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Model for Sustainable Evaluation of the Impact of the Total Number of Centers for Technical Inspections of Motor Vehicles on the Occurrence and Consequences of Traffic Accidents in an Area

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Abstract: Along with the development of capacities for the improvement of traffic safety, this work creates a model that analyzes the impact of the total number of centers for technical inspections of motor vehicles on the occurrence and consequences of accidents in a selected area. By using the statistical program SPSS26 and applying standard multiple regression, an analysis of the statistical correlations between a continuous dependent variable (number of accidents caused by technical malfunctions of vehicles) and two independent variables (number of centers for technical inspections of vehicles and number of vehicles registered by police jurisdictions) was performed. The aim of this work was to determine the influence of a part of the dependent variable's variance that was explained by the variance of independent variables. The research results showed that the total number of technical inspections in relation to the number of registered vehicles in the selected area included a much larger part of the dependent variable's variance, which referred to the total number of accidents caused by vehicles' technical inspections. The results also showed a negative correlation value, i.e., that a larger number of technical inspections in relation to the number of registered vehicles did not have a positive impact on the increase in the number of accidents and consequences where the cause was technical malfunction, as well as that the number of centers and the number of registered vehicles had different influences on the occurrence of accidents and their consequences.

Keywords: center; vehicle malfunction; traffic accidents; consequences

1. Introduction

The issue of road traffic safety is a very broad social aspect that depends primarily on the behavior of the driver and the technical characteristics of the vehicle, as well as the state of road safety and the materials used in the surface layer of pavement infrastructures [1].

Vehicle safety represents one of the basic pillars of traffic safety defined by the Global Plan for Traffic Safety Improvement [2]. In the professional literature, it is stated that the vehicle, as a factor of traffic safety, affects about 13% of traffic accidents [3].

Researchers who compared the average age of the fleet and the percentage of technical defects of vehicles in EU countries came to the conclusion that these variables have no mutual impacts and that the value of an impact is a separate factor in each state [4].

Technical inspection of a vehicle (TIV) is key to the sustainable state of traffic safety [5]. More than five individuals die every day in traffic accidents caused by technical malfunctions of motor vehicles in the territory of the European Union [6].

The examination of the impact of TIV on the occurrence of traffic accidents and the state of traffic safety in recent scientific research has been the research subject of a large number of researchers. Research one the impact of TIV on traffic safety generally goes in two directions [7]. In the first, the control of TIV is related to the state of mechanical correctness of vehicles with respect to their participation in traffic; in the second, the representation of TIV is analyzed within the total number of traffic accidents.

In order to ensure that vehicles on the roads are safe and technically correct, they must pass appropriate inspections immediately before their annual registration. The inspections can be performed only by authorized stations for the control of the technical correctness of vehicles in accordance with the provisions of the Law on Road Traffic Safety [8]. The criteria for their authorization are defined by the Rulebook on Technical Inspection of Vehicles [9].

The main motive for the creation of this study was the subject of an expert dilemma, which is reflected in whether a higher capacity of centers in a certain area can provide a better state of traffic safety from the perspective of accidents caused by technical malfunction of vehicles. The specific goal was to see how the greater representation of centers in relation to the number of registered vehicles in a certain area has an impact on the number and consequences of accidents where the cause is vehicle malfunction. In addition, this model is sustainable, and the key goal is to come to a conclusion on whether the number of centers and the number of registered vehicles have the same or different impacts on the occurrence of accidents where the cause is technical malfunction of a vehicle.

2. Review of Previous Research

In the previous century, some of the first studies [10–12] on the impact of TIV on traffic safety were conducted. The conclusions of these studies and research are generally divided. A first group of researchers [12–24] came to the conclusion that TIV has an impact on the state of traffic safety. Another group of researchers [25–27] came to the conclusion that TIV has no impact on the occurrence of traffic accidents and the state of traffic safety. A certain number of researchers [12,14,28,29] also analyzed the state of traffic safety before and after the mandatory introduction of TIV control, and after that, they made conclusions about the possible impacts of introducing a new TIV control program.

