The Fuel Consumption Rationalization for Public Transport by Maintenance Techniques Application

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Abstract

In the field of urban public transport, the implementation of an efficient system of fleet maintenance reflects the quality level of the service provided. An important aspect of maintenance activity is the possibility to reduce the fuel consumption for a fleet of buses with internal combustion engine, through the identification of all malfunctions which can affect fuel consumption.

The paper shows the main aspects of actions related to the organization, the exploitation process and the preventative maintenance activity, aiming at rationalization of the fuel consumption.

In order to establish connections between the number of malfunctions and increasing fuel consumption, we conducted a case study regarding monitoring a fleet of medium-sized passenger transport. Accordingly, data with regard to the fuel consumption and malfunctions recorded during a year, we have explained using the Pareto chart. Then, to estabilish the degree of association and correlation between these two variables, we use the mathematical regression method.

The results thus obtained confirm there is a very close connection between the two variables, so that an upward trend in the number of malfunctions implies an upward trend in fuel consumption.

Highlights

- Improvement of fuel consumption used for public transport ensure the reduction of transport costs.
- Using the appropriate techniques of preventive and corrective maintenance on a transport buses fleet, we lead to reduction the fuel consumption.
- Transportation company evidences, in terms of fuel consumption and specifical malfunctions recorded, are a solid base for maintenance process analysis.
- Mathematical analysis using regressive models determines the degree of correlation between the factor of fuel consumption and of the malfunctions recorded.
- The result of Pareto analyses shows that increasing of number of the malfunctions will determine a greater fuel consumption.

Keywords

maintenance, buses, fuel consumption, malfunctioning, regression, Pareto method;

Abbreviations

GPS: Global positioning system;
GPRS: General packet radio service.

1. Introduction

Strategic plans of urban public transport companies provide directions aiming at a sustainable development of services.

The main goal of management activities is to continuously increase the quality of services offered in terms of cost effectiveness of the economic activity.

The effect of maintenance process on the reliability has represented a continuous commentary with results that converge to highlight its importance. In this way, Selvik, J.T. and Aven , T. show the importance of maintenance to improve the systems reliability, thus preventive maintenance becomes an important task [1] .

Reliability analysis approach, made through the development of risk analysis, offers the possibility for taking the necessary measures to prevent the negative effects generated by the amount of observed values, theory proven by Apeland, S., Aven, T., and Nilsen, T. [2] .

A way of supervision the maintenance process is provided by J.M. van Noortwijk, through Gamma distribution [3] .

Maintenance analysis involves obtaining a volume of information sufficient of expensive in terms of necessary time to monitor the devices and in terms of testing methods required. M.J. Kallen and J.M. van Noortwijk shows that nondestructive inspection do not provide full information about the causes of the malfunctions, which is why they develop a shown decision model to ensure optimal maintenance with regard to the imperfect inspections [4] .

The probability models development, in order to establish the optimal maintenance decisions, also represents continues analyzing directions. A.Grall, C.Bérenguer and L.Dieulle establish a maintenance decision model based on a mathematical model [5] .

The optimization of buses fleet maintenance of urban public transport is an essential component in the path to achieving this goal [6] .

Through statistical analysis of recorded events we can take appropriate decision to optimize maintenance activities. Also, for obtain conclusive results, it is necessary to prepare and use historical records of each vehicle in part, but these must span a large range of time [7].

A case study developed by Uğur, E., Efendi, N., Mefharet, Ö., Ümit, K., showed that the main factors included in the database of the buses fleet activity, are [7, 8]:

- *Energy factors*: fuel consumption, power consumption, consumption of oil and other specific fluids;
- *Economic factors*: the cost of operation and maintenance of each vehicle in use;
- *Operational factors*: routes and distances traveled by each vehicle, drivers schedule;
- *Maintenance factors*: compliance of technical service intervals, the frequency and types of vehicle malfunctions, solutions to technical problems.

Specific analyses presented worries the public passenger transport companies. Each analysis promotes distinct primordial factors, socio-economic and of national interest regarding the organization of public passenger transport. Socio-economic factors related to satisfaction and profitability of the transport activity, are review by Muammer, O., Urkun, O., Irfan, Y. and Pundir, B., P. [8, 9] .

In the paper we present methods to reduce fuel consumption of a transport buses fleet by optimizing the operation and maintenance processes. To determine how the maintenance process can influence the fuel consumption, we performed a case study, as a result of a transport buses fleet observation.

2. Methods of reducing fuel consumption in urban public transport

Reducing fuel consumption in road transport is a major interest objective. The global tendency to increase the fleet of vehicles equipped with internal combustion engines entails the negative effects of petroleum fuels usage [7] .

