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unit material costs; vehicle operation

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AN ANALYSIS OF UNIT REPAIR COSTS AS A FUNCTION OF MILEAGE OF VEHICLES IN A SELECTED TRANSPORT COMPANY

Summary. This paper presents a statistical analyses which was performed for actual data associated with unit material costs of repairs of vehicles operated by the Polish Mail branch in Lublin in the period of three consecutive years. Conducted analyses allowed to determine the parameter values of prepared model of vehicles operating efficiency for considered transport system.

ANALIZA JEDNOSTKOWYCH KOSZTÓW NAPRAW W FUNKCJI PRZEBIEGU KILOMETROWEGO POJAZDÓW W WYBRANEJ FIRMIE TRANSPORTOWEJ

Streszczenie. W artykule opisano wyniki analiz statystycznych (przeprowadzonych na podstawie rzeczywistych danych eksploatacyjnych) związanych z jednostkowymi rzeczowymi kosztami napraw samochodów należących do lubelskiego centrum logistycznego Poczty Polskiej w okresie trzech kolejnych lat. Przeprowadzone analizy pozwoliły na określenie wartości parametrów przygotowywanego modelu efektywności eksploatacji samochodów rozważanego systemu transportowego.

1. INTRODUCTION

An assessment of the economic efficiency of a car as a means of transport should take into account numerous factors, including the intensity of its use, the adopted transport rates, personnel costs, costs of maintenance materials, etc. The two most important factors in the process of operation and maintenance of a vehicle are the vehicle's mileage travelled within a specified period of time (day, month or year) and the costs associated with service and repair of the vehicle [1, 2, 5, 9, 11, 16]. Repair costs are sum of the costs of operating materials and components and labor costs of the staff of a repair station. Operating materials and components include individual elements and assemblies of a vehicle, but also fluids, such as lubricating oil, brake fluid, etc. [4, 8, 14].

A parameter that brings together the two types of operating factors mentioned is unit material cost of repairs. This cost is a quotient of the costs of operating materials and components and the mileage travelled within a specified period of time. The use of this parameter allows one to make an independent comparison of the cost of repairs of vehicles with different cargo capacities [3]. For this reason, statistical analysis of unit material costs of repairs is a helpful tool for freight carriers when they make decisions related to the purchase of a new car [12, 13, 15].

In the present article such analyses were performed for actual data associated with unit material costs of repairs of vehicles operated by Poczta Polska (the Polish Mail) branch in Lublin in the period of three consecutive years.

2. STATEMENT OF THE PROBLEM

The analysis presented in this article covered a group of 116 cars used by Poczta Polska in Lublin in the period of three years (2008–2010) [7]. This group consisted of vehicles of different makes and types which performed a variety of transportation tasks specific to the manner of operation of postal service. The vehicles were divided into three groups which differed primarily in cargo capacity. Subgroup I were LCV vans (e.g., the Fiat Doblo), which ran between mailboxes and carried mail in the urban area of the city of Lublin and its vicinity. This group consisted of 32 cars.

MCV vans (e.g., the VW Transporter) were sub-group II. These vehicles moved a variety of mail between post offices in the city of Lublin and the former Lublin province. This group consisted of 60 vehicles. Lorries, characterized by the highest cargo capacity (e.g., the IVECO Stralis) represented sub-group III. These vehicles transported mail mainly on routes between regional logistics centres of Poczta Polska, thus connecting Lublin with other capitals of Polish provinces. This group comprised 24 vehicles.

3. STATISTICAL ANALYSIS

Statistical analyses of data related to monthly, annual and total (three-year) unit material costs of repairs of vehicles of Poczta Polska were performed using StatSoft Statistica software. The values of basic statistical parameters for this variable in the periods of one and three years of use for the three test subgroups are shown in table 1.

