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AN ANALYSIS OF THE RELATIONSHIPS AMONG SELECTED OPERATING AND MAINTENANCE PARAMETERS OF VEHICLES USED IN A TRANSPORTATION COMPANY

Summary. This paper presents results of the statistical analysis of the operating parameters of a vehicle population, which was operated by the Polish Mail delivery office in Lublin. The calculations were based on data from service in 2009.

ANALIZA ZWIĄZKÓW POMIĘDZY WYBRANYMI PARAMETRAMI EKSPLOATACJI POJAZDÓW W FIRMIE TRANSPORTOWEJ

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 2009 r.

1. INTRODUCTION

There are many parameters and operational indices that are used in the evaluation of a car transportation system of a given transportation company. The indices include the intensity of vehicle use, profit from transportation services, mass of cargo transported, etc. These parameters also include the costs of personnel, fuel, lubricating oil, repairs, etc [4, 5].

Some of the most important of those parameters are intensity of use and auto repair costs. Intensity of use is defined here as the number of kilometers travelled by a car within a specified period of time (day, month, or year) [3, 9]. The value of intensity of use affects many other operational indices: vehicle life, profits from transportation services, drivers' working time, etc. Auto repair costs, on the other hand, include the costs of operating materials and components and labour costs of the staff of a repair station. Operating materials and components comprises individual elements, parts and assemblies, and fluids (lubricating oil, brake fluid, etc.) [1, 7].

It seems interesting, from a utilitarian point of view, to determine the relationships observed among those parameters during operation of a car. This may be instrumental in evaluating the economic effectiveness of a transport system as well as in taking various decisions related to transportation services [6, 8].

The article presents the results of correlation analyses of real-life data related to the intensity of use, repair costs, and the number of replaced parts or assemblies for delivery vans of the Polish Mail company in Lublin. The data were collected during one year of operations.

2. A SHORT CHARACTERIZATION OF THE TEST POPULATION OF VEHICLES

The study was conducted using data for 179 vehicles operated in 2009 by the Polish Mail delivery office in Lublin. The test vehicles carried out various transportation tasks. Because the analyzed population consisted of many types and makes of cars, it was divided into three groups according to the criterion of load space volume.

Group I included passenger vehicles with small load space volumes (e.g., the Fiat Seicento). The cars in this group ran between post boxes and were also used to deliver mail in the city of Lublin and area. This group consisted of 47 vehicles.

Group II comprised 85 delivery vans with medium load space volumes (e.g., the Lublin III). They moved mail between post offices in the city of Lublin and the former Lublin voivodeship.

In group III, there were 47 vehicles characterized by large load space volumes (e.g., the Iveco Stralis). They carried postal packets between logistics centres of the Polish Mail outside the former Lublin voivodeship.

3. RESULTS OF CORRELATION ANALYSES

The authors of the paper had access to the following data related to the parameters of car operation in the Polish Mail delivery office in 2009: initial vehicle mileage (expressed in kilometres) denoted by l_0, monthly vehicle mileage l_m (characterizing the intensity of vehicle use), monthly auto repair costs k_m expressed in PLN, and the number n_m of parts or assemblies replaced per month. It should be noted that the costs of repairs of the vehicles of the Polish Mail in Lublin were only connected with replacement of operating materials and components. They did not comprise the personnel costs of Polish Mail staff members working in the company's repair station.

Statistical analyses of the data were carried out using STATISTICA® software. A first correlation analysis was performed to determine linear correlation coefficients for monthly intensity of use, monthly repair costs, and the number of parts or assemblies replaced within one month of operation for the entire test population and for the individual vehicle groups. The results of the calculations are shown in Matrices a–d in Table 1.

Table 1

Linear correlation coefficients for the studied operation parameters; a) for the entire population of vehicles, b) vehicle group I, c) vehicle group II, d) vehicle group III

a)

$$r = \begin{vmatrix} & l_m & k_m & n_m \\ l_m & 1.000 & .041 & .140 \\ k_m & .041 & 1.000 & .514 \\ n_m & .140 & .514 & 1.000 \end{vmatrix}$$

b)

$$r = \begin{vmatrix} & l_m & k_m & n_m \\ l_m & 1.000 & -.038 & -.001 \\ k_m & -.038 & 1.000 & .697 \\ n_m & -.001 & .697 & 1.000 \end{vmatrix}$$

c)

$$r = \begin{vmatrix} & l_m & k_m & n_m \\ l_m & 1.000 & .038 & .141 \\ k_m & .038 & 1.000 & .518 \\ n_m & .141 & .518 & 1.000 \end{vmatrix}$$

d)

$$r = \begin{vmatrix} & l_m & k_m & n_m \\ l_m & 1.000 & -.125 & .044 \\ k_m & -.125 & 1.000 & .423 \\ n_m & .044 & .423 & 1.000 \end{vmatrix}$$

The results of the calculations of linear correlation coefficients point to a relationship between the number n_m of operating materials and components replaced within one month and monthly repair costs k_m in the entire test population and within the individual groups of vehicles. This is indicated by the values of correlation coefficients shown in Matrices a–d in Table 1, for which $r \geq |0.4|$ [2]. The level of significance of these coefficients is $p < 0.001$, which allows one to conclude that an increase in the number of operating materials and components replaced within one month leads to an increase in monthly repair costs.

