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ORIGINAL SCIENTIFIC PAPER

The Impact of the Age of the Vehicle Fleet on Traffic Safety - Vehicle as the Third Pillar of Traffic Safety

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Abstract: Traffic accidents are, today, accepted as a global problem and activities are being undertaken to adapt and transfer successful practices from the most developed countries to underdeveloped and developing countries. The impact of a road transport system is so significant that its safety or lack of safety affects a wide range of social needs. Road safety or mobility without risk of death or injury affects health, poverty, equality, the environment, employment, education, gender equality and the sustainability of communities. Many nations around the world have improved the effect of pillar interventions by applying them selectively and strategically in accordance with the principles of the safe system approach. The safe system approach addresses problems closer to their root cause and on a broader level than conventional methods. The five pillars of road safety identified in the Global Plan for the Decade of Action 2011-2020 include a set of evidence-based interventions that can measurably improve road safety. Preparation and adoption of strategic documents- a traffic safety system development policy and strategy is a great way to demonstrate traffic safety management. The most important common denominator for all successful traffic safety practices is science-based strategic traffic safety management, which has clear, honest and publicly expressed political support. The paper presents the analysis of the third pillar „safer vehicles" and its influence on the approach of the safe system from different aspects.

Keywords: traffic safety, motor vehicles, road traffic, decade of traffic safety, critical headway.

INTRODUCTION

Numerous characteristics of the vehicle affect the occurrence of the accident, and especially the severity of the consequences (vehicle weight, vehicle construction, vehicle equipment, vehicle age, technical correctness of the vehicle, etc.). Crash tests (NCAP - New Car Assessment Program) are a good way to research the safety characteristics of vehicles and the basis for further improving the safety properties of vehicles. Fleets are being renewed at both the national and local levels, reducing vehicle age and improving performance in terms of vehicle safety. Vehicle characteristics represent the third pillar of traffic safety. It is possible to present the characteristics of vehicles related to the vehicle fleet in different ways, such as the age of the vehicle fleet, the structure of the vehicle fleet and the safety characteristics of the vehicle. [1]

In the third pillar, as in the other pillars, the action should focus on the following areas, [2]:

a) Legislation - to have a clear basis for improving road safety as well as to designate responsible agencies for implementation, education and supervision

b) Implementation (including inspections and audits as necessary) - to ensure that rules, regulations and standards are respected and / or enforced

c) Education - ensure that rules and regulations are known and applicable

d) Technology - to supplement and strengthen other areas to increase system efficiency

e) International regulatory support - to provide an international legal framework and institutional platforms to support work in other areas.

The aim of the research is to investigate the extent to which the average monthly salary and older vehicles (passenger cars over 10 years of age) affect the participation of younger vehicles (passenger cars under 6 years of age) in the set of registered vehicles in one municipality. The sample corresponds to the some municipalities on the territory of the Republic of Serbia.

PREVIOUS RESEARCH STUDIES

The United Nations Agenda 2030 for Sustainable Development, adopted by all member states in 2015, provides a common plan for peace and prosperity for people and the planet, now and in the future. The agenda is based on 17 sustainable development goals and is presented as

an urgent call to action for both the public and private sectors in a global partnership. The goals of sustainable development cover a number of needs for the improvement and stabilization of both the human condition and the condition of our planet, recognizing the interdependence of these two goals. [3, 4]

The effectiveness of any United Nations operation in the field is related to its mobility, which in turn correlates to the vehicle fleet. This includes the quantity, quality, condition and types of vehicles available in relation to the condition of the roads and the type of terrain in the operational area.

The following recommendations are offered by the Academic Expert Group for inclusion in the Stockholm Declaration and for use by political, corporate and civil society leaders and practitioners around the world. The recommendations are aimed at 2030 and aim to build on those previously set out in the Moscow Declaration of 2009 and the Brasilia Declaration of 2015, as well as previous United Nations General Assembly and World Health Assembly resolutions.

Recommendation No. 6 of this group applies to safe vehicles around the world. Vehicle safety technology has proven to be effective both in preventing collisions and in saving lives when accidents occur. Vehicle safety systems play an important role in the safe system approach by addressing these basic principles: 1) Accommodating human error, 2) Limiting crash forces to levels within human injury tolerance, and 3) Pursuing a commitment to proactive improvement. [4]

Recommendation No. 9 of this group refers to technology. The question of whether new in-vehicle technologies could be developed in the coming decades that could be suitable for use in low- and middle-income countries could almost certainly be answered in the affirmative. However, realizing that potential will require the commitment of both the public and private sectors. Automotive technology is changing at an unprecedented rate, so it is very likely that there will be candidates for safety devices in the coming years. Technologies outside the vehicle can also make a difference in low- and middle-income countries. One example is post-collision care.

