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Aspects concerning the linear association degree between the main influence factors of the car accidents with casualties that took place in the North East of Romania due to technical malfunction of the vehicles from traffic. Case study referring to the period of time 2006-2011

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I. INTRODUCTION

The statistic data of the competent bodies of UNO (UNECE and WHO) reveal that worldwide, annually, over 1,2 million people lose their lives in road accidents, and between 20 and 50 million people are hurt, the material damage registered as a consequence of these road accidents being of hundreds of million euro. The WHO studies underline the fact that the mortality through road accidents exceeds 3 times more the mortality caused by disease for the active class of population, being considered the third cause of death after heart and cancer disease. [1], [2]

Within the given international context, The General Assembly of UNO, through Resolution no. 64/255 of the 2nd of March 2010, declared the period of time 2011 – 2020 as being „the action decade for road safety", with the purpose to reduce mortality generated by the road accidents around the world. [3], [4], [5], [6], [7]

In order to apply the General Assembly Resolution of UNO. No 64/255 of 2nd March 2010, EC issued the Final Communication no. 0389 of 20th July 2010, where it was set, as a main objective, the decrease with 50%, till the year 2020, of the number of deceased people in road accidents that take place on the European roads open to public traffic. This general objective was approved by the European Union Council, through the Conclusions no. 16951/2010 and the European Parliament, through the Report no. P7-TA-0408/2011. [8]

Over the years, through different scientific research, it was shown that the road accidents have a key influence on the economic statistics of a country (for example, through the studies indicated at the bibliographic reference points [9], [10], [11]). Referring to the financial impact of the accidentologic phenomena from Romania, it is estimated that the economic and social loss owed to the road accidents are approximately 1,5 % of GDP. [12]

In conclusion, it can be stated that what it was more of a necessity (reducing mortality caused by road accidents), it has become an important, imperative and of a maximum priority objective, taken and stipulated in the strategic documents of the majority of the countries, among which also Romania.

The number of road accidents with casualties, that had as a starting point technical problems of the vehicles, underline the importance of the technical status of the national fleet and the contribution that the specialists from the domain are called to bring in order to fulfil the general strategic objective, proposed and taken by the Romanian Government, to reduce with 50%, till the year 2020, the mortality caused by the road accidents. [13]

Setting the influence of the vehicle performance and their technical characteristics that cause road accidents are, equally, elements with a major impact in road safety, that are left in the task of the domain specialists (transport/road vehicles engineers).

It is necessary to note that, according to the official statistics, Romania, Poland, Latvia, Greece, Bulgaria and Croatia are among the first European states whereas the number of the deaths caused by road accidents (fig. 1):