The most important consequences are environmental pollution and damaging health of beings. In this way, the negative impact of vehicle emissions on the environment and human health is reaching alarming levels [10] . In Europe the reduction of greenhouse gas emissions and the program targets are defined in the White Paper on Transport (Brussels, 2011) [11, 12] .

At present, although there are alternative solutions that counteract these negative effects, most vehicles are equipped with internal combustion engines [10] . Public transport of passengers is a segment of road transport with a significant contribution to the above mentioned negative effects. Hence, improving the energy efficiency of urban public transport systems is a condition "sine qua non".

The diagram presented in figure 1 propose two methods for reducing fuel consumption used by a fleet of buses in urban public transport. These methods can be applied simultaneously.

One way is to implement a programme for management and monitoring the buses fleet. From this point of view, the training of drivers has been proven to be effective. So that, the traning includes a core curricula that will consist of the following tasks: relating to the importance of driving economic and ecological, regarding to the proper use of systems and

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devices of transport vehicles and regarding to the obligations for general verification of buses.

A second goal is the buses fleet management by carrying out specific actions, resulting in the following tasks: ensuring the optimum transport capacity, optimizing routes carried out and optimizing the traffic frequency.

Monitoring the fleet of buses is an instrument with superior results relating to the fuel economy and is carried out through the following means: bus fleet tracking through GPS/ GPRS systems [13,14], detecting irregularities relating to fuel consumption and monitoring, notification, development and continuous improvement of a proper maintenance program, in accordance with the technical requirements of the buses fleet.

Accordingly, the actions described are unitary character and compete for assurance the quality and reliability on managed transport system.

Another way is to achieve a consistent maintenance system, to use rationally, preventive and corrective techniques. The success of this action directions is provided through the training of workers, made by following tasks: the ability to correctly use the diagnosis/ interventional technologies, to identify all issues which may lead to higher fuel consumptions and workers' awareness about the importance of the quality of work performed.

In order to ensure the performance maintenance program, are available some action directions reflected by: making correct and timely reviews and technical checks, the correct and complete execution of incidental, current and capital repairs and the need of compliance with the rules laid down or maintenance [15,16].

As a measurable result of the action directions is the monitoring of maintenance activities. This implies the following task: regarding compliance with the stages and time standards, regarding the quality of works performed and carrying out practical checks, after intervention.

The goal of performance and optimization into public urban transport companies, can be achieved by the benefits reflected by the implementation of management and monitoring actions and a high level of maintenance system on the buses fleet.

There are two directions through which the fleets of buses may be managed with low fuel consumption (fig. 1) [17].

