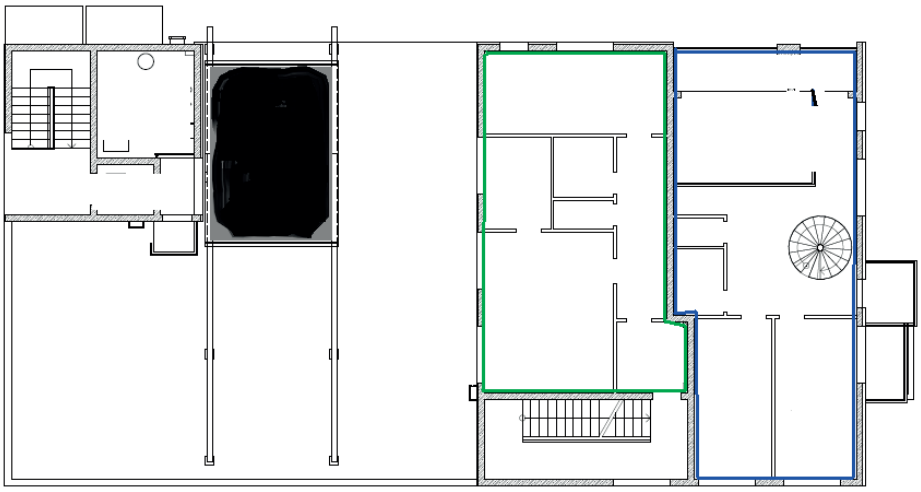

Figure 7 *The fourth floor*

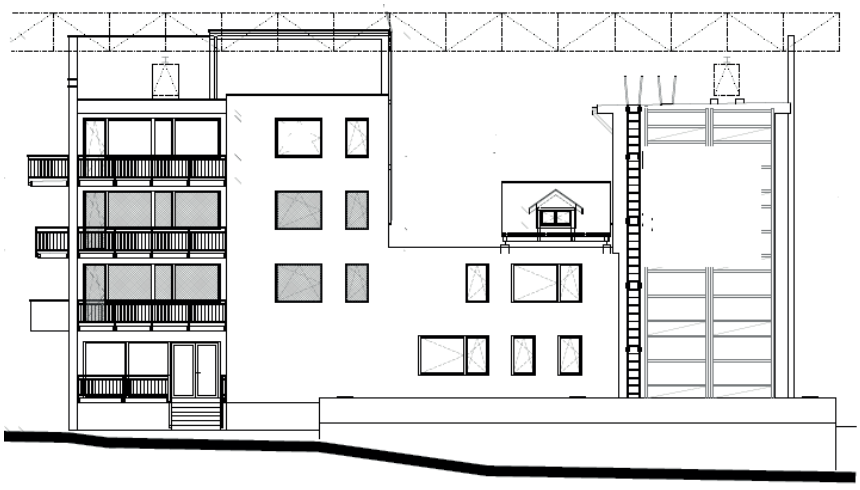

Figure 8 *The western view*

Figure 9 *The northern view of the realised construction*

4. Intervention units of the police of the Czech Republic

Intervention unit members are in brief very well - trained police officers of special units designated for interventions mainly against armed offenders and organised crime (often both), who are aware of the extent and especially punishableness (sentencing) of their actions and therefore not willing to give up, they resist actively, very often using firearms; they also have the necessary technology to protect themselves from being detected and detained. The Police of the Czech Republic has in total 8 seats of intervention units in the whole country, each of them has several tens of police officers with special equipment and they are directly subordinated to the deputy regional director for an external service in the following regions:

- Moravia and Silesia,
- South Moravia,
- South Bohemia,
- Pilsen,
- Usti nad Labem,
- Hradec Kralove,
- Central Bohemia,
- Capital city of Prague.

The deputy regional director for external service is directly subordinated and responsible for the activities and the fulfilment of tasks of the intervention unit to the regional director (to be exact, to the director of the regional police directorate). Intervention units are deployed not only on the territory of one region, but they are prepared to go to other regions beyond their service territory. Intervention units still have their competences according to the original format of borders of the so - called police regions, as this system was effective in the Czech Republic in connection with the original layout (e.g. Intervention units of the Moravian and Silesian Region perform their activities also in the territory of the Olomouc Region - originally the territory of the North Moravian Region).