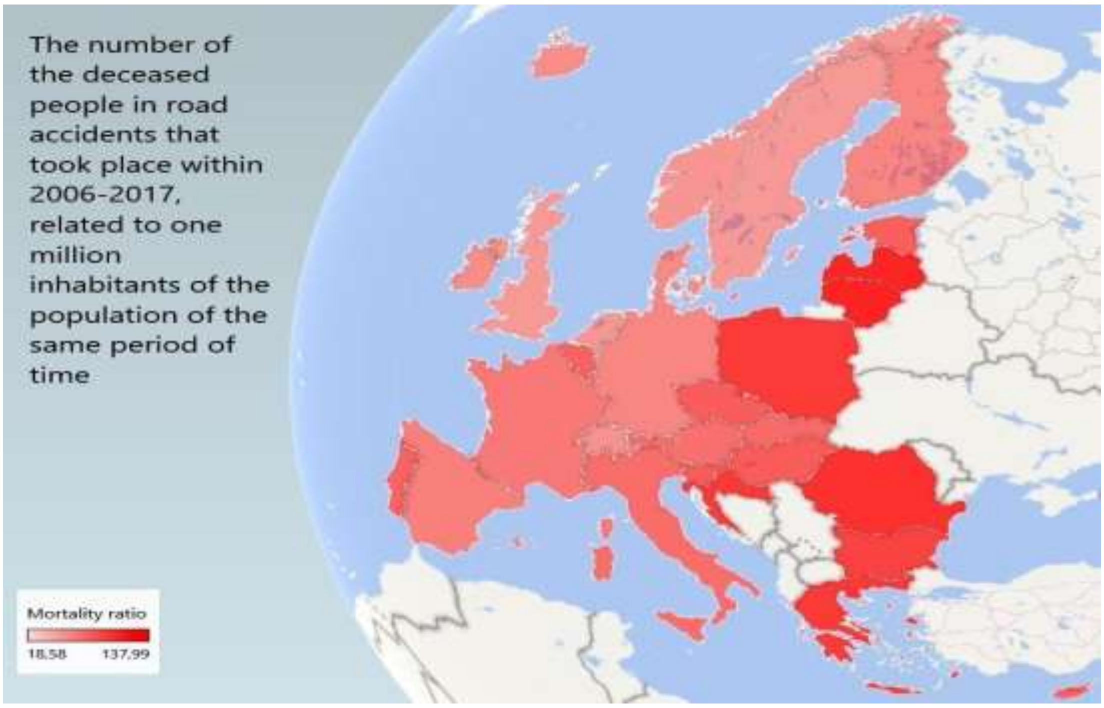

Figure 1: Distribution of the mortality ratio from some European countries calculated for the period of time 2006 - 2017 (the source of data [3])

II. BASIC ACCIDENTOLOGIC INFORMATION CONCERNING THE NORTH EASTERN REGION OF ROMANIA

The North Eastern region of Romania is a region of economic development, created in the year 1998, made of 6 counties: Bacău, Botoșani, Iaşi, Neamț, Suceava and Vaslui, having 32 municipalities and towns/cities. The great majority of the municipalities and towns are small and middle sized (with a population of 100.000 inhabitants). The total population of this region is of 3.951.765 inhabitants [14], being the most populated area of the country. With a surface of 36.850 km², the population density is of 107,23 inhabitants/ km², higher than the country average, of 93,09 inhabitants/km². 1.967.597 (49,79 %) of the inhabitants are male, and 1.984.168 (50,21 %) are female. [14], [15]

The value of the coverage ratio concerning the roads for the North Eastern region of Romania, on 31st December 2017, was of 51,1 km/100 km², superior to the country average (48,86 km/100 km²), higher in Iaşi, Botoșani, Vaslui and Bacău counties. Suceava and Neamț counties due to the predominant mountainous landform faces accessibility problems. [14], [15]

The territory of the North Eastern region of Romania is not crossed by any highway, its main road corridors being the national roads the derive from DN 1 and DN 2 (national roads 1 and 2), that have an European classification, namely: E85, E576, E574, E581 and E583. Approximately 80% of the regional roads opened to public traffic take part from the category of the county and communal roads. [15]

On the territory of the North Eastern region of Romania, between the years 2006 and 2011, the traffic of the vehicles with technical malfunctions on the public roads (main cause) generated 156 road accidents with casualties (20,49% of the total of these types of events, registered at the national level within the reference period of time). Alongside the important material damage, the human consequences due to the 156 road accidents are: 16 deceased people (16,49 % of their total at the national level), 76 seriously injured people (26,95 %) and 138 slightly injured people (18,42 %). [14], [15]

Of the 156 road accidents, 83 are minor accidents (led to 110 slightly injured people) and 73 are serious accidents (led to the death of 16 people, serious injury of 76 people and slight injury of other 28 people) [14], [15]

Compared to the other regions of Romania (fig. 2), in the North Eastern region, in the five consecutive years analyzed, took place the most road accidents that led to casualties against the backdrop of the indication of the technical malfunctions for the vehicles from traffic.