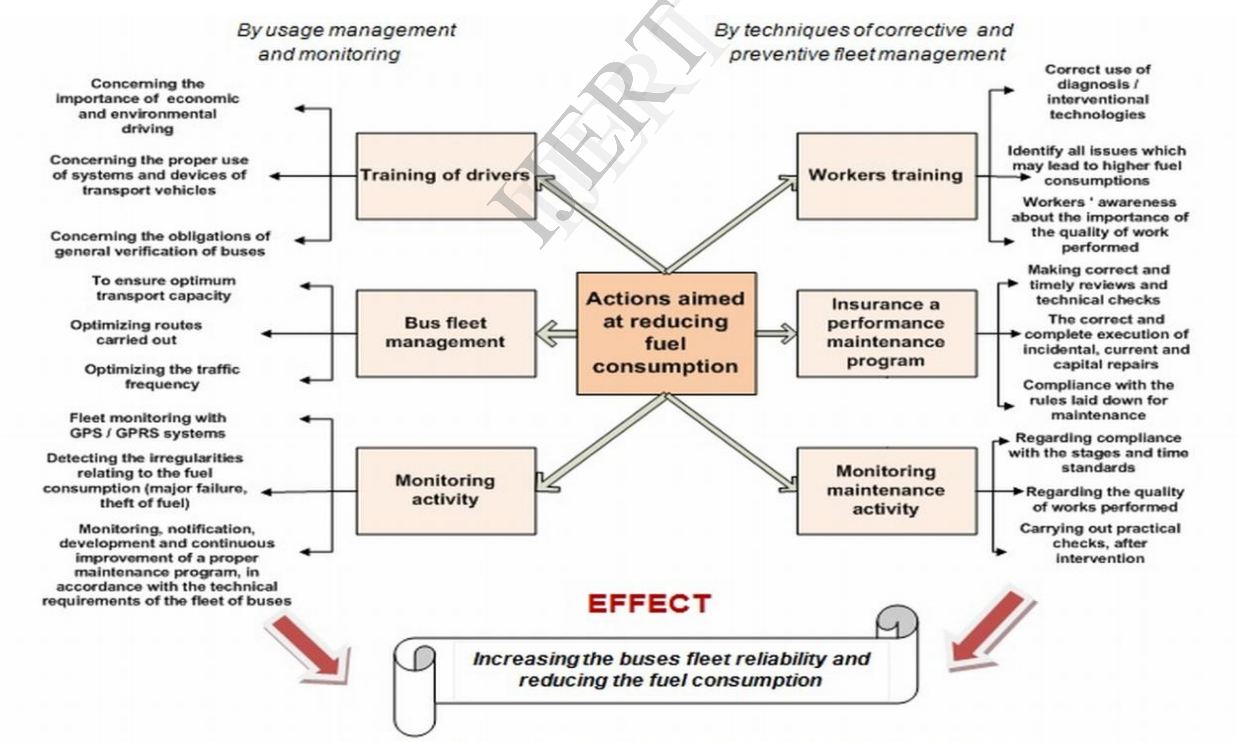

Fig. 1 Diagram of the methods of reducing fuel consumption

Further we present important measures that we can apply in order to reduce fuel consumption, which refers to the exploitation process and maintenance of the buses fleet.

Anticipating traffic. Although the nature of urban public transport involves frequent stops and starts in the bus stations, while in motion the driving speed and optimum locations for acceleration / deceleration will be evaluated optimally, depending on traffic conditions [18, 19] .

Proper torque operation. Changing gears at appropriate engine rotations and taking advantage of maximum torque help reducing fuel consumption. Although maximum engine power is not developed at peak torque speed, using engine power at maximum torque provides optimal traction and fuel consumption [20] .

Rational use of heating / air conditioning. In winter, to heat the buses, auxiliary heating systems are usually operated simultaneously with internal combustion engines. In order to save fuel, while achieving and maintaining a temperature around 20° C, both the heat generators and distributors must function optimally. Improper operation thereof must be identified and corrected immediately [17, 18].

In the summer, to reduce fuel consumption it is recommended to use ventilation and only turn on the air conditioning when strictly necessary. The optimal room temperature in the bus must be up to 5-10^{o} C lower than outside temperature. This way there is a gain in fuel economy and the negative effects related to the transition from the room temperature to the the inside of the bus are avoided. To maintain the temperature obtained using air conditioning, it is recommended that air exchange with the outside is as low as possible. Moreover, to avoid a raise in temperature inside the bus, cause by reflection of solar energy, it is recommended to apply ionized sheets on the glass of windows and doors.

Rational use of lighting systems. In urban transport, during daytime and in good weather conditions, outdoor and indoor lighting of buses is not strictly necessary. Thus the less electric energy used contributes to lower fuel consumption [9] .

Checking tire pressure before leaving. The maintenance of a proper tire pressure is a measure that increases the safe operation of motor vehicles, contributes to the life of its assemblies, and especially improves fuel consumption [17, 18].

Within both corrective maintenance interventions and especially within the planned preventive technical revisions, it is necessary to check the proper functioning of auxiliary equipment of internal combustion engines of vehicles used in public transport. The precise indication of failures and their symptoms allows complete their remediation and prevents the increase of fuel consumption [21] .

Checking the proper functioning of injection mechanisms and injection computer. The malfunction of the injection system pumps or the clogging of fuel filters and injectors usually entails increased fuel consumption [9, 18, 22] .

Checking the catalyst and lambda probe. The malfunction of these elements leads to the acquisition of misinformation on the amount of oxygen in the gas exhaust, a situation that results in sending a wrong signal to the controls of injection parameters, adversely affecting fuel consumption [23] .

Checking the turbocharging system. Although the turbo-compressor systems can work properly, most often the failure occurs within the radiators that cool the compressed air (intercoolers). Because of dirt deposited on the heat exchange surface, or due to deterioration cause by mechanical shock, the compressed air is not properly cooled, so the combustion processes will require more fuel [19] .

Checking the operation of the engine cooling system and preheaters. If the thermostat is not airtight or if it gets stuck on "on" switch, this will allow the coolant to enter the radiator and be cooled even when the internal combustion engine has not yet reached the optimal operating temperature (80-90^{o}C). This leads to the injection of a rich fuel mixture, which entails increased fuel consumption. Transmitting erroneous signals from the coolant temperature sensor generates an effect similar to that of thermostat failure [22, 23].

Increased fuel consumption due to incorrect operation of preheating systems has two causes:

- Malfunction of fuel injection (fuel leak)
- Incomplete combustion and insufficient heat (at cold start)

Checking fluid levels in the engine. If the levels of engine coolant or lubricant oil in the crankcase are below the minimum limit, the engine will overheat due to increased friction between metal parts of the motor mechanism. In addition to premature wear of the components, fuel consumption is higher as a result of increased mechanical work done and of the engine's energy loss [22, 23]..