A decent number of studies that analyzed the effects of TIV control on the state of traffic safety included the following four segments:

- Comparative studies between countries where technical inspection of vehicles is not or is mandatory;
- Studies before and after the introduction of mandatory TIV control;
- Analyses that compare data on accidents before and after mandatory introduction of TIV control;
- Analysis of representation of vehicles that have attended periodical technical inspections within the total number of traffic accidents.

There are different methodologies that have been used in research on the impact of TIV on traffic safety. The first group of authors [4] focused their research on the connection between the age of a vehicle and the percentage of participation in the total number of accidents based on a data frequency analysis. They concluded that there is a significant correlation between the increase in the age of the vehicle and the increase in the percentage of traffic accidents where the cause is a malfunction of the vehicle.

A very important study [30] was carried out in Slovakia, where the researchers analyzed the connection between periodic TIV and traffic accidents where the cause was a malfunction of a device on the vehicle. In their research, they applied Pearson's correlation coefficient and regression analysis for the purposes of linking dependent and independent variables. They concluded that, at the end of the validity period of the technical inspection of a vehicle, the percentage of participation in traffic accidents where the cause is a malfunction of the vehicle increases significantly. Another very important conclusion is that, with the increased number of vehicles declared as temporarily defective during technical inspections, the number of traffic accidents caused by defective devices on vehicles decreases.

In a study of the impact of TIV on the safety of freight vehicles in Norway [30], researchers used multiple regression analysis for the purposes of the work. Based on the obtained results, it was concluded that the impact of the inspection was relative; in the largest scope of application, it could contribute to a reduction of accidents in the range of 5–10%.

By applying negative binomial regression, the authors [21] assessed the impact of the period of TIV inspection on the occurrence and consequences of accidents. The conclusion of the research was that TIV control has very significant effects on reducing the failure of key devices on vehicles.

3. The Presence of Centers for the Control of the Technical Correctness of Vehicles in Serbia and Other Countries in the Region

The regulations of EU member states and of the Republic of Serbia do not define the maximum number of authorized TIV control centers. The EU directives provide basic guidelines that the centers must meet, but not the minimum and maximum numbers that may be authorized to operate.

In the territory of the Republic of Serbia, a total of 1196 centers for the control of the technical correctness of vehicles have been authorized in a total of 29 police jurisdictions, and a total of 2,357,699 vehicles have been registered.

Based on the data shown in Table 1, according to the number of authorized centers for the control of TIV, Serbia is a countries with a very large presence thereof per 100,000 registered vehicles [31].

Table 1. Total number and presence of TIV control centers with respect to the total number of registered vehicles by country [28].

State	Number of TIV Control Centers	Number of Registered Vehicles	Presence of Centers per 100,000 Vehicles
Sweden	550	5,804,296	9.475740038
Croatia	168	1,893,119	8.874244039
Estonia	128	871,642	14.68492799
France	6791	38,513,225	17.63290402
Germany	92,500	53,638,471	172.4508516
Lithuania	69	817,192	8.44354815
Portugal	221	6,360,765	3.474424853
Slovakia	157	2,714,784	5.783148862
Spain	470	33,656,638	1.396455582
Serbia	1196	2,357,699	50.72742534

Germany is the only state that has a total number of TIV control centers that is three times greater than that of Serbia, whereas the other countries certainly have less representation. An analysis of the available literature and research led to the conclusion that studies of this type have not been conducted in Serbia or in the surrounding countries so far. Research of this type is essential because it analyzes the impact of an increased capacity of institutions in charge of improving vehicle safety as one of the essential elements of traffic safety management. The answer of this study should be focused on whether larger numbers and capacities of TIV control centers mean greater traffic safety from the perspective of vehicles in the selected area.

4. Research Methodology

Before beginning to develop the model and analyzing the collected data, the initial hypotheses were defined:

Hypothesis 1. *The presence of a larger number of TIV control centers in comparison with the number of registered vehicles in the selected area does not have a greater impact on the occurrence of traffic accidents and consequences where the cause is a technical malfunction of a vehicle.*

Hypothesis 2. *The total number of TIV control centers and the number of registered vehicles in the selected area, as independent variables, have different shares and representations in the continuous dependent variable, which is related to the number of traffic accidents where the cause is a technical malfunction of a vehicle.*

4.1. Research Tools

For the purposes of the research, statistical data on traffic accidents kept by the Traffic Safety Agency of the Republic of Serbia were used, in addition to data from police administrations in the Republic of Serbia. The data on the total number of registered vehicles were taken from the annual bulletin of the Republic's Bureau of Statistics, and the data on the number of centers were taken from the website of the Ministry of Internal Affairs of the Republic of Serbia.