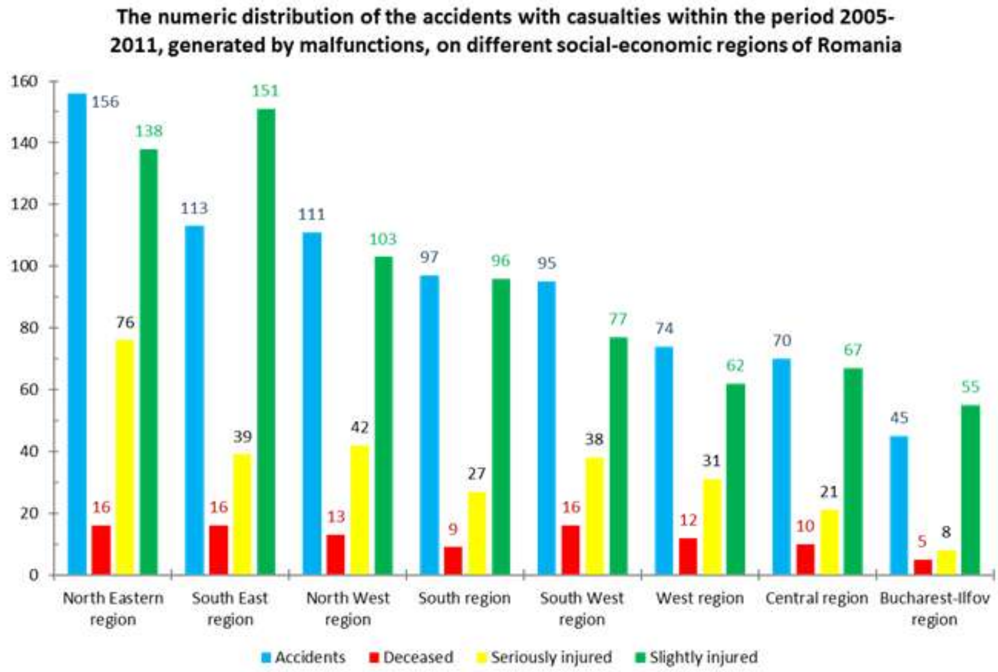

Figure 2: Distribution of the road accidents and their human consequences, that took place against the backdrop of the traffic vehicles malfunctions, depending on the region of Romania they were produced (source: [190])

III. THE MAIN INFLUENCE FACTORS OF THE ACCIDENTS ANALYZED

Within the research made, the main influence factors of the road accidents with casualties, that took place in the North Eastern region, between the years 2006 and 2011, due to the technical malfunctions of the vehicles from traffic, are structured in homogenous distinct groups and classes, such as:

- ✓ 32 continuous variables in statistics, noted with $x_1x_1 \div x_{32}x_{32}$, referring to the technical performances of the vehicles involved in the accidents that are the object of the analyses and the main accidentologic indexes (for example: overall dimensions; volume; wheel size; class and tyre load capacity; cylinder capacity; maximum power and torque developed by the engine ; the number of casualties resulted from an accident; annual average daily traffic values registered on the road the accident took place, in the year it was produced; the density of the population in the county where the accident took place; the percentage of the drivers, for the county taken into consideration, in the year the accident took place; the vehicle density in the county where the accident took place, in that particular year when it was produced etc.);
- ✓ 25 categorical variables in statistics, namely:
- ➢ basic indicators from group A, noted with $A_1A_1 \div A_3A_3$ – the main temporal and spatial characteristics of the road accident (if the road accident took place in the locality and its type; light conditions in the area of the road accident, at the time it took place and weather conditions in the area of the road accident, at the time it took place);
- ➢ basic indicators from group B, noted with $B_1B_1 \div B_{10}B_{10}$ – the main characteristics of the road factor specific to the place the road accident took place (for example: the road category; geometric configuration, inclination etc.);
- ➢ basic indicators from group C, noted with $C_1C_1 \div C_{12}C_{12}$ – the main characteristics of the vehicles involved in the road accident (for example: vehicle category, engine type, traction type, transmission type, the system/ subsystem found out-of-order at the time the road accident is investigated etc.).

The values of the each 57 variables in statistics for the road accidents analysed are presented detailed in the annexes of the Ph.D. thesis entitled ” The involvement of the vehicles' performances in the generation of the black areas that reduce the level of traffic safety”, elaborated by the first of the authors of the present article and they were obtained, with the support of the competent Romanian authorities, as a result of a laborious activity of the Ph.D. student.