Replacement of defective batteries. Using defective batteries leads to increased fuel consumption. Directly, if unloading takes place in a short time, their recharging energy required will increase fuel consumption. Indirectly, using defective battery is hindering the engine start, so that when engines operate in idle mode at the ends of the bus lines, more fuel is burned [22, 23].

The application and effects of the measures taken, are subject for the development of statistical analysis that forms the basis of preventive and corrective decisions, purposes in order to reduce fuel consumption and to increase the reliability of the bus fleet.

In this way, the analyses carried out using the Pareto method, prove to be extremely useful in monitoring the process of exploitation and maintenance [24]. So, we obtain a classification of transport vehicles, depending on the fuel consumption deviations from normed consumption. A clear identification of the buses with large deviations of fuel consumption, ensure increased efficiency of measures for reducing fuel consumption.

In addition, through the identification and classification of buses, depending on the manifestation mode of the faults recorded on the fuel consumption, Pareto method maximizes the priorities of optimizing the maintenance process of the buses fleet.

Effects of applying statistical analysis methods on the activities of exploitation and maintenance, are the levers driving to decrease total fuel consumption and raising the overall reliability of the buses fleet.

3. Statistic analysis of fuel consumption recorded at a sample of buses analyzed

To identify the malfunctions in the process of maintenance and to determine how they influence the recorded fuel consumption, we chose a sample of 11 urban buses, identical as design and age [25,26] .

These buses meet the Euro 3 emissions standard and are equipped with MAN D0834 diesel engines, having cylinder capacity of 4580 cm^3.

We will continue by recording the fuel consumption for every bus in the lot. Further, knowing the total number of malfunctions made by each bus, we can establish the relation with variation fuel for each bus.

Knowing the standard fuel consumption as of 25 l / 100 km, in table number 1 we present the average fuel consumption of buses in the sample lot, recorded in 2012, and the total number of malfunctions layout contributing to increasing fuel consumpt

Table 1 Average fuel consumption of the buses in the sample lot

Nr. crt.	The sample of buses analyzed [1]	Average fuel consumption (l/100 km)	The difference between registered and standardised consumption (l/100 km)	Cumulate relative frequency of fuel consumption differences (%)	Cumulate relative frequency of average fuel consumption (%)	Malfunctions total number	Cumulate relative frequency of malfunctions (%)
1	B1	29,27	4,27	19,31	9,85	12	18,18
2	B2	27,89	2,89	32,38	19,24	9	31,82
3	B3	27,69	2,69	44,55	28,56	7	42,42
4	B4	27,30	2,30	54,95	37,75	7	53,03
5	B5	27,15	2,15	64,68	46,88	6	62,12
6	B6	27,06	2,06	73,99	55,99	6	71,21
7	B7	26,69	1,69	81,64	64,98	5	78,89
8	B8	26,57	1,57	88,74	73,92	4	84,85
9	B9	25,95	0,95	93,03	82,65	4	90,91
10	B10	25,80	0,80	96,65	91,34	3	95,45
11	B11	25,74	0,74	100	100	3	100
Average fuel consumption of the buses fleet (l/100 km)		297,11	22,11		Total number of malfunctions of the buses fleet	66	

[1] Note: B1 – B11 represents the 11 buses examined

The average fuel consumption of each bus in 2012, were taken from the evidence of transport company. We determined the averages values by using relation (1) below, knowing the quantities of fuel loaded in the bus tank and the distance traveled.

$$C_m = (C_a / D) * 100 \quad (1);$$

where: C_m - average fuel consumption (l / 100 km);

C_a - quantity of fuel loaded (l);

D – distance traveled (km).

Column cumulative relative frequency of average fuel consumption presents gradually accumulated contribution of the average consumption records of each bus, reported to the total averages of fuel consumption.

Column cumulative relative frequency of malfunctions presents the gradually accumulated contribution of the number of malfunctions recorded for each bus, reported to the total number of malfunctions.

Column cumulative relative frequency of fuel consumption differences presents the gradually accumulated contribution of every deviations from the standardised average fuel consumption, reported to the total fuel consumption differences.

We picked up the number of malfunctions for the 11 sample buses in 2012 from the database of the Maintenance Workshop.

In figure 2 are presented, in descending order, the values of differences between the registered and standardised fuel consumption, for the sample analyzed, using the data shown in table 1.

Through the Pareto method, we have traced the variation curve of cumulative relative frequency for the calculated differences, reported to the total value of consumption differences.