Figure 10 *During the ceremonial opening a helicopter of the Aviation Service of the Police of the Czech Republic was engaged in the presentation of the intervention unit*

5. Conclusion

This report introduces information about the effort of the Public Order Police Service Directorate of the Police Presidium of the Czech Republic to create plans and to help by the project grants to build a polygon assigned for special police unit trainings, especially for intervention units (see Figure 10). This type of a training area has not been available up until now in this form and in such complexity within the whole territory of the Czech Republic. The whole project cost approximately CZK 20 million. We would like to thank the project donator, the country of Switzerland, for its cooperation and financial support, without which this project could not have been realised. The integral part of the project includes also a brief description of the organisation and seats of Intervention Units, in order to gain more comprehensive insight on the topic.

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kamUNikácie
COMMUNICATIONS

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AUGMENTED REALITY IN ENGINEERING EDUCATION: OPPORTUNITIES AND ADVANTAGES

The article is dedicated to the study of the possibility of applying augmented reality technologies in the field of engineering education. The prerequisites for creation and development of Industry 4.0 are considered. The study considers the concept and the technology of augmented reality. The ground of relevance and timeliness of its application in the professional training education process of engineers from different industrial departments is given. The problems of engineering education are reflected. The modern tendencies of engineering education development are considered. The methods of augmented reality technology application in support for the education process are reflected upon. The advantages and disadvantages of augmented reality technologies' usage in the engineering education are considered.

Keywords: *Industry 4.0, education process, augmented reality*

1. Introduction

In the near future, the industry will make a transition to the new technological structure called "Industry 4.0" [1]. The introduction of the "Industry 4.0" principles will increase production quality, provide the opportunity of fast line reestablishment, which will increase its competitiveness. Besides, the development of these new technologies stimulates innovation and employment.

"Industry 4.0" and its ideas resonate today on different continents and levels. For example, China has a comparable concept called Acceleration as a part of the "China 2025" strategy.

The prerequisites for creation and development of "Industry 4.0" are quite simple and apparent. First of all, if one takes a look at the young generation and people around in general, one will find that the majority uses smartphones, tablets and other gadgets. Secondly, social networks have spread widely: people use them to communicate, share media, work. Lastly, augmented reality technologies have been developed fast. Will such a way of communication gradually move to the industry? From our point of view, it is only a matter of time. In the future, besides the level of human - to - human communication, the machine interaction with other machines will change as well. The term "human - machine interface" has quite a different meaning today. Many machines have the ability to inform about their state and offer an appropriate course of action. In the future, they will interact with other machines, barely communicating with humans, which may mean that it is better to use the term "Machine - human interface" [2, 3].

Technologies of hybrid (or mixed) reality belong among the components of "Industry 4.0". The general model of hybrid reality (Figure 1) represents the path between Real Environment and Virtual Environment. The transitional links of this model are Augmented Reality - AR and Augmented Virtuality - AV. The AR is closer to the real environment and the AV is closer to the virtual environment.

Virtual Reality (VR) and Augmented Reality (AR) have recently been gaining popularity. These technologies provide us with a wide range of opportunities. AR and VR technologies can be applicable almost everywhere from the gaming industry, advertising and presentations (WOW - effect) to industrial and expert systems. AR is capable of turning our world upside down, making it more comfortable, more interactive and safer.

Augmented reality is the new interactive technology, which allows using computer graphics or text on the real - time objects. In comparison to virtual reality, AR - interfaces allow the users to see the virtual objects in reality and to manipulate them in real time [4].

Basically stated, Augmented Reality is the link between ordinary reality and fully virtual reality. Figure 2 shows the process of the Augmented reality appearance. Augmented reality is a real world, which is "completed" by the virtual elements.

The work begins with the camera initialization, the video stream request and the allocation of frame out of the stream.

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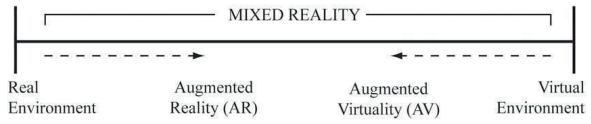

Figure 1 *The model of hybrid reality*

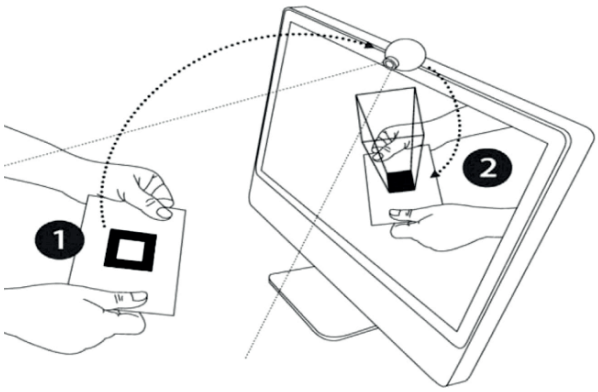

Figure 2 *The process of the Augmented Reality appearance*

Then, the necessary image, particularly the QR - code, needs to be found. When the code is found, the information is being exported. After this, the application sends a request to the data base in order to find the right object. Next, the information on the screen is supplemented by the visual objects from the data base.