IV. THE STUDY OF LINEAR CORRELATION BETWEEN THE MAIN INFLUENCE FACTORS OF THE ACCIDENTS ANALYZED

In order to make the analyses that refers to the degree of linear association between the continuous quantitative variables normally distributed, it was proceeded to the determination of the empirical correlation coefficient rr between the variables $x_1 x_1 \div x_{32} x_{32}$, using Pearson method (Karl Pearson, 1856 – 1936) according to the bibliographic source [16].

The correlation coefficient was calculated for each county within the North Eastern region and at the level of the entire region, such as:

It was defined

$$M_{m,n}(\mathbb{R}) = M = (a_{kl}) \tag{1}$$

where

$m, n \in \mathbb{N}^*$

$1 \leq k \leq m$

and

$1 \leq l \leq n$

The matrix with elements real numbers given by the value of the variables $x_1, x_2, \dots, x_{32} x_1, x_2, \dots, x_{32}$,which column is formed by the column vectors $\vec{x_1}\vec{x_1}$, $\vec{x_2}\vec{x_2}$, ..., $\vec{x_{32}}\,\vec{x_{32}}$.

At the same time, if:

$q, u \in \mathbb{N}^*$

and

$1 \leq k_1 < k_2 < \cdots < k_q \leq q$

and

$1 \leq l_1 < l_2 < \cdots < l_u \leq u$

was defined

$$M_{q,u}(\mathbb{R}) = \left(a_{k_q l_u}\right) \tag{2}$$

As being the submatrix type $(q,u)(q,u)$ of the matrix MM.

Results

$$M_{q,u}(\mathbb{R}) = M_{jud}\big|_{q=nr.accidente\ din\ judet\ \vee\ u=n=31} \tag{3}$$

where

$jud \in \{BC, BT, IS, NT, SV, VS\}$

Let $i, j \in \mathbb{N}^* i, j \in \mathbb{N}^*$, cu $1 \leq i \leq 321 \leq i \leq 32$ and $1 \leq j \leq 321 \leq j \leq 32$. Empirical correlation coefficient is determined with the relation:

$$r_{i,j} = \frac{s_{x_i x_j}}{s_{x_i} \cdot s_{x_j}} = \frac{m \sum x_i x_j - \sum x_i \sum x_j}{\sqrt{[m \sum x_i^2 - (\sum x_i)^2]\left[m \sum x_j^2 - \left(\sum x_j\right)^2\right]}} \tag{4}$$

In order to calculate the empirical correlation coefficient rr there were used the software PTC® Mathcad Prime® 4.0 and IBM® SPSS® Statistics, version 19. Its value are represented in chapter 4 and the annexes of the Ph.D. thesis previously mentioned.

The check of the statistics hypotheses concerning the correlation coefficient rr of the analysed characteristics was performed using, also, PTC® Mathcad Prime® 4.0, by applying the Student test, for different levels of significance $\alpha\alpha$. In this way, after the calculation of the test parameter, tt, further noted with $t_{calculat}$ $t_{calculat}$, to determine the trust range, respectively choosing the value of the parameter noted below with $t_{tabelat}$ $t_{tabelat}$, we use the quantiles of the Student distribution (saved in Excel format).

Let

$$t_{calculat} = (T_{i,j}) \tag{5}$$

$$T_{i,j} = \frac{\rho_{i,j}}{\sqrt{\dfrac{1-\rho_{i,j}^2}{m-2}}} \tag{6}$$

where

$\rho_{i,j} \simeq r_{i,j} \rho_{i,j} \simeq r_{i,j}$.

In PTC® Mathcad Prime® 4.0 we write and obtain:

$$\rho_{i,j} := r_{i,j}$$

$$T_{i,j} := \begin{array}{|l} \textbf{if } \rho_{i,j} \neq 1 \\ \quad \left\| \dfrac{\rho_{i,j}}{\sqrt{\dfrac{1-\rho_{i,j}^{\;2}}{m-2}}} \right. \\ \textbf{else} \\ \quad \| \; 0 \end{array}$$

After forming the trust range, it is performed the bilateral test, further noted with $TbTb$, unilateral test on the right, noted with $TudTud$ and the unilateral test on the left, noted with $TusTus$, on the empirical correlation coefficient.

