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AN ANALYSIS OF COSTS OF VEHICLE REPAIRS IN A TRANSPORTATION COMPANY. PART I

Summary. This paper presents results of the statistical analysis of the operating parameters of a vehicle population, which was operated by the Poczta Polska (Polish Mail) delivery office in Lublin. The calculations was based on data from service in the years 2008–2010.

ANALIZA KOSZTÓW NAPRAW POJAZDÓW NA PRZYKŁADZIE WYBRANEJ FIRMY TRANSPORTOWEJ. CZ. I

Streszczenie. W artykule opisano wyniki analizy statystycznej wybranych parametrów eksploatacyjnych populacji pojazdów należących do lubelskiego centrum logistycznego Poczty Polskiej. Obliczenia przeprowadzono na podstawie danych zebranych w latach 2008–2010.

1. INTRODUCTION

Many different operation and maintenance indices are used in evaluating a transport system. They include intensity of vehicle use, profit from a transportation service, mass of cargo transported, personnel costs, the costs of fuel and lubricating oil, etc. The most important of those indices is the intensity of use defined as the number of kilometers traveled by a car within a specified period of time (day, month, or year). Intensity of use affects other parameters of operation and maintenance of a given vehicle, such as vehicle life, the income from transportation services, drivers' working time, etc. [6, 8, 10].

Some of the most important parameters, apart from intensity of use, are service and repair costs. Repair costs are a sum of the costs of operating materials and components plus labor costs of the staff working at a repair station. The costs of operating materials and components include the costs of individual elements, parts, assemblies, and fluids (lubricating oil, brake fluid, etc.), excluding fuel costs.

It seems interesting, both from a scientific and an utilitarian point of view, to conduct a statistical analysis of costs of replacement of operating materials and components for a specific car transport system. Results of such an analysis may be instrumental in taking decisions related to transportation services or purchase of new means of transport. Statistical analysis may also represent an important criterion in the assessment of the economic effectiveness of a transport system [1, 2, 9, 11].

This article presents the results of statistical analyses of real-life data related to the costs of replacement of operating materials and components for delivery vehicles belonging to the fleet of the Polish Mail company in Lublin. The analyses span three years of operation.

2. A CHARACTERIZATION OF THE ANALYZED POPULATION OF VEHICLES

The authors of the paper had access to information regarding a population of 179 cars operated in the years 2008–2010 in the Polish Mail company in Lublin. Only data for vehicles which were used uninterruptedly over those years (116 test objects) were subjected to statistical analyses. The test vehicles represented many makes and types and carried out various transportation tasks. On the basis of previous analyses [4, 5, 7], the vehicles were divided into three distinctive groups differing in load space volume.

Group I included passenger vehicles with small load space volumes (e.g., the Citroen Berlingo). The cars in this group ran between post boxes and were used to deliver mail in the city of Lublin and vicinity. This group consisted of 32 vehicles. Group II were delivery trucks characterized by medium load space volumes (e.g., the Ford Transit). They moved mail between post offices in the city of Lublin and the former Lublin voivodeship. This group was the largest and consisted of 60 vehicles. Vehicles with large load space volumes (e.g., the Iveco Stralis) were classified in group III. They ran along routes outside the area of the former Lublin voivodeship between regional logistics centers of the Polish Mail. That group consisted of 23 vehicles. Two of those vehicles were brand new and began to be operated in January 2008.

3. RESULTS OF STATISTICAL ANALYSES

Statistical analyses of the data related to the yearly costs (in PLN) of replacement of operating materials and components in vehicles operated in the Polish Mail company in Lublin over the years 2008–2010 were performed using Statistica® software. The descriptive statistics for yearly costs of replacement of operating materials and components in vehicles from group I are shown in Table 1.