Figure 1 shows countries applying priority UN vehicle safety standards. The 2018 Global Status Report on Road Safety identifies eight critical safety vehicle standards and indicates that while 40 countries have implemented 7 or 8 of these standards, 124 countries worldwide have implemented none or just one of these requirements. [5. 6]

Improvements in the secondary safety characteristics of vehicle design (reduction in the severity of collision injury outcomes) are responsible for much of the reduction in casualties observed worldwide over the last thirty years. These characteristics are increasingly relevant for the protection of vulnerable road users. [7]

Vehicles are designed and regulated to minimize the occurrence and consequences of collisions. Making vehicles safer may include installing „active" safety measures, which can prevent collisions, such as autonomous emergency braking or „passive" safety measures, which protect passengers in the event of a collision, such as seat belts and airbags. Roads and vehicles will increasingly be managed within an intelligent transport system that relies on increasingly autonomous vehicles and smart infrastructure. As safety becomes embedded in vehicle technology and road design, there is the potential to fur-

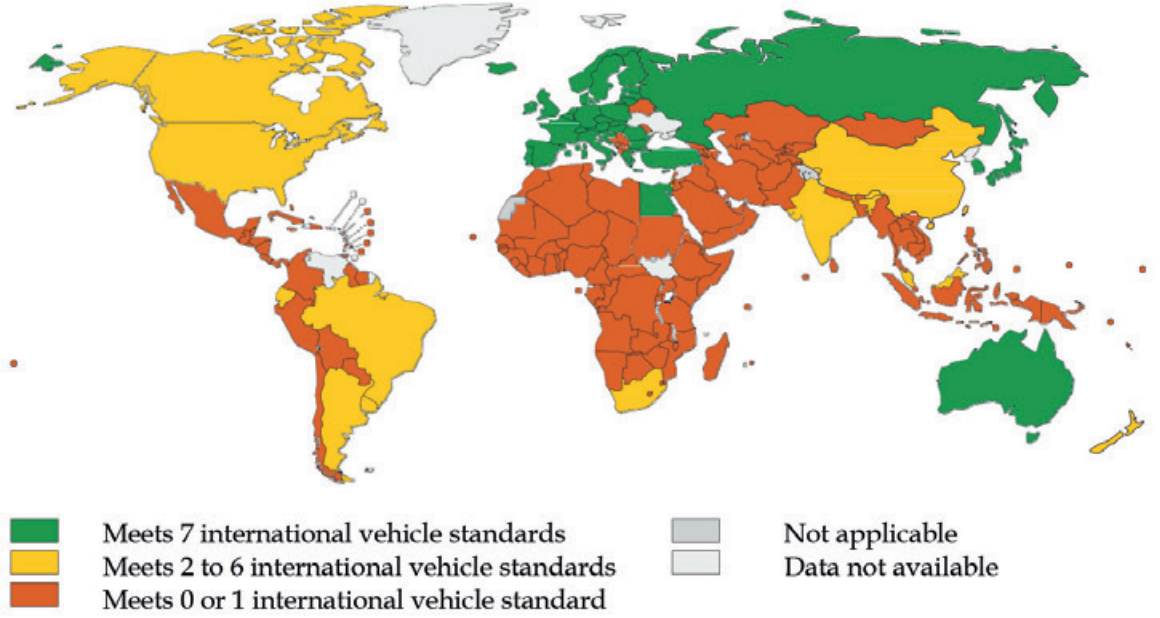

Figure 1. Countries applying priority UN vehicle safety standards
Source: https://www.who.int/violence_injury_prevention/road_safety_status/2015/Section_3_GSRRS2015.pdf

ther reduce the number of casualties and deaths on the roads. The third pillar includes encouraging the universal application of improved vehicle safety technologies for passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the adoption of new technologies. [8]

Important actions under the third pillar of the Global Plan for the Decade of Action for Traffic Safety, [9, 10]:

- implementation of UN vehicle safety regulations and New Car Assessment Programmes (NCAPs), recommendations for inclusion of technologies such as ESC (Electronic stability control) and ABS (Anti-lock Braking System),
- discouragement of import and export of new or used cars that have inferior safety levels increased research into safety technologies designed to reduce risks to vulnerable road users,
- encouragement of managers of governments and private sector fleets to purchase vehicles,
- that offer advanced safety technologies and high levels of occupant protection.