For each test, respectively bilateral, superior and inferior, the null hypothesis – H_0H_0 concerning the correlation coefficient, alternative or research hypothesis– H_1H_1 concerning the correlation coefficient and their acceptance/rejection rule is set at the beginning of the test.

At the same time, for each testing procedure, the calculated value of the test from the decision table, generally, means:

✓ H_0H_0 – the data are not tied to one another; they are independent and

✓ H_1H_1 – the data are linked; are dependent.

$$t_{tabelat} := \text{READEXCEL}\left(\text{".\textbackslash Quantilele t pentru distributia Student.xlsx"}, \text{"Quantile t-Student!B1:L37"}\right)$$

$$\alpha := 0.01$$

$$t_i := \begin{array}{|l} \textbf{if } m \leq 31 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, (m-2)+1\right) \\ \textbf{else if } 32 \leq m \leq 48 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 32\right) \\ \textbf{else if } 49 \leq m \leq 72 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 33\right) \\ \textbf{else if } 73 \leq m \leq 95 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 34\right) \\ \textbf{else if } 96 \leq m \leq 800 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 35\right) \\ \textbf{else if } 801 \leq m \leq 1000 \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 36\right) \\ \textbf{else} \\ \quad \| \text{hlookup}\left(1-\alpha, t_{tabelat}, 37\right) \end{array} = [2.364]$$

$$t_{iii} := -1 \cdot t_i = [-2.364]$$

$$t_{II} := \left\| \begin{array}{l} \textbf{if}\ m \le 31 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, (m-2)+1\right) \right. \\ \textbf{else if}\ 32 \le m \le 48 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 32\right) \right. \\ \textbf{else if}\ 49 \le m \le 72 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 33\right) \right. \\ \textbf{else if}\ 73 \le m \le 95 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 34\right) \right. \\ \textbf{else if}\ 96 \le m \le 800 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 35\right) \right. \\ \textbf{else if}\ 801 \le m \le 1000 \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 36\right) \right. \\ \textbf{else} \\ \quad \left\| \text{hlookup}\left(1 - \frac{\alpha}{2}, t_{tabelat}, 37\right) \right. \end{array} \right\| = [2.626]$$

$$t_{IV} := -1 \cdot t_{II} = [-2.626]$$

The bilateral test – $TbTb$:

$$H_0 = \left(\rho_{i,j} \leftarrow 0\right)$$

$$H_1 = \rho_{i,j} \neq 0$$

$$Tb_{i,j} := \left\| \begin{array}{l} \textbf{if}\ \det(t_{IV}) \le T_{i,j} \le \det(t_{II}) \\ \quad \left\| \text{"H0"} \right. \\ \textbf{else} \\ \quad \left\| \text{"H1"} \right. \end{array} \right\|$$

Unilateral test on the right – $TudTud$:

$$H_0 = \left(\rho_{i,j} \leftarrow 0\right)$$

$$H_1 = \rho_{i,j} > 0$$

$$Tud_{i,j} := \left\| \begin{array}{l} \textbf{if}\ T_{i,j} < \det(t_I) \\ \quad \left\| \text{"H0"} \right. \\ \textbf{else} \\ \quad \left\| \text{"H1"} \right. \end{array} \right\|$$

Unilateral test on the left – $TusTus$:

$$H_0 = \left(\rho_{i,j} \leftarrow 0\right)$$

$$H_1 = \rho_{i,j} < 0$$

$$Tus_{i,j} := \left\| \begin{array}{l} \textbf{if}\ T_{i,j} > \det(t_{III}) \\ \quad \left\| \text{"H0"} \right. \\ \textbf{else} \\ \quad \left\| \text{"H1"} \right. \end{array} \right\|$$

The results of the check of the statistics hypotheses concerning the correlation coefficient rr of the analysed characteristics are presented, also, in chapter 4 and the annexes of the Ph.D. thesis mentioned previously.