An analysis of the results from table 1 shows that there are differences in the yearly values of mean unit repair costs between the subgroups of vehicles. The highest values occur in group I and the lowest in group III. To test whether the observed differences were statistically significant, an analysis of variance was carried out.

Table 1

Unit material costs of repairs for three groups of vehicles – descriptive statistics

Vehicle group	Year	Mean value	Median	Min. value	Max. value	Standard deviation
		[PLN/km]	[PLN/km]	[PLN/km]	[PLN/km]	[PLN/km]
I	2008	0.099	0.090	0.0135	0.248	0.054
	2009	0.139	0.109	0.0159	0.388	0.082
	2010	0.221	0.196	0.0047	0.770	0.144
	2008–2010	0.141	0.142	0.0122	0.284	0.055
II	2008	0.088	0.071	0.0010	0.434	0.0793
	2009	0.086	0.075	0.0001	0.246	0.062
	2010	0.098	0.085	0.0007	0.318	0.068
	2008–2010	0.089	0.088	0.0010	0.228	0.054
III	2008	0.051	0.039	0.0027	0.176	0.048
	2009	0.045	0.045	0.0021	0.140	0.039
	2010	0.071	0.070	0.0052	0.220	0.055
	2008–2010	0.056	0.052	0.0047	0.130	0.042

The first step of the analysis of variance, as is well known, is to test the assumption of normal distribution of unit material costs of repairs of vehicles. The Shapiro–Wilk (**SW**) test was used for this purpose [6]. The results of the calculations are shown in table 2. Normality of distribution was assumed at the level of significance of the test $\alpha = 0.05$.

On the basis of the results presented in table 2, it can be stated that the assumption of normal distribution of the analyzed variable is not satisfied in the individual periods compared. For that reason non-parametric analysis of variance was applied using the Kruskal-Wallis test **KW** [6]. The results of this analysis in the individual years of vehicle operation for the grouping factor "membership of the

vehicle in a specific group" is shown in table 3. Table 4, in turn, presents the results of multiple comparisons of the **KW** test in the individual years analyzed.

Table 2

Unit material costs of repairs for three groups of vehicles – normality test

Vehicle group	Year	Value of the SW test statistic	*p*-value	Normality of distribution
I	2008	0.9537	0.1833	Yes
	2009	0.9213	0.0225	No
	2010	0.8656	0.0009	No
	2008–2010	0.9706	0.5161	Yes
II	2008	0.8613	0.0000	No
	2009	0.9452	0.0013	No
	2010	0.9110	0.0000	No
	2008–2010	0.9613	0.0128	No
III	2008	0.8817	0.0090	No
	2009	0.8908	0.0138	No
	2010	0.9030	0.0250	No
	2008–2010	0.9127	0.0405	No

Table 3

Results of the Kruskal-Wallis **KW** test of equality of mean unit material costs of repairs for the three test groups of vehicles (grouping factor – vehicle group)

Year	Value of the KW test statistic	*p*-value	Differences
2008	11.9251	0.0026	Yes
2009	26.4993	0.0000	Yes
2010	31.0487	0.0000	Yes
2008–2010	29.9017	0.0000	Yes

Table 4

Results of multiple comparisons for mean unit material costs of repairs for the three test groups of vehicles

a) year 2008

	Group I	Group II	Group III
Group I		1.0000	**0.0038**
Group II	1.0000		**0.0075**
Group III	**0.0038**	**0.0075**	

b) year 2009

	Group I	Group II	Group III
Group I		0.1725	**0.0000**
Group II	0.1725		**0.0002**
Group III	**0.0000**	**0.0002**	

c) year 2010

	Group I	Group II	Group III
Group I		**0.0000**	**0.0000**
Group II	**0.0000**		0.1420
Group III	**0.0000**	0.1420	

d) years 2008–2010

	Group I	Group II	Group III
Group I		**0.0034**	**0.0000**
Group II	**0.0034**		**0.0049**
Group III	**0.0000**	**0.0049**	