A special database containing the data entered into the statistical program SPSS26 was created. For the purposes of proving Hypothesis 1, the Pearson correlation method was used, and for the purposes of proving Hypothesis 2, the method of standard multiple regression was used.

4.2. Materials and Methods of Data Analysis

In this segment of the work, the theoretical model created for the purpose of data collection and processing, as well as for proving the set hypotheses, is presented.

Figure 1 shows the structure of the model, which includes the following segments:

1. Data on traffic accidents from the Traffic Safety Agency.
2. Data on the total number of centers for the control of the technical correctness of vehicles by police jurisdiction and from the RS Ministry of the Interior.
3. Data on the total number of vehicles registered by police administrations from the Republic's Bureau of Statistics.
4. Summarized database for the purpose of conducting analyses and statistical comparisons.
5. Entry of data into SPSS and analysis thereof using Pearson's correlation.
6. Entry of data into SPSS and analysis thereof using standard multiple regression.
7. Analysis and generation of reports for data obtained with Pearson's correlation method.
8. Analysis and report generation for data obtained with the method of standard multiple regression.
9. Final conclusions and sustainable impact assessment.

Based on the research model from Figure 1, it was concluded that the entire research process of drawing conclusions had two directions depending on the research technique applied and the proof of the defined hypotheses.

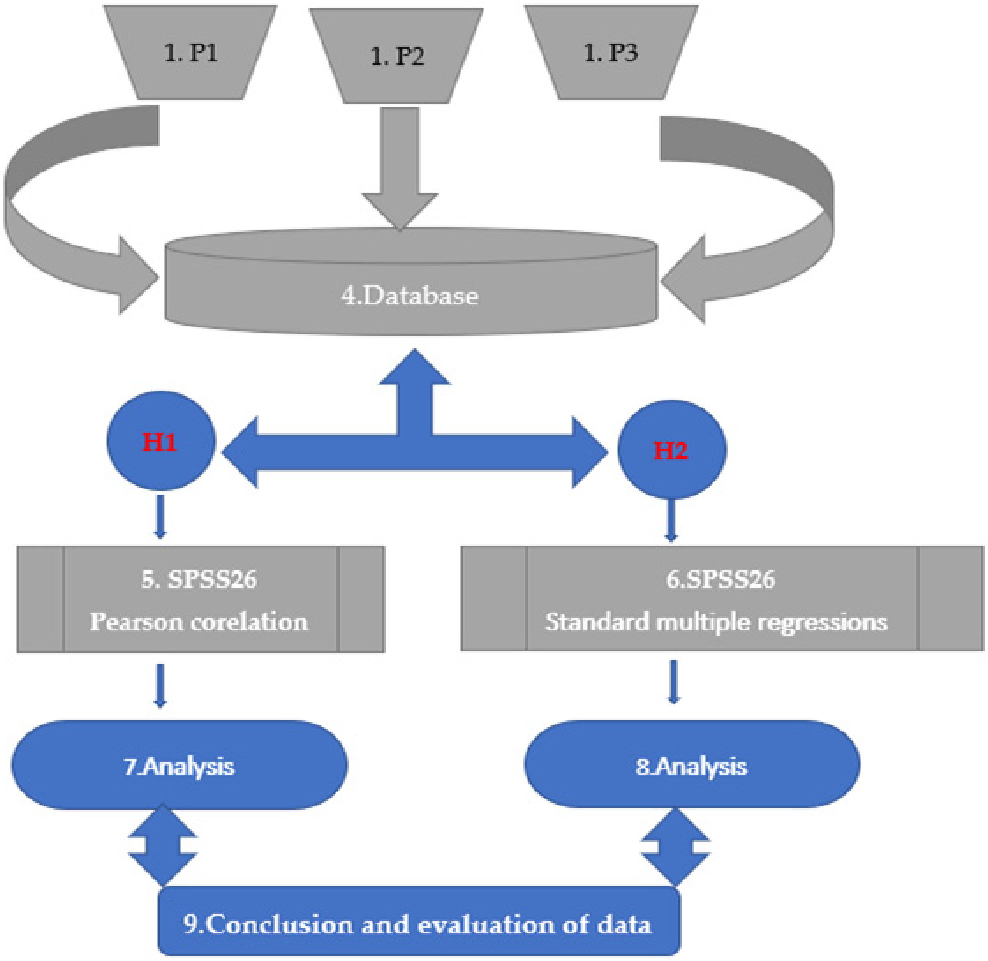

Figure 1. Research model.