Analysing all of the above, the logical solution is the creation of the mixed environment that includes the perceived environment and the virtual objects added in it. This approach would allow expanding the stream of the information received in time unit and, as a result, to increase the efficiency of work [5].

In other words, Augmented Reality is a combination of two initially independent fields: the world of real objects around the human and the virtual world, created by computer, on the screen. This interactive technology provides the user with an opportunity to use special 2D and 3d objects over the camera image, and by this "completing" the reality [6].

2. The significance of AR technology application in engineering education

The question of professional training of engineering from different industrial departments is a timely issue.

The following disadvantages can be highlighted, considering the main problems of engineering education:

- Remoteness of engineer training facilities from real functioning companies;
- Incongruity of the specialists' training cycles and the changes in technology sphere;
- Insufficient number of highly trained teaching staff;
- Absence of systematic discovery of talented people in engineering area;

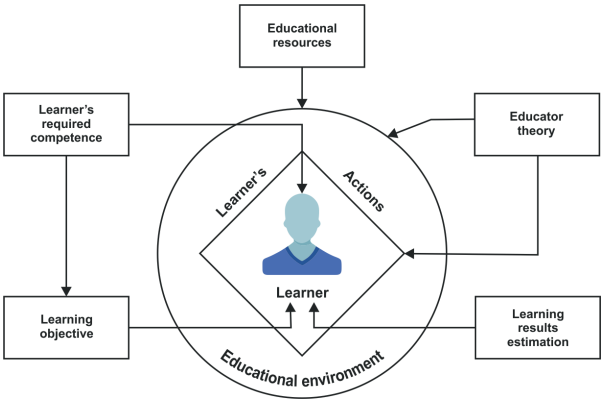

Figure 3 *The schematic representation of the MARE methodology*

In addition, the following key tendencies of technical specialists training can be noted:

- Creating an education process that is oriented towards integration with industry at the university;
- Using the CDIO (Conceive, Design, Implement, Operate) standard;
- Modelling the objective and social content of the professional work, transforming the educational work of a student into the professional work of a specialist;
- Development and application of the new principles of engineering education integration system with an "immersion" of the student into the professional environment.

The ways of the AR application in education were established quite a long time ago. They are reflected in the MARE (Mobile Augmented Reality Education) methodology (Figure 3).

As it can be seen in the representation above, the AR sphere includes educational resources, the composition of which creates the educational environment.

3. The advantages of AR technology application in education

What practical realization are the education resources with the AR supposed to have? Analysing the current educational situation, one can make the conclusion that the best option is the training equipment with augmented reality.

The introduction of AR technologies in the educational process will increase the efficiency of education in technical specialists' training by realizing the following objectives:

1) Realization of the "immersion effect" systems, in which the image is created most realistically. It is known that a human perceives about 80% of information visually.
2) Creating laboratory complexes which include the AR technologies. There is no need of a rational change of teaching methods. AR will allow expanding the possibilities of a regular training equipment, changing it into an interactive educational complex. It is an evolutionary, not revolutionary way.

3) Elimination of the digital gap. It is no secret that many educators (considering an average age of university professors which is 50 years in Russia) have difficulty adopting new IT - technologies, which younger people are easily accustomed to. Training equipment with augmented reality will focus on elimination of this gap. The laboratory complex keeps its regular look, but its elements and contents would serve as markers, recognized by the AR application.
4) Transmission of information to a learner by a much wider channel "animation + sound" in addition to the regular channel "laboratory work". The functions of a regular training equipment are rapidly expanding.
5) Increasing the attractiveness of the educational process to a generation that grew up using gadgets.
6) Development of new technologies, which stimulate innovation and employment.

4. AR methods in education

The educational process consists of a number of sub - processes which need to be actively sustained. One of the ways of the educational process' sustainability is its informational support. It is executed by the implementation of the new communication technologies in educational activity; using these innovative technologies allows completing the traditional methods of education, which help improving the process and accelerating access to the information sources. The informational support consists in increasing the quality of students' and educators' activity, aimed at the formation of a personal information culture, which is oriented to gaining information knowledge and obtaining information skills [7 - 9].