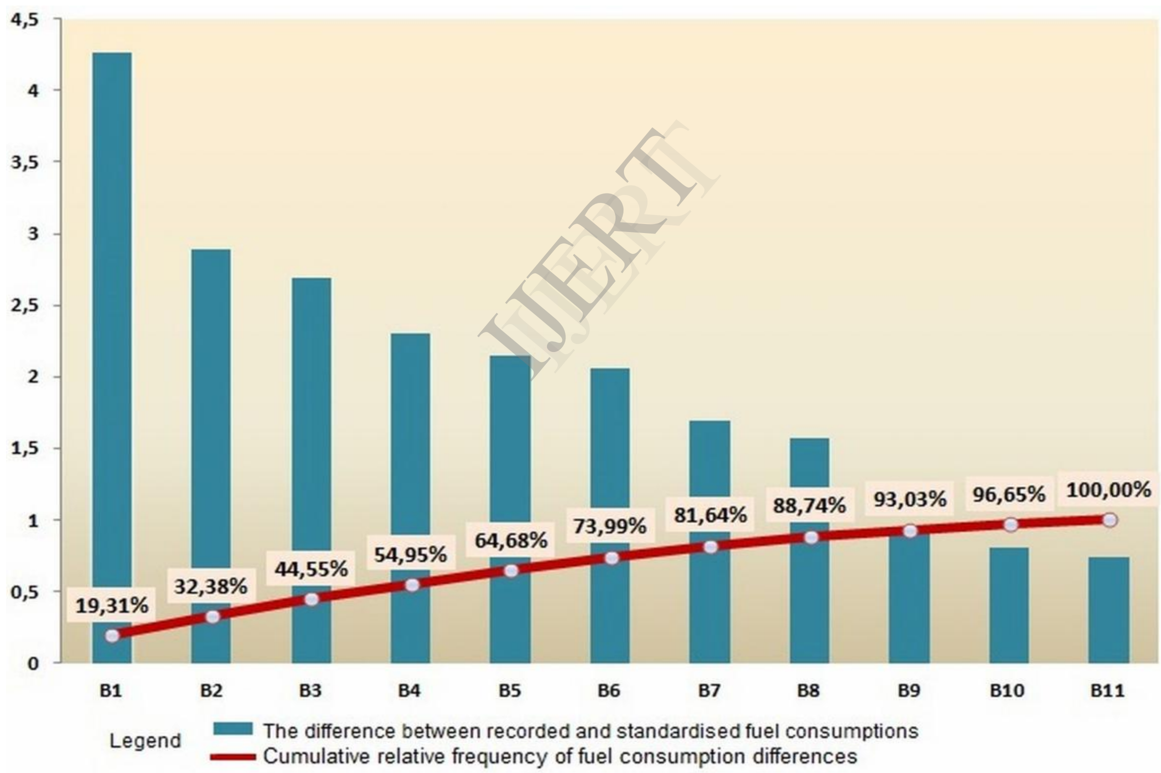

Fig. 2 Gradual ranking of differences between recorded and standardised fuel consumption

To highlight the influence of analyzed malfunctions over the increased amount of fuel consumed by the 11 buses from the analyzed sample lot, we traced Pareto diagram, presented in figure 3.