5. Research Results and Discussion

Table 2 provides data on the basis of which a comparative analysis was performed to compare the coefficient of TIV control centers' presence in relation to 100,000 registered vehicles and the consequences of accidents where the cause was technical malfunction of a vehicle.

The data on traffic accidents and consequences were related to the period 2018–2020 by police jurisdiction in the Republic of Serbia. In order to determine whether the greater representation of TIV control centers in the number of registered vehicles did or did not have an impact on accidents where the cause was technical malfunction of a vehicle, SPSS26 and Pearson's correlation method were used; the results of analysis are shown in Tables 3–5.

When the data obtained in the previous three tables were systematized, it was concluded that a negative value of Pearson's correlation coefficient was present in all three analyzed cases. In the analysis of the representation of centers in relation to the total number of accidents (TAtotal) where the cause was vehicle malfunction, the correlation value was obtained ($p = -0.224$; Sig. 0.263). In addition, in the analysis of centers' representation in relation to the total number of accidents with casualties (TAcas), the correlation value was obtained ($p = -0.210$; Sig. 0.294). Finally, in the analysis of the impact of the representation of the centers in relation to the number of accidents with only material damage (TAmd), the correlation value was obtained ($p = -0.223$; Sig. 0.263).

Table 2. Total number of TIV control centers, consequences of accidents where the cause was vehicle malfunction, and representation of centers with respect to the total number of vehicles registered by police administrations in Serbia.

Police Administration	Total Traffic Accidents	Total Traffic Accidents with Casualties	Total Traffic Accidents with Material Damage	Number of Registered Vehicles (2017)	Number of TIV Centers	TIV Centers' Representation per 100,000 Vehicles
Belgrade	240	141	99	661,007	255	3.857750
Bor	28	11	17	53,312	20	3.751501
Čačak	25	16	9	75,247	35	4.651348
Jagodina	39	28	11	74,436	42	5.642431
Kikinda	30	12	18	42,446	21	4.947463
Kragujevac	29	15	14	98,792	49	4.959916
Kraljevo	31	14	17	63,598	34	5.346080
Kruševac	32	15	17	75,785	43	5.673946
Leskovac	46	31	15	59,311	40	6.744112
Niš	84	45	39	108,880	40	3.673769
Novi Pazar	16	9	7	28,204	25	8.863991
Novi Sad	162	101	61	132,533	101	7.620744
Pančevo	53	42	11	85,191	41	4.812715
Pirot	4	2	2	24,094	14	5.810575
Požarevac	148	60	88	72,297	35	4.841141
Prijepolje	2	2	0	10,272	14	13.629283
Prokuplje	6	4	2	24,349	14	5.749723
Šabac	73	37	36	99,912	72	7.206342
Smederevo	61	35	26	57,226	32	5.591864
Sombor	28	15	13	53,312	29	5.439676
Sremska Mitrovica	98	39	59	100,272	58	5.784267
Subotica	20	12	8	62,864	29	4.613133
Užice	71	37	34	89,960	29	3.223655
Valjevo	43	29	14	60,374	36	5.962832
Vranje	40	25	15	53,504	32	5.980861
Zaječar	74	31	43	36,801	29	7.880221
Zrenjanin	47	35	12	53,720	27	5.026061

Table 3. Values of Pearson's correlation coefficient between the presence of technical inspections and the total number of traffic accidents by police jurisdiction in Serbia.