Table 1

Yearly costs of replacement of operating materials and components
for group I vehicles – descriptive statistics

Year	Mean value	Median	Min. value	Max. value	Standard deviation
	[PLN]	[PLN]	[PLN]	[PLN]	[PLN]
2008	1902.25	1849.64	288.90	5306.22	1118.09
2009	1981.11	2141.11	243.00	4875.72	1106.60
2010	2681.15	2422.46	71.65	8481.73	1802.38

Fig. 1 shows histograms for yearly costs of replacement of operating materials and components in group I vehicles. The Shapiro–Wilk test was used to assess the goodness-of-fit of these distributions to the normal distribution [3]. And so in the year 2008, the value of the **SW** statistic was $\mathbf{SW} = 0.9393$ at the level of significance $p = 0.0715$. In 2009, $\mathbf{SW} = 0.9639$ at $p = 0.3576$. In 2010, $\mathbf{SW} = 0.8288$ at $p = 0.00015$. These results indicate that at the adopted level of significance of the test ($p = 0.05$), the hypothesis of the fit of the empirical distribution to the normal distribution for yearly costs of replacement of operating materials and components in vehicles from group I should be rejected only for the year 2010.

Next, the analysis of variance was carried out to test whether the observed differences in mean values for yearly costs of replacement of operating materials and components in vehicles from group I in the three years of observation were statistically significant. Because the classical analysis of variance could not be used (lack of fit of the empirical distributions to the normal distribution), a non-parametric method of analysis of variance was applied using the Kruskal-Wallis **KW** test [3]. The calculations demonstrated that the value of the Kruskal-Wallis statistic was $\mathbf{KW} = 4.88$ at the level of

significance $p = 0.087$. This result indicates that there were no significant differences in mean yearly costs of replacement of operating materials and components in group I vehicles in the analyzed years. Fig. 2 shows a categorized box plot for yearly costs of replacement of operating materials and components in group I vehicles.
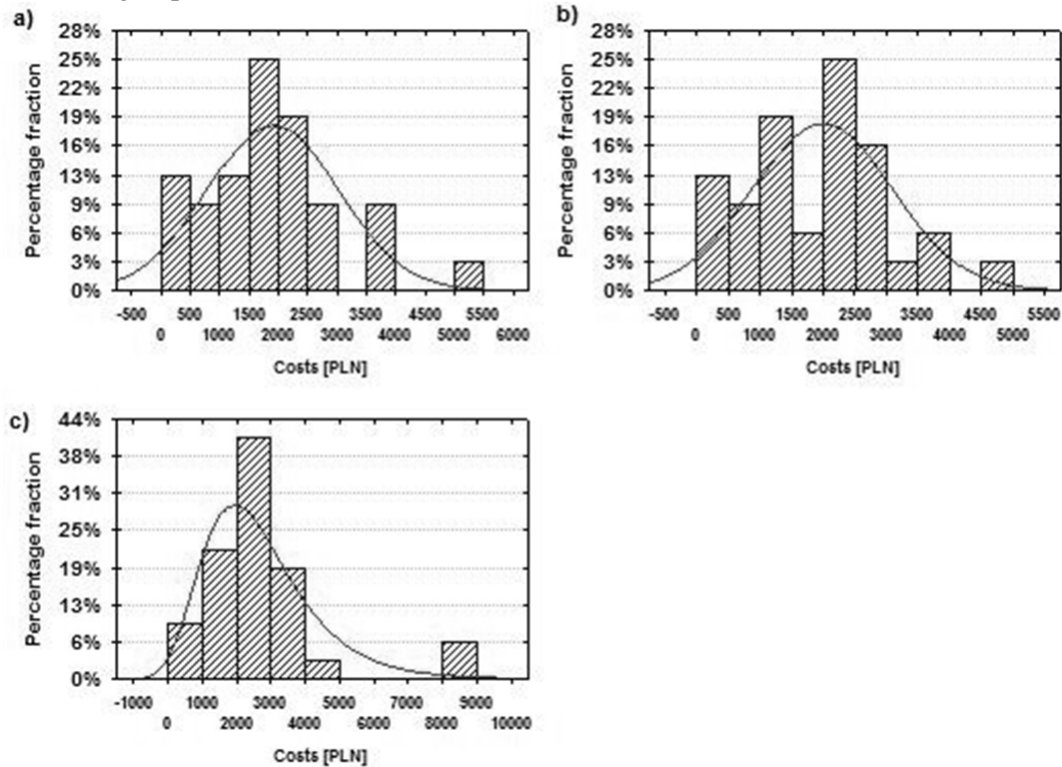