The results of the calculations presented in tables 3 and 4 show that, at the adopted level of significance of the test $\alpha = 0.05$, the differences observed in mean values of yearly unit material costs of repairs are statistically significant for the investigated vehicle groups. In the years 2008 and 2009, the differences occurred between group III and the remaining two groups of vehicles. In the year 2010, they were observed between group I vs. groups II and III. Within the analyzed three-year period, these differences concerned each of the test groups. The highest mean values of yearly unit costs of vehicle repairs were found for group I vehicles. This follows from the fact that the vehicles travelled along urban routes. Such operating conditions are, as commonly known, characterized by a high load variation, which causes faster wear of parts and assemblies.

Fig. 1 shows a categorized box plot for yearly unit costs of repairs in the investigated groups of vehicles of Poczta Polska.

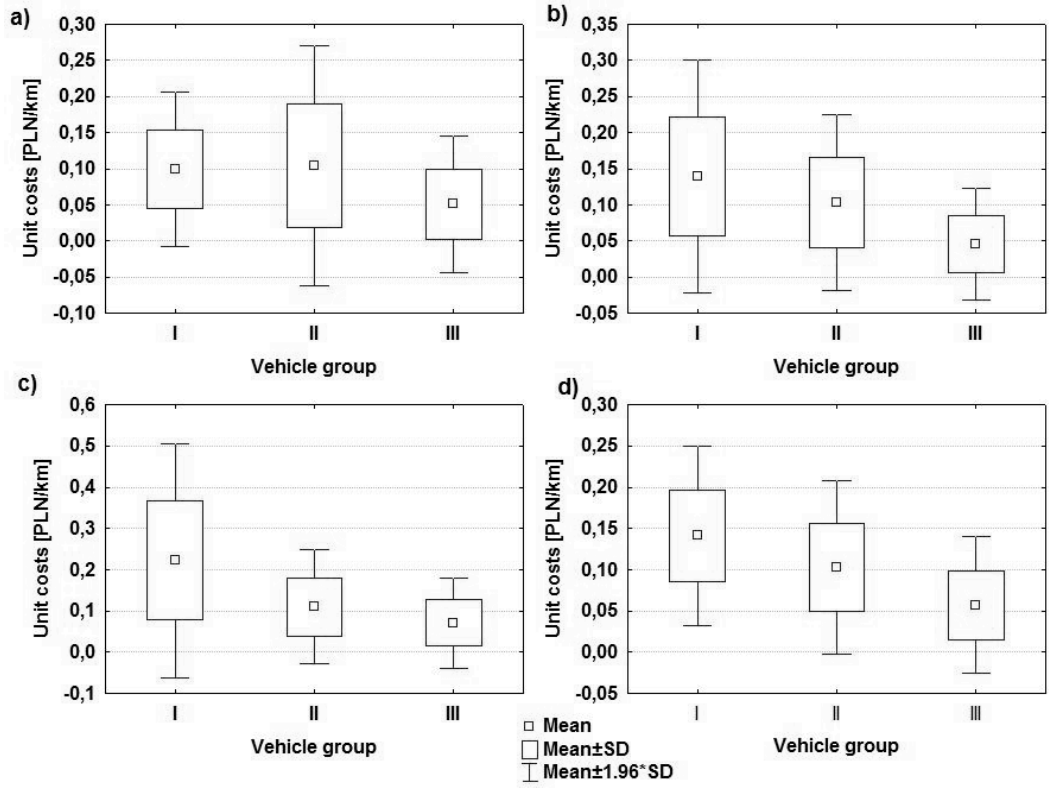

Fig. 1. A categorized box plot for the independent factor – vehicle group, and the dependent variable – yearly unit material costs of their repairs; a) year 2008, b) year 2009, c) year 2010, d) sum of unit costs in the period 2008-2010

Rys. 1. Skategoryzowany wykres ramkowy dla czynnika niezależnego, jakim jest grupa pojazdów, i zmiennej zależnej – roczne jednostkowe rzeczowych kosztów ich napraw; a) rok 2008, b) rok 2009, c) rok 2010, d) suma jednostkowych kosztów w okresie 2008-2010

Another statistical analysis involved a comparison of mean values of yearly costs of repairs in the individual groups of vehicles for the successive years of their use. The results of this analysis are shown in Table 5. Table 6 shows the results of post-hoc tests.