The question of the educational process' support using innovative technologies, particularly the AR technologies, is quite timely due to the increased quality and efficiency being the main objectives.

There are several methods of using the AR technologies in support of the educational process [10, 11]:

- Method of using the QR - codes in educational institutions' practice
- Using the QR - codes with a link, leading to the multimedia resources, which help solving a certain problem. Printing the codes, one can put them in the text books or students' handbooks.
- While organizing the project activity, one can use the collection of links, information blocks, comments and other QR - codes. They can be published on websites, posters etc., supporting the project.
- The QR - codes can be put on the information panels as a video or multimedia comment (as a link), in addition to an announcement or other type of material.

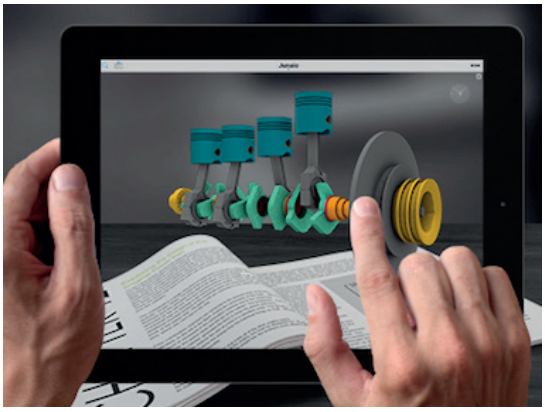

Figure 4 *The AR work demonstration*

- Putting the code in a university library prospectus: code automatically shows to conclude the general information, table of contents, author and location on the shelf.
- The codes are automatically added in the educational information environment. These codes content directions to the URL - page of a certain educational course, a link to the schedule, availability of vacant lecture halls.

A. The method of using the AR and virtual media objects

- A vivid demonstration of the complex processes. AR allows not only seeing the object, but also understanding what it is made of, how it functions, what has been happening to it in time, how it interacts with other objects. The learners will be able to control not only the material objects themselves, but also the process, for example, the magnetic field effect or the water cycle [8]. Figure 4 demonstrates how AR works.
- Video - streaming. The screen shows certain videos, which explain the topic that is being learned.
- Educational literature with AR [9].

5. Engineering education technology improvement

The tendency of recent decades is a constant increasing complexity of different systems, above all those technological in nature. This leads to prolongation of the specialists training, and its quality decrease. Using the active industrial systems is obstructed by a number of reasons: expensive system work time, high degree of risk to one's health/life, and a high price.

One of the ways to perfect the engineering education technologies is using the AU systems and 3D educational systems. This will allow a decrease in training time, while increasing the education quality and strengthening the practical part of the educational process:

- Organization of training the learners to model, construct and use AR.
- Making the textbook vivid, by literally controlling the 3D computer models.

- Adding some change to the educational process, making it more visual and interactive.
- Increasing the level of perception due to students' involvement in the educational process, etc.

As these educational systems are rather complex, the developers must have a special training. In addition, specialists in this field are supposed to be knowledgeable in other areas, such as technical and humanities:

- Readiness to explore the objects, which are represented by complex systems, and to describe them by using adequate models [12];
- Ability to use innovative technologies of the learning systems creation, based on the ideas of the professional performance visualization made by AR and VR;
- Ability to develop and to implement the educational systems based on 3D - models, as well as on methods and technologies of their application;
- Readiness to update and/or to create new forms and methods, taking into account the conceptual features of 3D E - learning.

Today, the main problem of the engineering education is a minimum interaction of those who develop the technologies with those who implement it into the educational system. Among the reasons for this is a lack of financial support give to educational institutions and a low level of awareness about this sort of technologies. The AR technologies are mainly used in medical training. There are many programs, which model the inner structure of an organism, nerve and blood systems etc., with the help of which one can understand it easier and remember the images visually.

6. Conclusion

The analysis of AR made in this article shows new horizons in the educational area. Firstly, the implementation of AR technologies stimulates the students to study themselves, catching the audience's interest, developing an aspiration to discover new possibilities, replacing expensive laboratory equipment by multimedia models. Secondly, the real objects can be supplemented by adding context information and the visualization of the learning material, which would increase the level of material perception and interest. And finally, the professional training quality is increased by using the training equipment with AR. The process becomes more interactive and more productive.

In conclusion, it needs to be noted that the AR technologies open new horizons in the training of technical institution graduates, using the right methods and educational systems.

Acknowledgement

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