According to the strategy [11], one of the goals related to the third pillar is that 100% of new vehicles (defined as manufactured, sold or imported) and used vehicles will meet very high safety standards, such as the United Nations Regulations or the Global Technical Regulations recommended as priority, or national performance requirements recognised as equivalent by 2030.

The traffic safety indicator related to the age of the vehicle fleet can be observed in different ways. The average age of the vehicle fleet is the first and basic indicator of the vehicle fleet. The second approach considers the percentage of vehicles that are younger or older than some predefined limit.

Based on the two approaches [12], key traffic safety indicators related to vehicles can be defined: average age of all vehicles (fleet),

- average age of passenger car fleet,
- % of passenger cars under 6 years of age and
- % of passenger cars older than 10 years.

Influence of vehicle age on the occurrence of vehicle defects are investigated in paper [13] and the results showed that the average results of the assessment of the technical roadworthiness of vehicles in individual states differed diametrically from each other and did not depend on the average age of the vehicle fleet in a given state.

OVERVIEW OF TRAFFIC SAFETY STRATEGIES IN THE REPUBLIC OF SERBIA

The Road Safety Strategy of the Republic of Serbia for the period from 2015 to 2020 envisages the adoption of the Action Plan for the implementation of the Road Traffic Safety Strategy of the Republic of Serbia for the period from 2015 to 2020, which will elaborate the goals of the Strategy. Specific measures and tasks, holders of activities, deadlines for the implementation of activities, monitoring of traffic safety, responsibilities and sources of funding are contained in the Action Plan. The Action Plan is a set of concrete measures and activities, systematized through five pillars listed in the Strategy. For each of the pillars, the Action Plan sets out the goals to be met. The objectives in the Action Plan for pillar 3. safer vehicles are: [14]

- Objective 1. Harmonization of regulations in the field of vehicle type-approval
- Objective 2. Improvement of the vehicle technical control system
- Objective 3. Technological improvement of vehicles and stimulation of the use of ecological fuels and ecological vehicles
- Objective 4. Development of intelligent transport systems in / on the vehicle in the function of traffic safety

According to the strategy [15], from the point of view of traffic safety, three groups of countries can be distinguished:

1. States that have accepted that traffic safety can be managed, have built an organized protection system and are successfully implementing management in practice, constantly reducing the number of casualties (Great Britain, Sweden, the Netherlands, Norway, etc.),

2. States that in principle accept the idea of the possibility of reducing the number of casualties in traffic, but have not built a strong protection system, fail to manage traffic safety, and record large fluctuations in the number of casualties (Serbia, Croatia, Macedonia, Montenegro, Bosnia and Herzegovina, Romania, Bulgaria, etc.)

3. countries that have not yet accepted the idea of traffic safety management (most countries from the African continent, India, etc.).

The basic guidelines in the field of action towards improving vehicle safety are: [15]

1) the vehicle must not be the cause of a traffic accident,

2) the vehicle should prevent a traffic accident when there is an error of traffic participants, a road error or other dangerous situation,

3) the vehicle should prevent or mitigate the consequences of a traffic accident.

Problems of traffic safety in the Republic of Serbia related to vehicle safety are: [15]

1) the average age of vehicles in the Republic of Serbia is more than 16 years, which is directly related to the economic standard of the population,

2) inconsistent implementation of regulations and procedures related to the control of technical correctness of vehicles,

3) production and placing on the market of non-homologated and low-quality parts and equipment of vehicles,

4) inadequate maintenance of technical correctness of vehicles,

5) a large number of unregistered and technically defective tractors,

6) a large number of unlit and unmarked vehicles in traffic (trucks, tractors, mopeds, bicycles, working machines),

7) small percentage of vehicles with sufficient elements of active and passive vehicle safety,

8) insufficient promotion of „clean" and energy efficient vehicles.