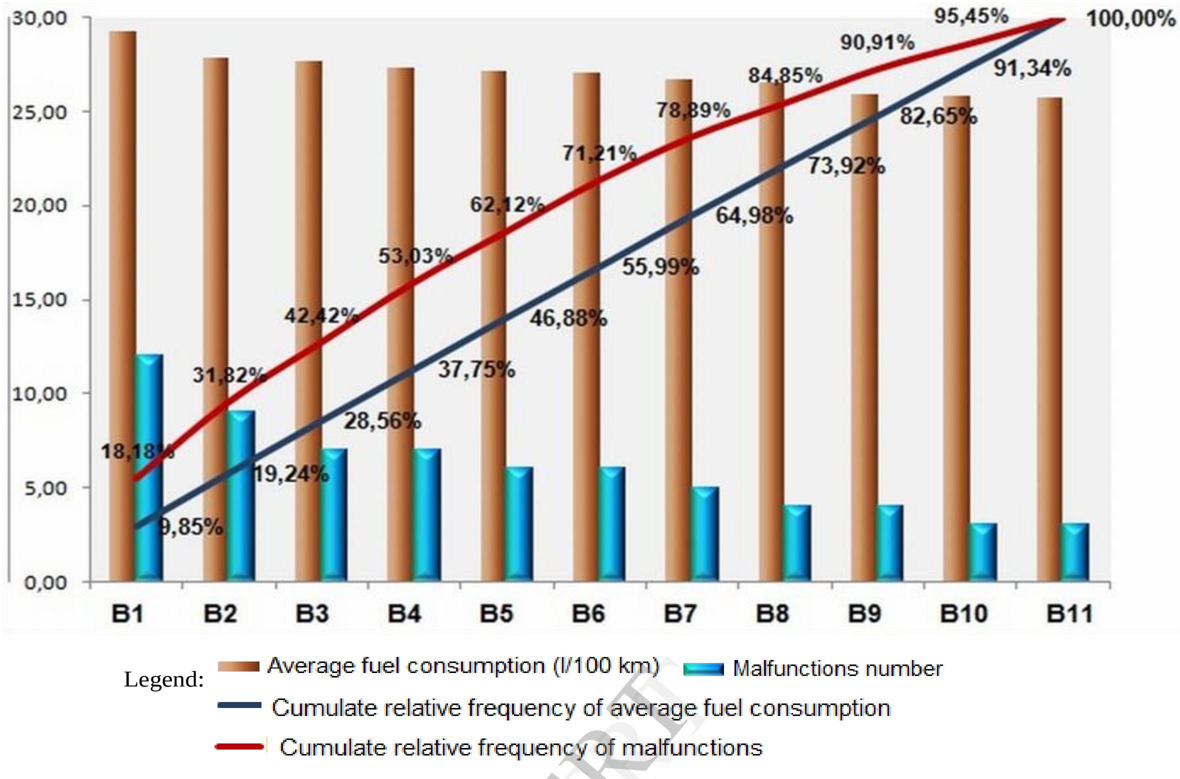

Fig. 3 The influence of malfunctions over increased fuel consumption

To determine the influence of the variable composed of malfunctions upon variable composed of fuel consumption values, we used the mathematical regression method. In this way it is possible to determine the relationship between the two statistical variables.

We will establish how possible it is to have a degree of statistical association between the two analyzed variables by using correlation method. Thus, a first observation is that the upward trend of the cumulative relative frequency of the number of malfunctions recorded, implies an ascending trend of the cumulative relative frequency of achieved fuel consumption, which can be seen in the diagram in figure 3. In this case the link is a direct correlation [27, 28, 29] .

The correlation coefficient between the two variables is calculated in equation (2) [29] .

$$r(x,y) = n\sum xy - \sum x \sum y / (\sqrt{n\sum x^2 - (\sum x)^2})(\sqrt{n\sum y^2 - (\sum y)^2}) \quad , [-1, +1] \qquad (2);$$

where: r – correlation coefficient;
x – fuel consumption variable;
y – malfunctions variabile.

After the calculation that we have performed on the data sets analyzed, we follows that r = 0.989, so the value is very close to the upper limit of the range. We can be concluded that the two variables have a very strong correlation.

To calculate the proportion by which the total variations of fuel consumption are determined by variations of recorded malfunctions, will be used relation (3) to calculate the coefficient of determination [30] .

$$cd = r^2 \qquad (3);$$

As cd=0,978, we follows that 98% of the variations of fuel consumption are caused by the variations of malfunctions.

Having established the links between the two statistical variables analyzed, we can plot the dispersion graph of bivariate values and their regression curve, using the cumulative relative frequency data, presented in table 1.

This graph is shown in figure 4.