Fig. 1. Histograms of empirical distributions of yearly costs of replacement of operating materials and components in group I vehicles; a) year 2008, b) year 2009, c) year 2010; (goodness of fit for the extreme value distribution with a location parameter = 1938.88 and a scale parameter = 1260.21)

Rys. 1. Histogramy rozkładów empirycznych wartości rocznej intensywności użytkowania pojazdów grupy II; a) rok 2008, b) rok 2009, c) rok 2010; (dopasowanie rozkładem wartości ekstremalnych o parametrze położenia = 1938,88 i skali = 1260,21)
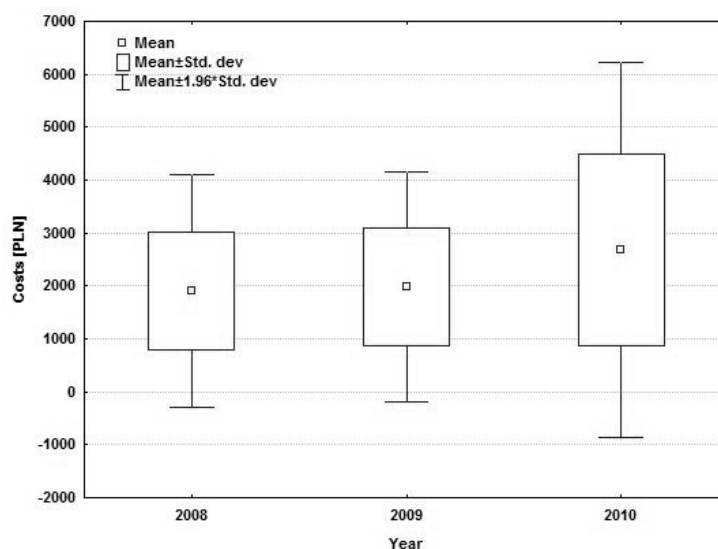

Fig. 2. A categorised box plot for the independent factor – year of operation, and the dependent variable – yearly costs of replacement of operating materials and components in group I vehicles

Rys. 2. Skategoryzowany wykres ramkowy dla roku eksploatacji jako czynnika niezależnego i zmiennej zależnej – rocznej wartości kosztów wymiany rzeczowych czynników eksploatacji pojazdów grupy nr I

The descriptive statistics for yearly costs of replacement of operating materials and components in vehicles from groups II and III were also calculated. The results are shown in Tables 2 and 3.

Table 2

Yearly costs of replacement of operating materials and components
for group II vehicles – descriptive statistics

Year	Mean value [PLN]	Median [PLN]	Min. value [PLN]	Max. value [PLN]	Standard deviation [PLN]
2008	4218.12	3528.10	56.46	19244.70	3295.38
2009	4132.91	3816.65	11.62	11771.18	2923.96
2010	4184.30	4048.92	27.71	12232.07	2800.91

Table 3

Yearly costs of replacement of operating materials and components
for group III vehicles – descriptive statistics

Year	Mean value [PLN]	Median [PLN]	Min. value [PLN]	Max. value [PLN]	Standard deviation [PLN]
2008	5807.52	5453.67	300.31	14816.52	4936.72
2009	4463.66	3911.00	359.19	15246.44	4196.42
2010	9111.05	9115.71	776.54	26706.73	7383.46

Fig. 3 shows histograms for yearly costs of replacement of operating materials and components in group II vehicles. The Shapiro–Wilk test was used to assess the fit of these distributions to the normal distribution. In 2008, the value of the **SW** statistic was $SW = 0.8688$ at the level of significance $p = 0.00001$, and in the year 2009 $SW = 0.9389$ at $p = 0.0048$. In 2010, $SW = 0.9301$ at the level of significance $p = 0.0020$. The results indicate that at the adopted level of significance of the test ($p = 0.05$), the hypothesis of the fit of the empirical distribution to the normal distribution for yearly costs of replacement of operating materials and components in vehicles from group II in the successive years of observation should be rejected. All empirical distributions in Fig. 3 were fitted by the extreme value distribution.