A REVIEW OF THE THIRD PILLAR OF TRAFFIC SAFETY

According to the paper [16], the third pillar of traffic safety (Safer Vehicles) is in the Development Phase, given that the percentage of performance in relation to the maximum performance is 66%. The third pillar of traffic safety is in the Development Phase, which represents a higher level of development status and implies that certain procedures have been adopted but are not systemically linked, and there is no systematic, planned and well-coordinated, synergistic contribution to strategic traffic safety goals. The third pillar (Safer Vehicles) is considered through the following eight areas: Legal Framework, Strategic Framework, Traffic Safety Financing, Data-Based Traffic Safety, Science-Based Traffic Safety, Safe system approach, Capacity and integrity of the most important stakeholders / institutions and Performance of the most important institutions. [16]

Having in mind the goals of the national traffic safety strategy, as well as the fact that Belgrade largely participates in achieving those goals, these will be the final goals (defined for 2020), but the so-called transitional goals (by years from 2017 to 2020), achieved by implementing measures and activities in key areas of work, which are systematized according to the pillars of the Global Plan of the Decade of traffic safety action [17]:

1. improving the organization and management of traffic safety,
2. improving road and street safety,
3. improving the safety properties of vehicles in traffic,
4. improving the behavior of traffic participants and
5. improvement of action after a traffic accident.

In order to improve the safety properties of vehicles in traffic, the City of Belgrade will establish regular field research on safety and other properties of vehicles in traffic, analyze the situation, inform the public about the results and conduct campaigns aimed at improving the safety properties of vehicles in traffic. mandatory equipment, especially in winter conditions, etc.). In the annual traffic safety programs, the city of Belgrade will implement support to the owners of agricultural machines, which use public roads, by purchasing and distributing appropriate rotating lights and appropriate campaigns. In order to better visibility and visibility of bicycles, the City will encourage the use of appropriate lights and retroreflective materials for bicycles. Appropriate campaigns will be conducted for motorized two-wheelers, in order to improve the visibility and technical correctness of these vehicles. [17]

The basic guidelines in the field of action towards improving vehicle safety are, [18]:

- improving the quality of technical inspections in the city,
- establishment and improvement of a system based on the concept that the vehicle must not be a contribution to the occurrence of a traffic accident,
- promoting a system in which the vehicle should prevent a traffic accident when there is an error of traffic participants, a road error or other dangerous situation,
- systematic planning of control and sanctioning of congestion of trucks on local roads
- improving the vehicle element in order to prevent or mitigate the consequences of a traffic accident.

Problems of traffic safety on the territory of the city in connection with vehicle safety are, [18]:

- insufficient knowledge of the driver about the importance of a safe vehicle, ie the magnitude of the impact of a faulty vehicle on the occurrence of a traffic accident,
- inadequate maintenance of technical correctness of vehicles,
- inconsistent implementation of procedures related to the control of technical correctness of vehicles, which characterizes the entire Republic of Serbia,
- a large number of unlit and unmarked vehicles in traffic (bicycles, trucks, mopeds, work machines),
- insufficient control of truck overload,
- small percentage of vehicles with sufficient elements of active and passive vehicle safety and
- insufficient promotion of „clean" and energy efficient vehicles.

Vehicle safety should be improved by improving existing procedures and harmonizing with relevant world standards and mechanisms, with the aim of faster adoption of new technologies that affect safety. Activities within the third pillar according to the strategy are

related to vehicle standards and vehicle technical inspection. Within the vehicle standards, activities related to the improvement of the vehicle and parts type-approval system, the improvement of the vehicle certification system, and incentives for the procurement of new vehicles are envisaged. Within the Check of technical correctness of vehicles, the following activities are envisaged related to:

- Improving procedures and updating the methodology of performing technical inspections,
- Improve the system of emergency control of technical correctness of vehicles,
- Publish the results of the control of vehicles sent for extraordinary technical inspection by the police along with the data on regular technical inspections,
- Publish statistics on technical inspections of vehicles,
- Improve supervision and enable supervisory bodies access to data from the information system for monitoring the work of vehicle technical inspection stations,
- Review the legal regulations regarding the issuance of approvals for the operation of technical inspection stations,
- Introduce procedures for technical inspection of vehicles after major repairs or alterations to the vehicle,
- Upgrading of standards when inspecting vehicles depending on age,
- Accreditation of technical inspections according to the ISO 17020 standard for inspection bodies,
- Technical inspection of the vehicle after a traffic accident.