The calculation of the frequency for the nominal/qualitative variables (some of them, dichotomous), measured in the same pattern mm with quantitative variables $x_1 \div x_{32} x_1 \div x_{32}$, was performed with the software IBM® SPSS® Statistics, its results can be found in chapter 4 and the annexes of the Ph.D. thesis mentioned previously.

The association between the categorical variables was studied taking into account the size of the pattern and the fact that the contingency table is multidimensional, with dichotomous nominal variables and more than two categories, that are not ordinal. In this way, there were applied two tests with the help of the software IBM® SPSS® Statistics, respectively the contingency coefficient $\chi^2 \chi^2$ and the contingency coefficients $\varphi\varphi$ Pearson and vv Cramer, their results being detailed presented in the Ph.D. thesis mentioned above.

V. CONCLUSIONS

The identification process of some new improvement solutions of the road safety under the specific conditions from Romania, brought into the researcher's attention, from this country, the issue of setting a way of efficient check of the link between the main influence factors of the road accidents with casualties. The purpose of taking this check is the one of understanding the real situation, present in each administrative-territorial area of the country and to rapidly identify the most efficient, but also reasonable, measures, necessary for the decrease of the number of road accidents with casualties.

The mathematic model presented previously, for highlighting the dependency between the statistic variables discussed, is a real success.

For example, its implementation within the context of the ones that precede it made possible the observation of the fact that among the obtained results, referring to the high linear associations, it is interesting the solid and direct link that exists between the density of the vehicles, $x_{27} x_{27}$ (expressed in $veh./km^2$ $veh./km^2$) and the density of the accidents with casualties, $x_{32} x_{32}$ (expressed in $nr.acc./km^2 nr.acc./km^2$) registered in the North Eastern region of Romania, within the period of time 2006 – 2011 (fig. 3).

Interpreting this dependency in order to give relevance to the idea of contribution of some qualitative explanations to the scientific approach, we can affirm that, practically in the analyzed region, the increase of the fleet between 2006 and 2011 called for the increase of the road risk, fact that was proved through the increase of the number of road accidents with casualties.

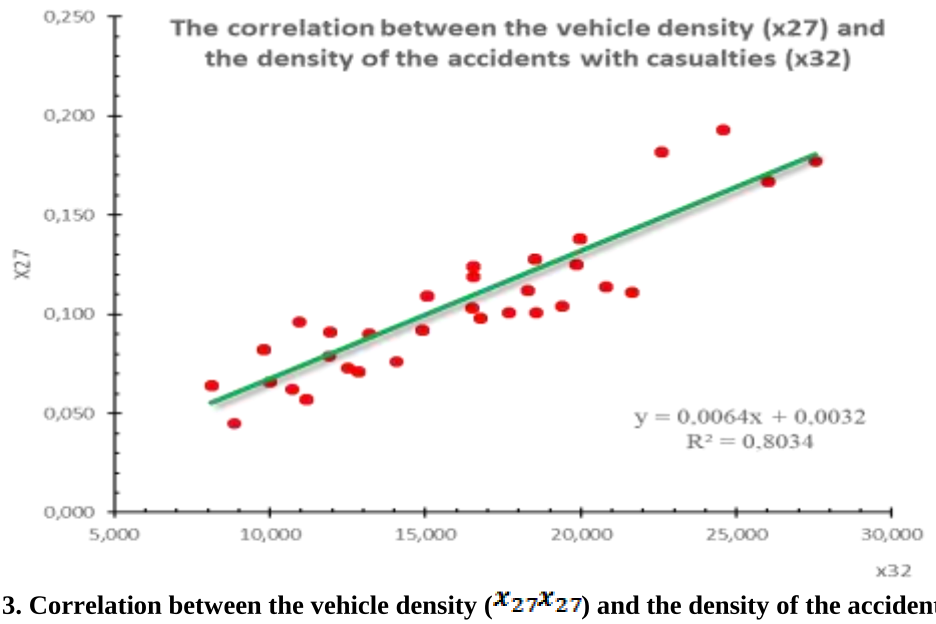

Figure 3. Correlation between the vehicle density ($x_{27} x_{27}$) and the density of the accidents with casualties ($x_{32} x_{32}$) in the North Eastern region, in the period of time 2006 – 2011

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