Correlations			
		Presence/ Representation	Total Traffic Accidents
Presence/Representation	Pearson Correlation	1	−0.224
	Sig. (2-tailed)		0.261
	N	27	27
Total Traffic Accidents	Pearson Correlation	−0.224	1
	Sig. (2-tailed)	0.261	
	N	27	28

In all three cases, the values of the correlations and statistical significance were approximately the same, which told us how confidently we could observe the obtained values. Precisely because of that, it could be concluded that the greater representation of centers in relation to the number of registered vehicles in the selected area (police jurisdiction) did not have a direct impact on the total number of traffic accidents and the consequences of these accidents. Then, in order to determine whether the total number of TIV control centers had an impact on the total number of accidents caused by the technical malfunction of vehicles that was independent from the total number of registered vehicles, data analysis was performed by using standard multiple regression. Essentially, a research question was asked that should tell us how much of the variance of the dependent variable was explained by the variance of the independent variables.

Table 4. Values of Pearson's correlation coefficient between the presence of technical inspections and traffic accidents including lightly and seriously injured individuals by police jurisdiction in Serbia.

Correlations			
		Presence/ Representation	**Total Traffic Accidents with Casualties**
Presence/Representation	Pearson Correlation	1	−0.210
	Sig. (2-tailed)		0.294
	N	27	27
Total Traffic Accidents with Casualties	Pearson Correlation	−0.210	1
	Sig. (2-tailed)	0.294	
	N	27	28

Table 5. Values of Pearson's correlation coefficient between the presence of technical inspections and the consequences of traffic accidents with only material damage by police jurisdiction in Serbia.

Correlations			
		Presence/ Representation	**Total Traffic Accidents with Material Damage**
Presence/Representation	Pearson Correlation	1	−0.223
	Sig. (2-tailed)		0.263
	N	27	27
Total Traffic Accidents with Material Damage	Pearson Correlation	−0.223	1
	Sig. (2-tailed)	0.263	
	N	27	28

Within that process, the following variables were defined:

- The number of traffic accidents where the cause was technical malfunction of vehicles according to the police administrations in Serbia (TAtmv) was considered as a continuous dependent variable.
- The total number of TIV control centers by police jurisdiction in Serbia (Ntp) and the total number of registered vehicles in the area of these police jurisdictions (NVehicles) were considered as two independent variables.

The aim of the analysis was to determine and evaluate the contribution of each independent variable. The values of both independent variables were entered into the model defined in Figure 1 at the same time, and the results shown below show the ability of this set of variables to predict the impact on TAtmv.

Considering the results and correlation values from Table 6 (p = 0.786, p = 0.883; Sig. for all three cases was less than 0.005), it was concluded that there was a very large value between the number of TIV control centers and the number of registered vehicles with the total number of accident, but the stated value could not be considered very reliable because the statistical significance was very small (Sig. < 0.005). The total number of accidents where the vehicle's technical malfunction was caused was more closely correlated with the total number of centers, and there was a slightly smaller statistical correlation with the total number of registered vehicles. Table 7 provides the values of the descriptive statistics and the values of the determination coefficient.

Table 6. Values of Pearson's correlation coefficient between Ntp, NVehicles, and Tatmv.

Correlations				
		TAtmv	**NVehicles**	**Ntp**
Pearson Correlation	TAtmv	1.000	0.786	0.833
	NVehicles	0.786	1.000	0.972
	Ntp	0.833	0.972	1.000
Sig. (1-tailed)	TAtmv		0.000	0.000
	NVehicles	0.000		0.000
	Ntp	0.000	0.000	
N	TAtmv	27	27	27
	NVehicles	27	27	27
	Ntp	27	27	27

Table 7. Values of the descriptive statistics and determination coefficient for the observed values.

Descriptive Statistics				
	Mean	**Std. Deviation**	**N**	
TAtmv	56.6667	53.35296	27	
NVehicle	87,322.1852	118,140.75700	27	
Ntp	44.2963	45.90443	27	
Model Summary [b]				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.839 [a]	0.704	0.679	30.23627

[a] Predictors: (Constant), Ntp, NVehicle. [b] Dependent variable: TAtmv.

As shown in Table 7, the value of R Square, which was 0.704 (determination coefficient) was taken into account indicated how much of the variance of the dependent variable explained the model (which included two variables, i.e., the number of registered vehicles and the number of technical inspections). When the same was expressed in percentages, we found that the presented model explained 70.4% of the total number of accidents where the cause was technical malfunction of a vehicle. In addition to this indicator, the important data were found in the adjusted determination coefficient (adjusted R Square), which was 0.679. These data gave a better estimate of the actual value of the determination coefficient in the total number of traffic accidents. It is specifically used for small samples to obtain more optimistic results.