METHOD AND RESEARCH RESULTS

The paper [12] presents the values of traffic safety indicators related to the vehicle fleet, which were collected within the project „Research of traffic safety performance indicators for 2018", implemented by the Traffic Safety Agency. The project collected data on the values of indicators according to the police administrations in Serbia, which are aggregated at the national level. By analyzing the age of passenger cars in Serbia, it was found that there are 133,051 cars under the age of 6, which is about 7% of the vehicle fleet. There are 1,450,501 passenger cars older than 10 in Serbia, which is 76% of the vehicle fleet. Passenger vehicles over 15 years of age were also analyzed, of which there are 682,801, ie. about 36% of the total number of vehicles. The average age of the vehicle fleet in Serbia is 17.1 years, with the lowest average age in Belgrade (13.3 years), and only in Belgrade is the double-digit percentage of cars under 6 years (13.2%).

The method used in this paper is multiple regression. A regression model that contains two or more explanatory variables is called a multiple regression model and is given in the following form, [19]:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + \varepsilon \quad (1)$$

Where Y is a dependent variable, and X_1, X_2, X_3,…, X_k are explanatory variables, while ε is a random error of a multiple regression model.

In this part of the paper, it is examined whether the percentage of older passenger cars than 10 years in the fleet of a certain city and the average monthly net salary at the same city affect the percentage of passenger cars younger than 6 years in the city under study. Table 1 provides data on the percentages of passenger cars younger than 6 years and older than 10 years in certain cities of the Republic of Serbia from the 2018 survey, as well as the average monthly net salary in dinars for 2020. [12, 20]

Let them be:

Y - % of passenger cars under 6 years of age in Republic of Serbia from the 2018 survey, [12]

X_1 - % of passenger cars older than 10 years of age in Republic of Serbia from the 2018 survey, [12]

X_2 - average net salary in RSD in Republic of Serbia from the 2020 survey. [20]

Table 1. Data for multiple regression equation

Observation No.	City	Age of cars < 6 years (%) (Y)	Age of cars > 10 years (%) (X_1)	Average net salary in RSD (2020) (X_2)
1	Beograd	13.2	73.0	74,296
2	Novi Sad	6.2	82.2	67,933
3	Subotica	4.4	87.7	55,686
4	Zrenjanin	3.8	87.7	57,228
5	Pančevo	3.7	87.3	59,357
6	Kragujevac	3.2	89.3	57,371
7	Sombor	3.2	89.6	53,622
8	Čačak	3.1	90.3	51,401
9	Kikinda	3.1	90.4	54,809
10	Sremska Mitrovica	3.0	90.5	55,000
11	Niš	2.9	90.1	54,640
12	Požarevac	2.9	90.2	60,310
13	Užice	2.6	90.4	56,980
14	Jagodina	2.4	91.5	48,883
15	Bor	2.1	90.7	69,459
16	Kraljevo	2.0	92.3	50,881
17	Šabac	1.9	92.9	53,452
18	Kruševac	1.9	93.0	50,442
19	Valjevo	1.8	93.4	53,520
20	Novi Pazar	1.8	93.5	45,461
21	Smederevo	1.7	93.1	56,930
22	Pirot	1.4	94.5	57,213
23	Leskovac	1.4	94.7	47,475
24	Zaječar	1.3	93.8	52,897
25	Vranje	1.3	94.8	49,828
26	Prijepolje	1.2	94.9	46,050
27	Prokuplje	1.2	95.4	51,055

The estimated regression equation is:

$$\hat{y} = 54{,}42 - 0{,}5445 \cdot x_1 - 0{,}000039 \cdot x_2 \quad (2)$$

The values of the standard regression error, the coefficient of multiple determination and the corrected coefficient of multiple determination are:

$$s = 0{,}504140; \quad R^2 = 95{,}76\%; \quad \overline{R}^2 = 95{,}41\% \quad (3)$$

The standard regression error is about 0.5. Value R^2= 95.76% shows that % of passenger cars older than 10 years and average net salary in RSD explain 95.76% of the variation % of passenger cars under 6 years of age. The value of 95.41% is the value of the coefficient of multiple determination corrected for the number of degrees of freedom. After correction, it follows that the mentioned two explanatory variables explain 95.41% of the variation of the dependent variable.

The value of b_1= - 0.5445 in the estimated regression model shows the change in y at a unit increase of x_1, while x_2 is constant.

The value of b_2 = - 0.000039 in the estimated regression model shows the change of y at the unit increase of x_2, while x_1 is constant.

In those cases, there is a negative relationship between the observed two variables (y and x_1, y and x_2).