The results of the calculations presented in tables 5 and 6 show that the observed differences in mean values of yearly unit material costs of repairs in the successive years of use are statistically significant only for vehicles belonging to group I. A systematic increase in their mean value is observed (see table 1).

Table 5

Results of the Kruskal-Wallis **KW** test of equality of mean unit material costs of repairs for the three test groups of vehicles (grouping $_{\text{factor}}$ – year of use)

Vehicle group	**Value of the KW test statistic**	***p*-value**	**Differences**
I	21.0968	0.0000	Yes
II	1.1221	0.5706	No
III	4.9332	0.0849	No

Table 6

Results of multiple comparisons for mean unit material costs of repairs for the three test groups of vehicles

a) Group I

	Year 2008	Year 2009	Year 2010
Year 2008		0.2013	**0.0000**
Year 2009	0.2013		**0.0188**
Year 2010	**0.0000**	**0.0188**	

b) Group II

	Year 2008	Year 2009	Year 2010
Year 2008		1.0000	0.9137
Year 2009	1.0000		1.0000
Year 2010	0.9137	1.0000	

c) Group III

	Year 2008	Year 2009	Year 2010
Year 2008		1.0000	0.2693
Year 2009	1.0000		0.1099
Year 2010	0.2693	0.1099	

Fig. 2 shows a categorized box plot for yearly unit costs of repairs of vehicles of Poczta Polska in the individual years of use.