In order to assess the statistical significance of the determination coefficient, it was necessary conduct an ANOVA, which is shown in Table 8. It provided the results of the null hypothesis, where $R^2 * = 0$. In our case, the model reached statistical significance (Sig. = 0.000, which means that p is less than 0.0005).

Table 8. Estimation of the statistical significance of the coefficient R.

ANOVA [a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	52,068.426	2	26,034.213	28.477	0.000 [b]
	Residual	21,941.574	24	914.232		
	Total	74,010.000	26			

[a] Dependent variable: TAtmv. [b] Predictors: (Constant), Ntp, NVehicle.

The next step was to know how much each independent variable in the model contributed to the prediction of dependent variable. This information can be found in Table 9.

Table 9. Results of the evaluation of independent variables.

Coefficients [a]													
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	9.429	9.551		0.987	0.333	−10.283	29.141					
	NVehicle	0.000	0.000	−0.411	−0.876	0.390	−0.001	0.000	0.786	−0.176	−0.097	0.056	17.799
	Ntp	1.432	0.545	1.232	2.628	0.015	0.307	2.557	0.833	0.473	0.292	0.056	17.799

[a] Dependent variable: TAtmv.

In this table, one can observe the values of the standardized Beta coefficients. In order to be able to compare different variables, it was necessary to observe the standard coefficients exclusively. Standardized means that the variables values have been converted to the same scale so that they can be compared.

In our case, we wanted to compare the impacts of both independent variables. In this regard, we observed the Beta values and analyzed the highest value regardless of the sign. We found the highest coefficient for Ntp, which was 1232. This actually meant that this variable individually contributed the most to the explanation of the dependent variable when the variance explained by the other variables in the model was subtracted. The coefficient was significantly lower for NVehicle, and it was 0.411.

The Sig. column was observed for each of the variables. It told us whether the variable made a statistically significant and unique contribution to the prediction of the dependent variable. In this case, the values were compared in relation to 0.05, so we had the case with NVehicle in which the value was 0.390; there, we could conclude that this variable did not provide a significantly unique contribution to the prediction of the dependent variable. On the contrary, for Ntp, we had a value of 0.015, which was less than 0.05; here, it was clear that this variable made a significantly unique contribution to the prediction of the dependent variable.

The data in the Part column of the previous table, where the correlation coefficients are presented, were particularly important. When these coefficients were squared, the contribution of each variable to the total R^2 was obtained. In our case, for the variable Ntp, it amounted to 29.2 percent of the variance in the total number of traffic accidents where the cause was technical malfunction of a vehicle.

Finally, in order to check all previous assumptions, it is necessary to look at Figure 2 (normal P-P plot) and Figure 3 (scatterplot).

The values in Figure 2 clearly show that the points lie approximately on a straight diagonal line from the lower left to the upper right corner of the diagram. This indicates that there are no significant deviations compared to the normality.

In Figure 3, which shows the scattering of the standardized residues, it can be seen that all residues are approximately rectangular and that most of them are accumulated in the center (around point 0). It can also be concluded that there are not many atypical points.