The analysis of variance was performed to test whether the observed differences in mean values for yearly costs of replacement of operating materials and components in vehicles from group II in the three years of observation were statistically significant. Again, a non-parametric method of analysis of variance was applied using the Kruskal-Wallis **KW** test. The value of the test statistic was $KW = 0.0657$ at the level of significance $p = 0.9677$. This indicates that there were no significant differences in mean yearly costs of replacement of operating materials and components in group II vehicles. Fig. 4 presents a categorized box plot for yearly costs of replacement of operating materials and components in group II vehicles.

Fig. 5 shows histograms for yearly costs of replacement of operating materials and components in group III vehicles. The Shapiro–Wilk test was used to assess the goodness-of-fit of these distributions to the normal distribution. And so, in the year 2008, $SW = 0.8900$ and the level of significance $p = 0.0133$, and in the year 2009 $SW = 0.8509$ and $p = 0.0022$. In 2010, $SW = 0.9123$, and the level of significance $p = 0.0397$. These results indicate that at the adopted level of significance of the test ($p = 0.05$), the hypothesis of the fit of the empirical distribution to the normal distribution for yearly

costs of replacement of operating materials and components in vehicles from group III in the successive years of observation should be rejected. All empirical distributions in Fig. 5 were fitted by the extreme value distribution.
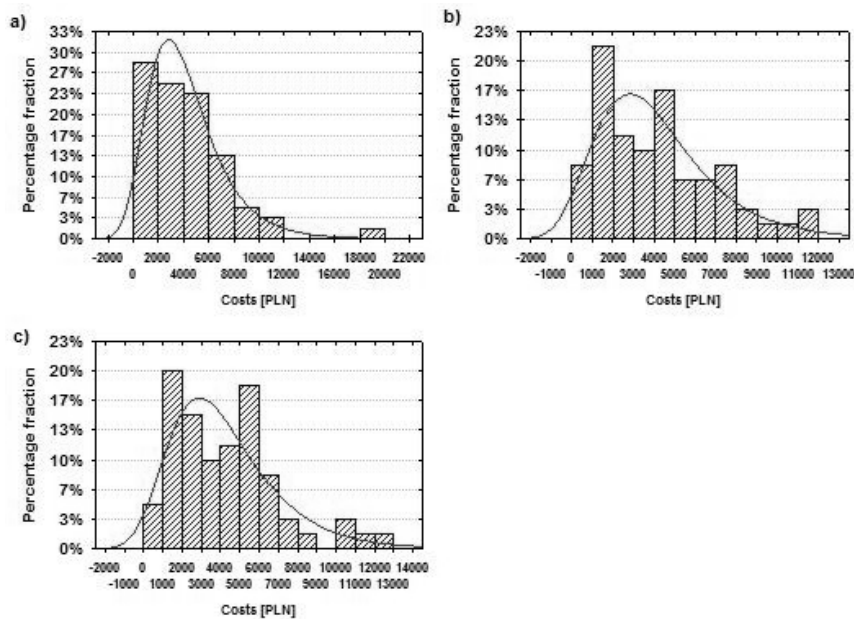

Fig. 3. Histograms of empirical distributions of yearly costs of replacement of operating materials and components in group II vehicles; a) year 2008 (location parameter = 2825.69 and scale parameter = 2300.80), b) year 2009 (location parameter = 2792.21 and scale parameter = 2259.12), c) year 2010 (location parameter = 2910.96 and scale parameter = 2171.32)