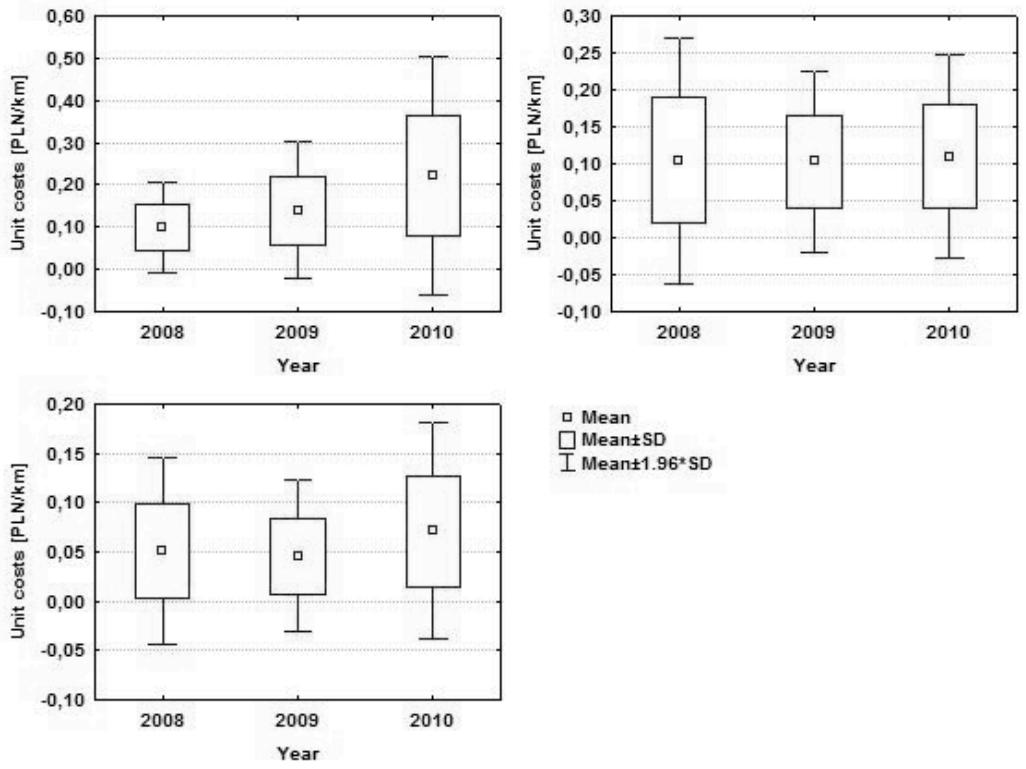

Fig. 2. A categorized box plot for the independent factor – year of use, and the dependent variable – yearly vehicle repair costs; a) group I, b) group II, c) group III

Rys. 2. Skategoryzowany wykres ramkowy dla czynnika niezależnego, jakim jest rok użytkowania pojazdów, i zmiennej zależnej – roczne jednostkowe rzeczowych kosztów ich napraw; a) grupa nr I, b) grupa nr II, c) grupa nr III

A final statistical analysis involved a comparison of mean values of monthly unit material costs of repairs in the individual groups of vehicles for the successive years of their use. The results of this analysis are shown in table 7.

Table 7

Results of the Kruskal-Wallis **K-W** test of equality of mean unit material costs of repairs for the three test groups of vehicles (grouping factor – year of use)

Vehicle group	Year	Value of the K-W test statistic	*p*-value	Differences
I	2008	21.7592	0.0263	Yes
	2009	22.6987	0.0165	Yes
	2010	8.0588	0.7080	No
	2008–2010	12.0580	0.3593	No
II	2008	13.0256	0.2917	No
	2009	12.0877	0.3571	No
	2010	26.0485	0.0055	Yes
	2008–2010	17.7135	0.0885	No
III	2008	5.5617	0.8956	No
	2009	14.5586	0.2036	No
	2010	23.4847	0.0151	Yes
	2008–2010	11.8887	0.3721	No

The results of multiple comparisons tests demonstrated that in group I of vehicles in the year 2008 there were differences in the value of mean monthly unit material costs of repairs between June (the lowest values) vs. May, October and November. In the year 2009, differences were observed between February vs. July and August (lowest values) and April vs. the same two months. For vehicles of group II, differences in mean values of monthly unit material costs of repairs in the year 2010 concerned the month of November relative to February, July, September, and December. The results of post-hoc tests showed that for group III differences in mean monthly unit material costs of vehicle repairs were found between May (the lowest value) vs. March, June, October, November and December 2010. Figures 3–5 show categorized box plots for monthly unit material costs of repairs of the three investigated groups of vehicles of Poczta Polska in each year of use.

Higher mean values of monthly unit material costs of repairs are due to the impact of weather conditions on the circumstances in which the cars travelled (the autumn period). The deterioration of transport conditions in autumn leads to more frequent traffic collisions and faster wear of machinery, which significantly increases the costs of auto repairs.

4. CONCLUSIONS

Based on the results of the present analyses of variance performed on actual data related to the costs of replacement of operating materials and components as related to the number of kilometers travelled by vehicles of the fleet of Poczta Polska in Lublin during the specified time of use (one year or more), it can be concluded that the lowest unit material costs were incurred by vehicles with large cargo capacity. This is due to the fact that these cars ran mostly on routes outside the city, which are characterized by lower variability of loads. This resulted in lower intensity of wear of machine components of these technical objects.

There was also a steady increase in the average unit values of material costs of repairs, which was a consequence of inflation occurring in the investigated three-year period. This is particularly evident in the group of vehicles which are characterized by a higher failure rate. Additionally, the value of the analyzed unit material costs of repairs increased during periods of bad weather (early spring and autumn).