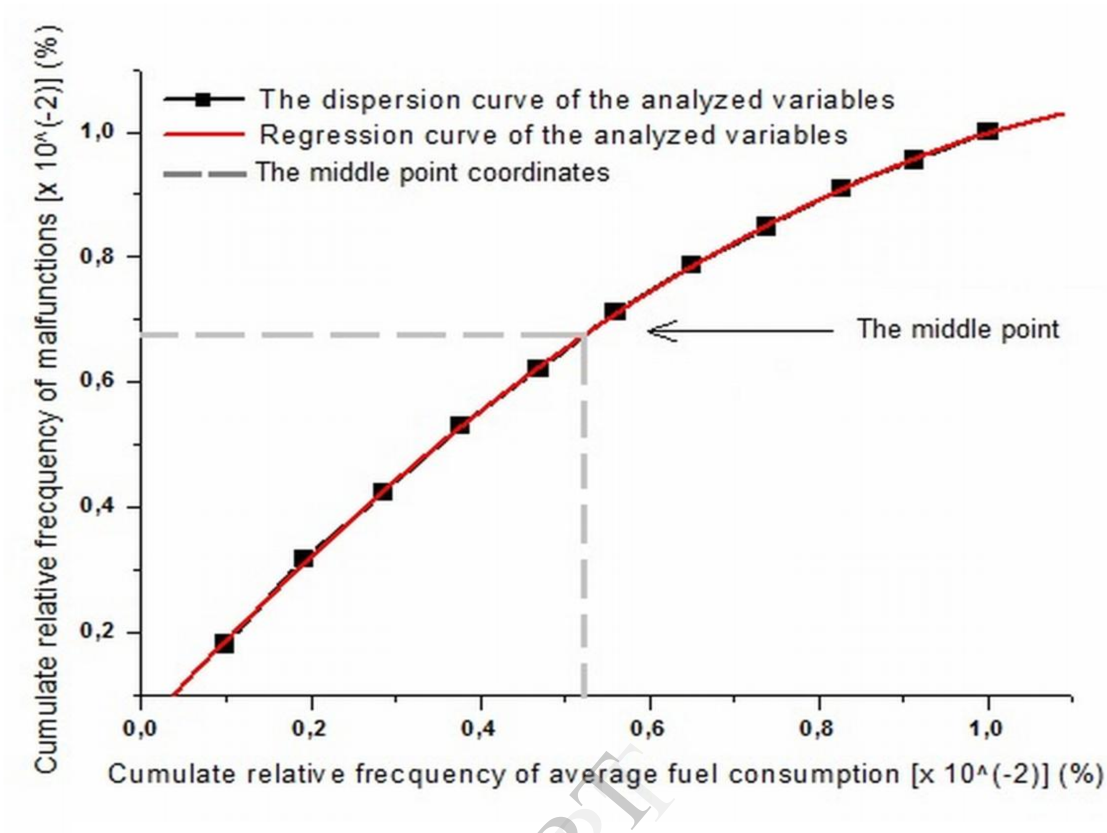

Fig. 4 The dispersion curve and regression curve of the analyzed variables

The dispersion curve corresponding to the values of the analyzed variables is of polynomial type. Due to the close correlation between the values of these variables, the polynomial regression curve intersects every point of the dispersion curve. Thus, as follows from the numerical calculation, the mathematical equation corresponding to the regression curve, relation (4), has polynomial form of degree 2 [31].

$$y = -0{,}533x^2 + 1{,}486x + 0{,}045 \quad (4);$$

where:

"y" is the dependent variable of the regression equations;

"x" is the independent variable of the regression equations.

Knowing the values of variables x and y, using the method of least squares, we will calculate the average values of these variables, using the relations (5) and (6).

$$\bar{x} = \frac{\sum x}{n} \quad (5);$$

$$\bar{y} = \frac{\sum y}{n} \quad (6);$$

where:

"$\bar{x}$" - the corresponding parameter for the average value of the string "x";

"$\bar{y}$" - the corresponding parameter for the average value of the string "y";

"n" - the number of values corresponding to the data set analyzed.

Replacing the coordinates of the middle point obtained, in the regression curve equation, it obtain the equation described by the relation (7).

$$\bar{y} = -0{,}533\bar{x}^2 + 1{,}486\bar{x} + 0{,}045, \quad (7);$$

Thus, after the replacements, result: $0{,}662 = -0{,}533 \cdot (0{,}525)^2 + 1{,}486 \cdot (0{,}525) + 0{,}045 = 0{,}678$

The difference obtained comes from the roundings of the equation parameters and coefficients. This verification proufs that the point of coordonates ($\bar{x}$; $\bar{y}$) is on the regression curve, fact reflected by the figure 4, where are illustrated the bivariate values and the regression curve obtained.

The negative sign and the value of the second-degree term from the equation regression curve, obtained using the relation (4), indicate concave allure and the upward slope of the curve thus obtained. This can be seen in the graph from figure 4.

Over-unit value of the first-degree term from the regression equation, indicates a linearity relation between the set of the analyzed values, which can be seen in the Pareto chart from figure 3.

With regard to the constant term from the regression equation, we can say that value is close to zero, reflecting in this way the existence of a not significant relative error and a high degree of correlation between the values from the data set analyzed.

Taking into account the degree of correlation between the experimental data and the probabilistic distribution law, we can say that a share of up to 32% from malfunctions recorded generates increase in fuel consumption up to 20%.

At the same time, 18% among the transport units sample, (made up of B1 and B2), generates a share of 32% from the cumulated number of malfunctions recorded, reported to the total number of malfunctions recorded and generate an cumulated fuel consumption up to 20%, reported to the total averages of fuel consumption, while 82% among the transport units sample generates a share of 68% from the cumulated number of malfunctions recorded, reported to the total number of malfunctions recorded and an cumulated fuel consumption up to 80%, reported to the total averages of fuel consumption.

The same share of 18% among the transport units sample analyzed, produces a share of 32% from the cumulative relative frequency of fuel consumption differences, reported to the total fuel consumption differences, while 82% among the transport units sample generates a share of 68% from the cumulative relative frequency of fuel consumption differences, reported to the total fuel consumption differences.

As a first decision resulting from the Pareto analysis, is the need for revising the technical condition of the first two buses (B1 and B2), representing a share of 18% of the buses fleet sample analysed. Strategically, on optimizing management through preventive maintenance, defects found have imposed an upgrade of the technical inspections program.

4. Discussions

The mathematical models used to determine the existing conections and their type, between two statistical variables specific to a sample analyzed, is a sure way to obtaining conclusive results.