Rys. 3. Histogramy rozkładów empirycznych wartości rocznej intensywności użytkowania pojazdów grupy II; a) rok 2008 (parametr położenia = 2825,69, parametr skali = 2300,80), b) rok 2009 (parametr położenia = 2792,21, parametr skali = 2259,12), c) rok 2010 (parametr położenia =2910,96, parametr skali = 2171,32)
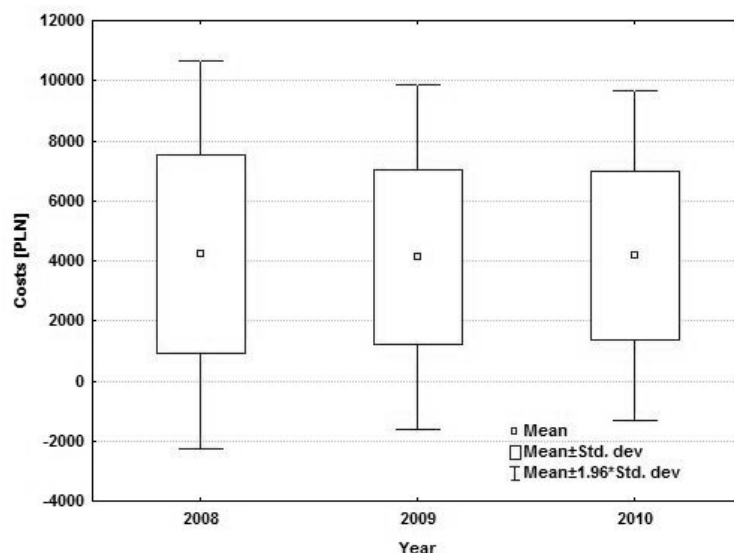

Fig. 4. A categorized box plot for the independent factor – year of operation, and the dependent variable – yearly costs of replacement of operating materials and components in group II vehicles

Rys. 4. Skategoryzowany wykres ramkowy dla roku eksploatacji jako czynnika niezależnego oraz zmiennej zależnej – rocznej wartości kosztów wymiany rzeczowych czynników eksploatacji pojazdów grupy nr II
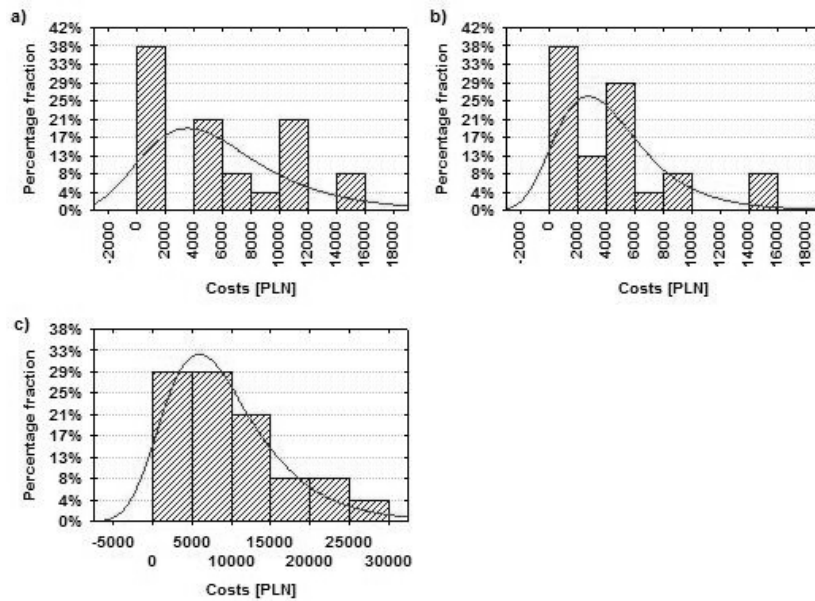
Fig. 5. Histograms of empirical distributions of yearly costs of replacement of operating materials and
      components in group III vehicles; a) year 2008 (location parameter = 3487.29 and scale parameter =
      3934.280), b) year 2009 (location parameter = 2673.71 and scale parameter = 2828.49), c) year 2010
      (location parameter = 5754.40 and scale parameter = 5647.98)
Rys. 5. Histogramy rozkładów empirycznych wartości rocznej intensywności użytkowania pojazdów grupy III;
      a) rok 2008 (parametr położenia = 3487,29, parametr skali = 3934,280), b) rok 2009 (parametr położenia
      = 2673,71, parametr skali = 2828,49), c) rok 2010 (parametr położenia = 5754,40 parametr skali =
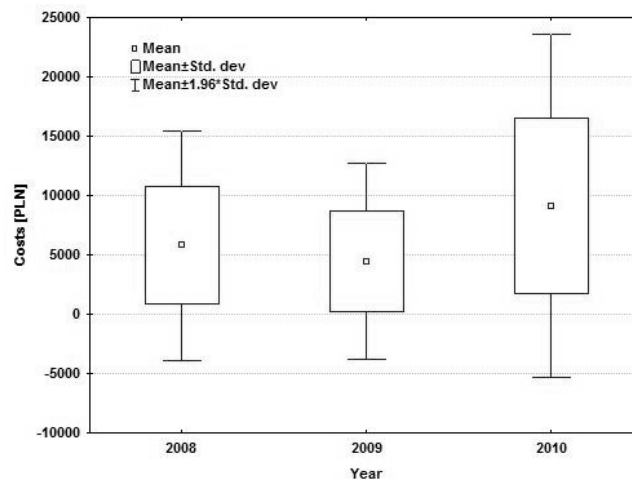   5647,98)