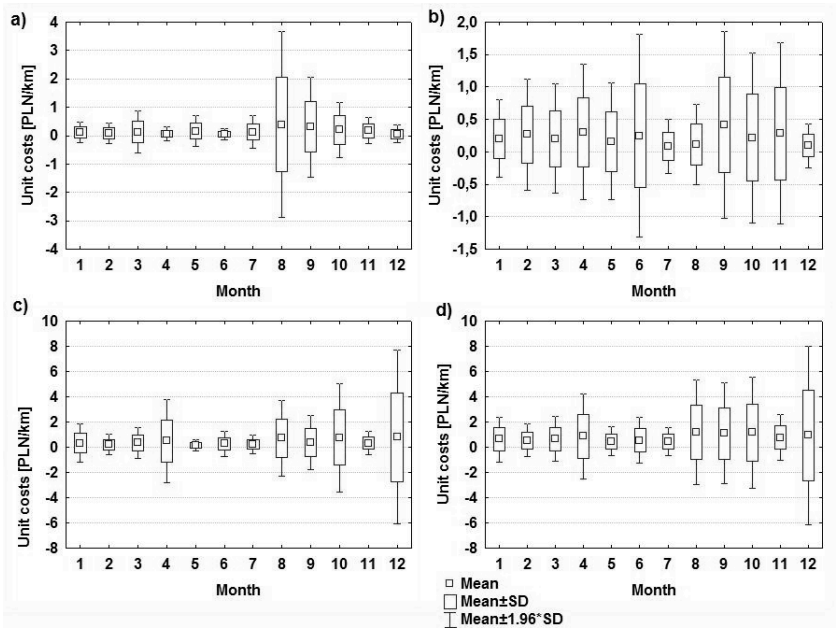

Fig. 3. A categorized box plot for the independent factor – month of use, and the dependent variable – monthly unit material costs of repairs of group I vehicles; a) year 2008, b) year 2009, c) year 2010, d) years 2008-2010

Rys. 3. Skategoryzowany wykres ramkowy dla czynnika niezależnego, jakim jest miesiąc użytkowania pojazdów grupy nr I, i zmiennej zależnej – miesięczne jednostkowe rzeczowych kosztów ich napraw; a) rok 2008, b) rok 2009, c) rok 2010, d) lata 2008-2010

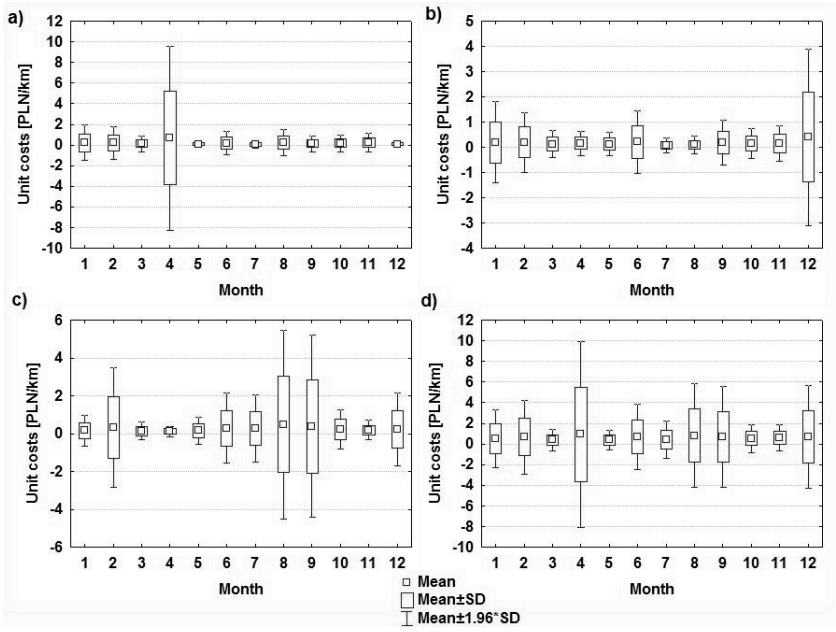

Fig. 4. A categorized box plot for the independent factor – month of use, and the dependent variable – monthly unit material costs of repairs of group II vehicles; a) year 2008, b) year 2009, c) year 2010, d) years 2008-2010