Starting from a solid database in terms of records relating to the transport vehicles activity, we fulfill the conditions for using the statistical calculating methods, in order to improve the quality of services offered and the profitability of work carried aut. In this sense, the Pareto method presents the advantages of clear identification of buses with most malfunctions and their type, but also how the defects affect fuel consumption.

Using the mathematical regression method provides the advantages of establishing the degree of correlation between two variables analyzed and verified the results obtained by the Pareto method.

Through mathematical models described, we can identify and certify the existence of irregularities in exploitation of buses, results obtained representing a strong support for the improvement of activities performed, showing imedate, positive visible effects.

5. Conclusions

Improvement of fuel consumption is a major concern for all carriers. By proper definition, implementation and monitoring of technical and administrative measures of fuel consumption reduction, there can be a significant decrease in transportation expenditures.

In addition to optimizing the transport buses fleet operation, an important component that helps to reduce fuel consumption is the application of rigorous preventive and corrective maintenance.

In order to assess the maintenance system applied on a buses fleet of urban public transport, was conducted an analysis of the malfunctions that influence the fuel consumption, on a sample of 11 buses with identical engines.

Knowing the standardised and recorded fuel consumptions of the buses sample analyzed, through the Pareto method, we have traced the variation curve of cumulative relative frequency for the calculated differences between standardised and recorded fuel consumptions, reported to the total value of consumption differences.

Having the fuel consumption recorded and the number of malfunctions recorded for the 11 buses, we have calculated the cumulative relative frequencies of the fuel consumption and malfunctions recorded, using the Pareto method.

In order to determine the influence of the number of malfunctions recorded over fuel consumption, we have performed a statistical analysis using regression models.

By associating the cumulative relative frequencies of the two variables we have found a growing trend, so we can conclude that is a direct correlation between them.

The calculated value of the correlation coefficient being very close to the upper limit of the [-1, +1] range, it confirms that there is a full link between the fuel consumption variable and the "number of malfunctions recorded" variable. The higher the number of registered malfunctions is, the greater fuel consumption there will be.

We have estabilished the degree of influence of the malfunctions number over the fuel consumption, by using the "coefficient of determination". From the calculations we follows that 98% of fuel consumption variations are caused by variations within the recorded malfunctions.

Association of the Pareto analysis results, lead to the conclusion that share of 18% of the buses fleet sample , made by B1 and B2, represents a major risk because of their low reliability level and shows the greatest fuel consumption. In this way, this two units of transport require checking and revising of their technical conditions and also require the need for improving the programmes for technical inspections, through preventive maintenance oriented management.

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6. Glossary [32, 33]

Maintenance - represents a series of organizational and technical measures but also economic, applied in order to maintain the optimal functioning of transport vehicles.

Malfunction - non-compliance in the operation of a system or subsystem of vehicle component which can lead to stopping the vehicle functioning.

Reliability capacity of the transport vehicles to operate a timetable, while maintaining and default parameters.

Fuel consumption - is the fuel consumption of the vehicle fleet, used for carrying out the transport service.

GPS (global positioning system) - technology based on a worldwide radio-navigation system formed from a constellation of satellites and ground receiving stations, fixed or mobile, through which one can determine the position of a vehicle on the globe.

GPRS (General packet radio service) - a packet-based wireless communication service that promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users.

Exploitation - the process of organizing, tracking and using the transport vehicles and the workers in the transportation activity.

Engine torque - Engine torque is the force driven by a lever on a rotation point (torque = force x leverage). An internal combustion engine converts the movement of the lifting and lowering of the piston, through the reciprocating rod, into a rotary motion of the crankshaft with a couple good engine at the crankshaft.

Injection mechanisms - system that ensures optimum fuel quantity distribution for functioning of the internal combustion engine.

Catalyst - It contains a chemical catalyst material efficient, the ceramic carrier material or a metallic material, a housing and various control systems. Are designed to control the catalytic cleaning process exhaust gases .

Lambda probe - measures the amount of oxygen in the exhaust gases and sends the signal to the engine control unit ECU (Engine Control Unit). This signal is used to adjust the air-fuel mixture exactly at the optimum level for an efficiency and a lifetime maximum of catalyst.

Turbocharger system - compress the air required for the combustion process, with results in increased air flow of an engine and increase the engine power, torque and efficiency.

Preheaters systems - is used to preheat the engine at cold starting , in winter.

Pareto method - This technique helps to identify the top portion of causes that need to be addressed to resolve the majority of problems . While it is common to refer to pareto as "80/20" rule, under the assumption that, in all situations, 20% of causes determine 80% of problems, this ratio is merely a convenient rule of thumb and is not nor should it be considered immutable law of nature.

Regression analysis - is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables.

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