Fig. 6. A categorized box plot for the independent factor – year of operation, and the dependent variable – yearly
      costs of replacement of operating materials and components in group III vehicles
Rys. 6. Skategoryzowany wykres ramkowy dla roku eksploatacji jako czynnika niezależnego oraz zmiennej
      zależnej – rocznej wartości kosztów wymiany rzeczowych czynników eksploatacji pojazdów grupy nr III

    A non-parametric method of analysis of variance was used to test whether the observed differences
in mean values for yearly costs of replacement of operating materials and components in vehicles from
group III in the three years of observation were statistically significant. The value of the test statistic
KW = 6.7642 at $p = 0.034$ indicates that there were significant differences in the mean values of yearly
costs of replacement of operating materials and components among vehicles from group III. Fig. 6
presents a categorized box plot for yearly costs of replacement of operating materials and components
in group III vehicles.

As a next step, it was tested whether there were statistically significant differences, for the individual years of operation, among the mean costs of replacement of operating materials and components in the investigated groups of delivery vehicles operated by the Polish Mail in Lublin. The value of the test statistic in 2008 was **KW** = 13.9008 at the level of significance $p = 0.001$. In 2009, **KW** = 11.482 at $p = 0.0032$. And in 2010, **KW** = 12.8479 at $p = 2010$. The results obtained indicates that there were significant differences among the mean values of costs of replacement of operating materials and components for the investigated groups in the individual years. Fig. 7 presents a categorized box plot of yearly costs of replacement of operating materials and components for the tested groups of vehicles belonging to the Polish Mail in Lublin for the individual years.
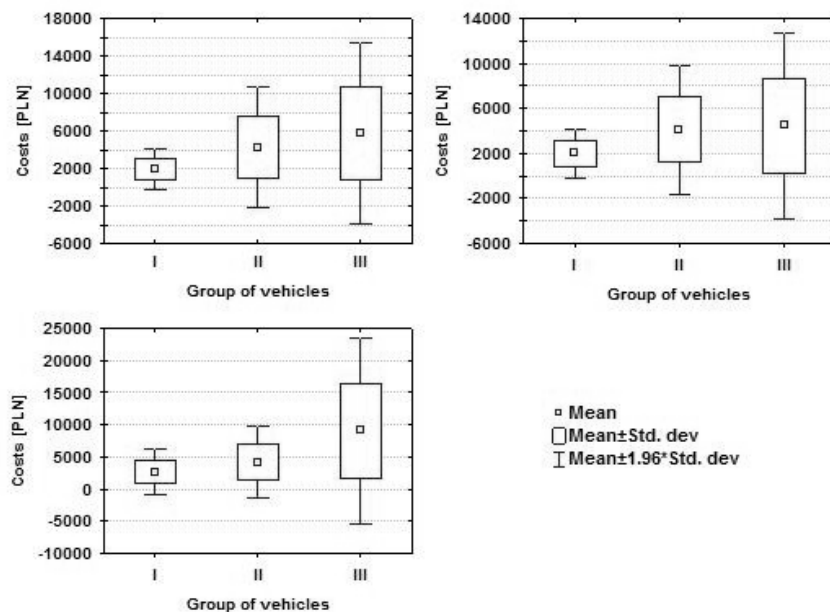