Figure 2 shows histogram of residuals, normal probability plot of residuals, residuals versus fits and residuals versus order. One of the evaluation criteria is the least squares method. The method consists in taking the value for which the sum of the squares of the residual is minimal to estimate the parameter. Residuals (errors) should be approximately normally distributed, which is in accordance with Figure 2.

CONCLUSION

The age of the vehicle fleet is largely related to the economic situation in the local community. The local community has very little or limited opportunities to influence the condition of the vehicle fleet. The key parameters of action on the condition of the vehicle fleet, and thus on the vehicle safety indicators, are within the state competence. The fleet renewal policy brings vehicles with driver assistance systems, which can significantly contribute to the reduction of certain types of traffic accidents. The national fleet strategy must be based on a fleet renewal policy, in line with the vehicle's innovative safety features. Vehicle-related traffic safety indicators were considered in Republic of Serbia for the first time in 2018, which is why it is necessary to encourage similar research in the coming period. The limitations of the paper are in the fact that the analysis was done only on a sample of one year (data on the age of cars from 2018 (from paper [12]) and data on salaries from 2020) and that only the category of passenger cars was used.

The directions of further research would be turned to the calculation of traffic safety indicators by municipalities, such as the traffic safety indicator related to the vehicle fleet in the regional unit and the vehicle fleet indicator for the national level (Republic of Serbia) and their comparison for a period of 5 years.

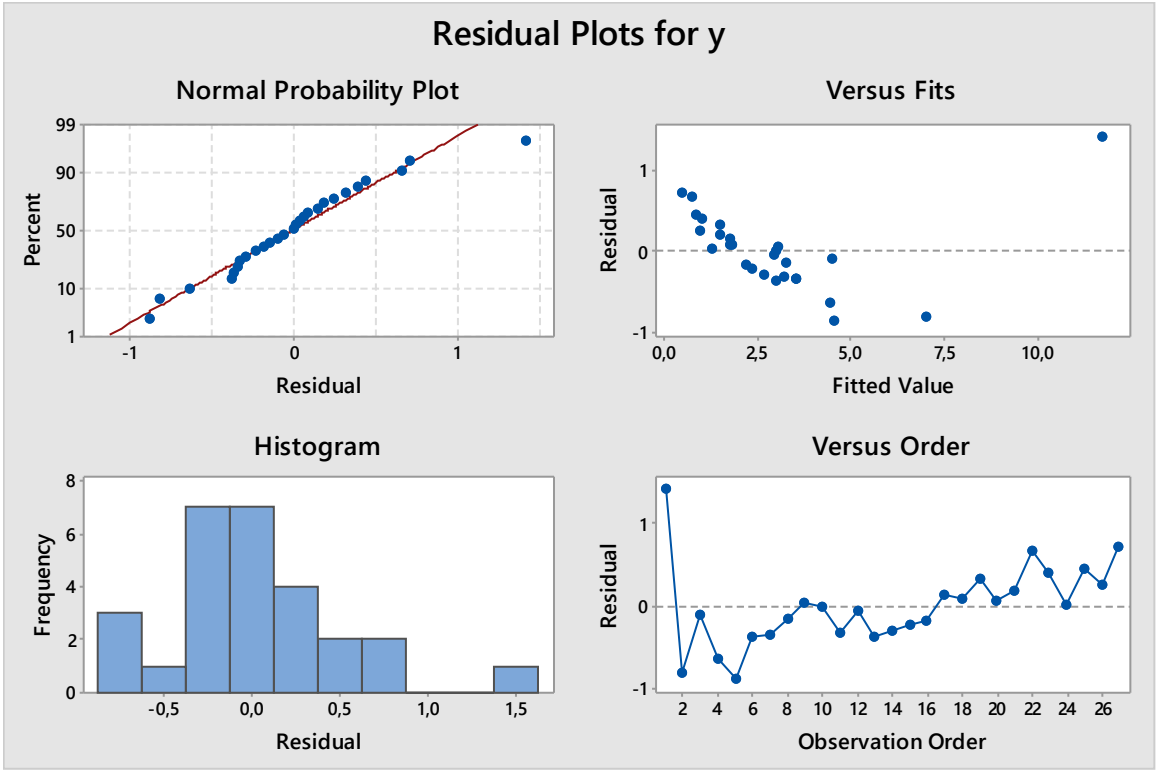

Figure 2. Plots of multiple regression equation

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