Rys. 4. Skategoryzowany wykres ramkowy dla czynnika niezależnego, jakim jest miesiąc użytkowania pojazdów grupy nr II, i zmiennej zależnej – miesięczne jednostkowe rzeczowych kosztów ich napraw; a) rok 2008, b) rok 2009, c) rok 2010, d) lata 2008-2010

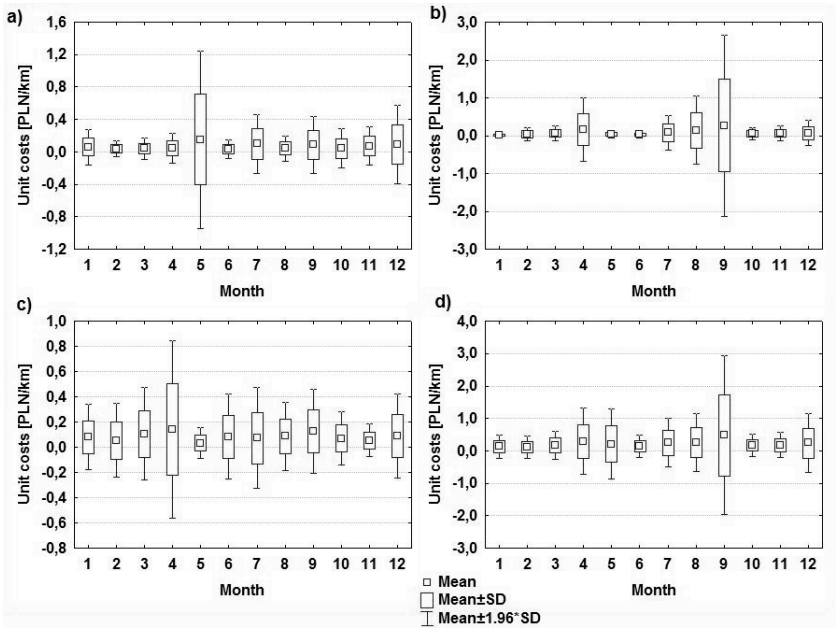

Fig. 5. A categorized box plot for the independent factor – month of use, and the dependent variable – monthly unit material costs of repairs of group III vehicles; a) year 2008, b) year 2009, c) year 2010, d) years 2008-2010

Rys. 5. Skategoryzowany wykres ramkowy dla czynnika niezależnego, jakim jest miesiąc użytkowania pojazdów grupy nr III, i zmiennej zależnej – miesięczne jednostkowe rzeczowych kosztów ich napraw; a) rok 2008, b) rok 2009, c) rok 2010, d) lata 2008-2010

5. FINAL REMARKS

The article uses a simplified methodology of calculating unit costs of repairs of a fleet of a car transport system. The aim of the present analysis was only to determine the approximate values of this operation parameter for comparative reasons (in the entire studied population as well as in groups of vehicles with a similar cargo capacity). When developing a computational model for forecasting and planning costs of repairs of a fleet operated at a selected company, one should also take into account the fact that each car manufacturer have their own specific standards, specifying the required scheduled servicing of their product and the relevant frequency depending on the vehicle's mileage or age [10]. Age of the vehicle and its mileage have a significant impact on its operational reliability. Older and intensely used vehicles are more likely to be prone to random failures, which cannot be prevented solely by observing the services and repairs recommended by the manufacturer. Thus, in addition to cargo capacity, one should take into account other factors grouping objects of the studied population: vehicle mileage and calendar age. In the future, after collecting sufficient research material, the authors of the article intend to expand the presented analyses to include the above-mentioned aspects.

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