Fig. 7. A categorized box plot for the independent factor – group of vehicles, and the dependent variable – yearly costs of replacement of operating materials and components in a given group; a) year 2008, b) year 2009, c) year 2010

Rys. 7. Skategoryzowany wykres ramkowy dla czynnika niezależnego – grupy pojazdów oraz zmiennej zależnej – rocznej wartości kosztów wymiany rzeczowych czynników eksploatacji w danej grupie; a) rok 2008, b) rok 2009, c) rok 2010

Finally, the previously employed non-parametric method of analysis of variance was used to test whether the observed differences in mean values of yearly costs of replacement of operating materials and components for all the investigated vehicles in the three years of observation were statistically significant. The value of the test statistic **KW** = 4.0297 at $p = 0.1333$ indicates that there were no statistically significant differences in mean values of yearly costs of replacement of operating materials and components for all the investigated vehicles in the three years of observation. Fig. 8 shows a categorized box plot for yearly costs of replacement of operating materials and components in the investigated vehicles of the Polish Mail in Lublin.

An analysis of the plot in Figure 8 demonstrates that in the years 2008–2010, the mean values of costs of replacement of operating materials and components in the vehicles belonging to the fleet of the Polish Mail changed from 3908.12±3564.44 PLN in the year 2008, to 3607.74±3044.89 PLN in 2009, to 4788.97±4596.65 PLN.
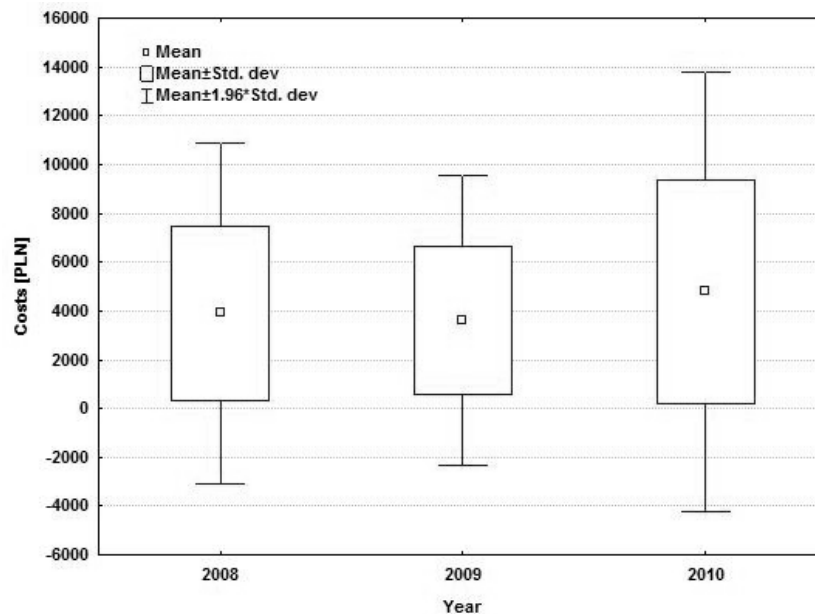
Fig. 8. A categorized box plot for the independent factor – year of operation, and the dependent variable – yearly costs of replacement of operating materials and components for all cars operated by the Polish Mail in Lublin

Rys. 8. Skategoryzowany wykres ramkowy dla czynnika niezależnego –roku eksploatacji oraz zmiennej zależnej – rocznej wartości kosztów wymiany rzeczowych czynników eksploatacji dla wszystkich samochodów Poczty Polskiej w Lublinie

4. CONCLUSIONS

The results of the statistical analyses conducted in this paper for real-life data from three-year observations related to the costs of replacement of operating materials and components in delivery vehicles of the Polish Mail company in Lublin allows us to say that

1) The division of the population of the delivery vehicles into three groups according to the criterion of load space volume is accurate and should be taken into consideration each time a transport system is being evaluated. This conclusion is supported by the differences in the mean values of costs of replacement of operating materials and components for those groups.

2) No changes in the costs of replacement of operating materials and components were observed over the analyzed years 2008–2010. This probably results from a lack of changes in the costs of parts as well as a decrease in the intensity of use of the investigated vehicles, described by the present authors in other articles.

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