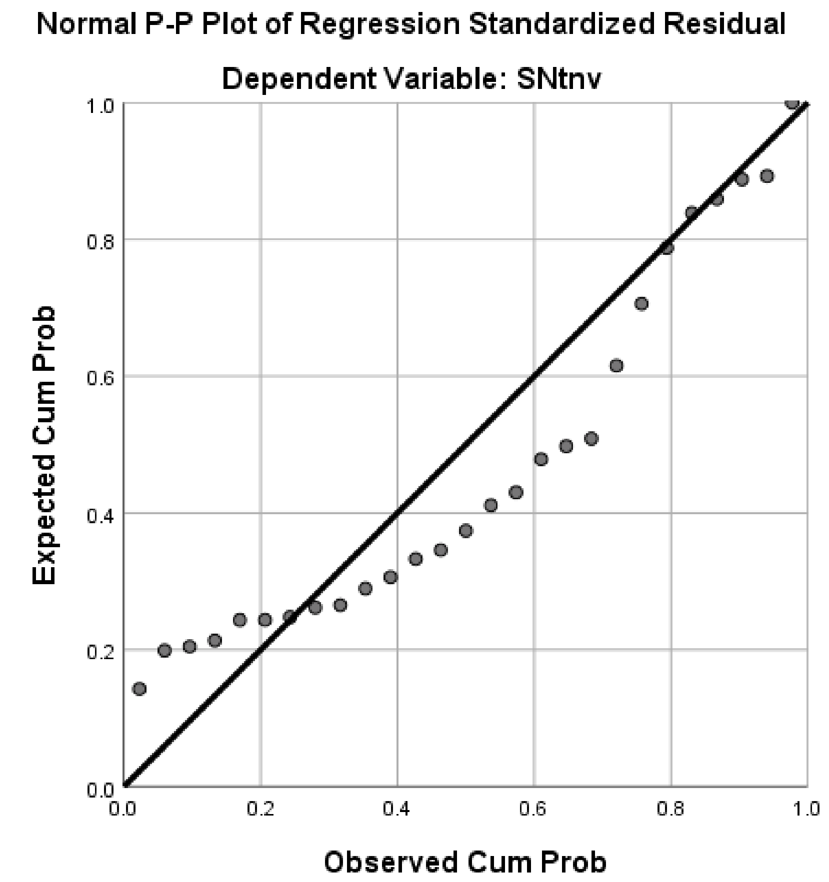

Figure 2. Normal P-P plot for the standard regression analysis.

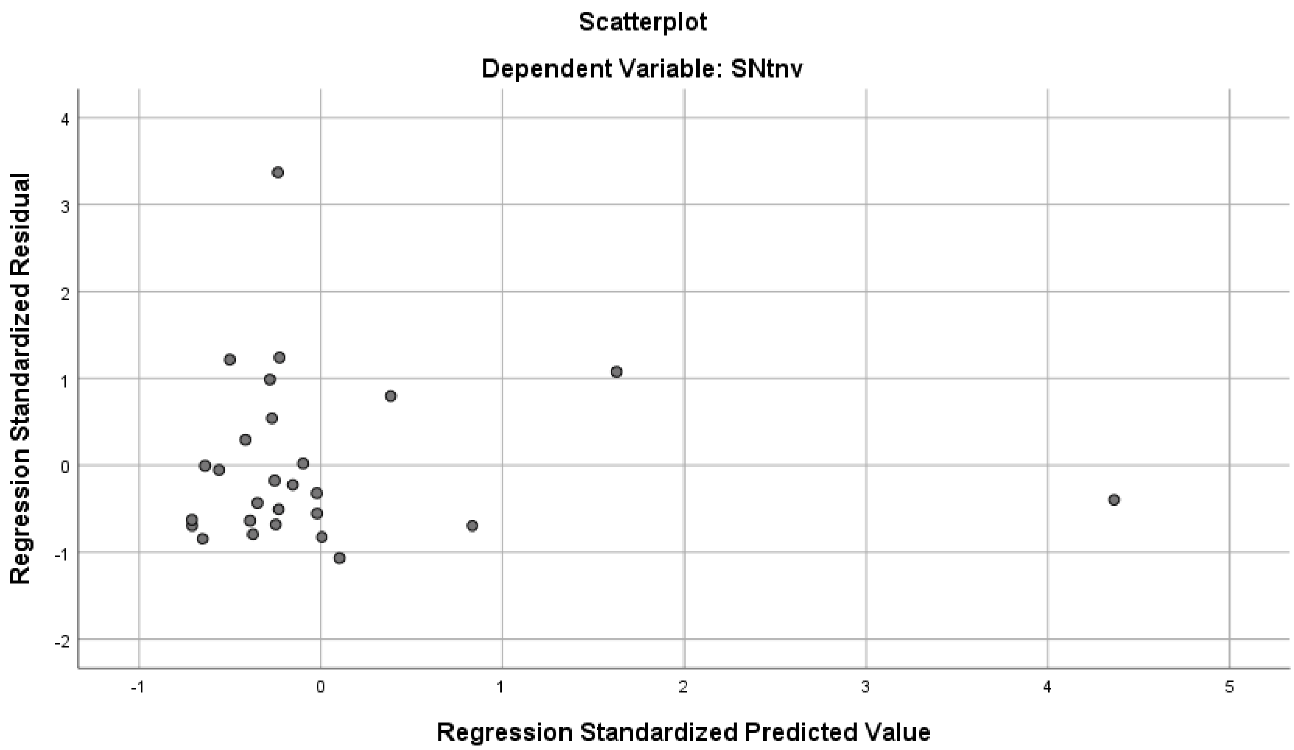

Figure 3. Scattering of the standardized residues—scatterplot.

6. Conclusions

The specificity of the entire research model in this work was focused on researching the impact of the number of TIV control centers in relation to the number of registered vehicles, as well as the number and consequences of traffic accidents where the cause was technical malfunction of vehicles, in Serbia and the surrounding countries [32]. research of this type has not been performed so far in the territory of the Republic of Serbia or in the surrounding countries. This representation in the form of a value was obtained by finding the number of centers per 100,000 vehicles registered by police administrations in the Republic of Serbia. These data has enabled statistical analyses, through which two hypotheses were tested with the help of statistical program SPSS26 and by using the methods of Pearson's correlation and standard multiple regression, which were textually processed [33]. The specific goal of this work was to improve sustainability and reliability within vehicle controls through an investigation of whether the number of centers for TIV control had an impact on traffic safety and the consequences in the defined area. This type of research model is useful for predicting the success of public services, as described in [34].

By applying the defined model and analyzing the data using Pearson's correlation coefficient, Hypothesis 1 was proved, i.e., it was confirmed that the presence of a larger number of TIV control centers with respect to the number of registered vehicles in the selected area did not have a greater impact on the accidents and consequences caused by technical malfunctions. This was exactly the case with TAtotal ($p = -0.224$; Sig. 0.263), TAcas ($p = -0.210$; Sig. 0.294), and TAmd, for which the correlation values were obtained ($p = -0.223$; Sig. 0.263). Precisely because of this, the contribution of this study is unique because it shows that higher capacities and numbers of centers do not result in higher numbers of accidents where the cause is technical malfunction of vehicles.

When it comes to Hypothesis 2, which indicated that the total number of TIV control centers and the number of registered vehicles in the selected area, which served as independent variables, had different shares and representations in the continuous dependent variable in relation to the number of accidents where the cause was technical malfunction of a vehicle, the following conclusions could be drawn:

- The results of the analysis of the defined model, which included the total number of registered vehicles and the number of centers for the control of the technical correctness of vehicles, explained 67.9% of the variance in the total number of accidents where the cause was technical malfunction of vehicles.
- Out of the two independent variables, the largest unique contribution (beta = 1.232) was provided by the number of technical inspections, and the number of registered vehicles (beta = −0.411) provided significantly less.

Based on that, it is possible to confirm the justification of Hypothesis 2 on the difference in impact of the total number of centers and the number of vehicles registered by police administrations in Serbia.

If we take the relationship between the number of TIV centers, the number of registered vehicles, and the number of traffic accidents, we can conclude that these three variables are not strongly dependent among themselves.

So, regardless of the fact that Serbia a country with a significantly larger number of centers in relation to the number of registered vehicles, this capacity and these statistical data do not have a significant impact on accidents where the cause is vehicle malfunction, which is in accordance with the conclusions of other researchers [12,14,28,29]. This conclusion can be especially important for decision makers who create policies for improving traffic safety in selected areas, i.e., a larger number of centers will not provide a better state of traffic safety in terms of accidents where the cause is vehicle malfunction. Finally, the number of TIV control centers should not be associated with larger number of registered vehicles because, statistically, there is no significant impact on the reduction of the number of accidents where the cause is vehicle malfunction.

Future research on this topic should focus on more detailed analyses of the causes of accidents related to vehicle malfunctions because, in our research, technical correctness was considered as a group of causes. Thus, preventive and repressive measures must be directed by the competent authorities in order to improve vehicle safety. It is especially necessary that future research be reduced to the micro level, i.e., the level of local self-governments, in order to define the activities and measures needed to improve vehicle safety on the roads in more detail.

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