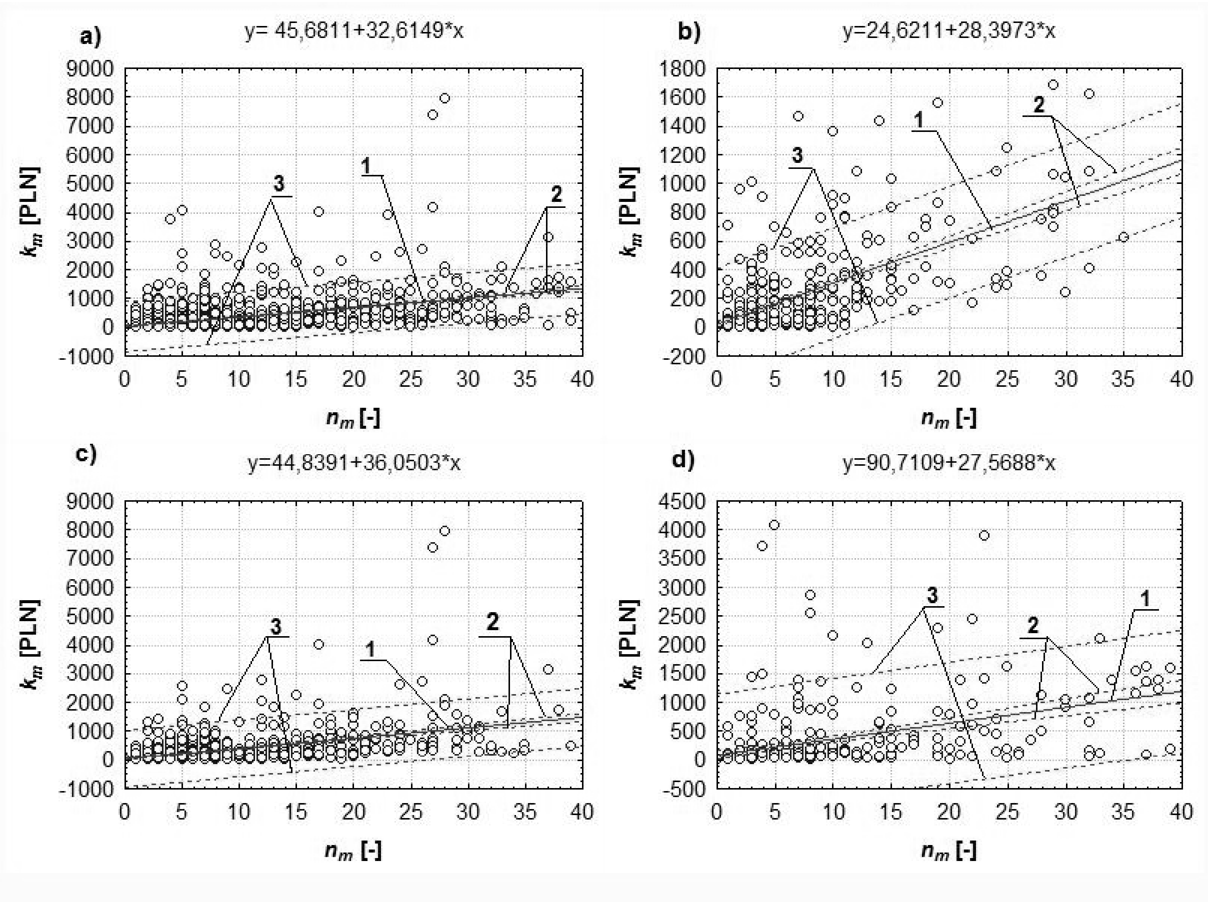

Fig. 1. A scatter plot of the number n_m of replaced parts and monthly repair costs k_m; 1 – regression line, 2 – confidence interval for the predicted mean observation, 3 – confidence interval for the predicted observation; a) the entire population of vehicles, b) group I vehicles, c) group II vehicles, d) group III vehicles

Rys. 1. Wykres rozrzutu liczby n_m wymienianych części i miesięcznych kosztów k_m napraw; 1 – linia regresji, 2 – przedział ufności dla prognozowanej średniej obserwacji, 3 – przedział ufności dla prognozowanej obserwacji, a) cała populacja, b) pojazdy grupy I, c) pojazdy grupy II, d) pojazdy grupy III

Fig. 1 shows scatter plots of the number n_m of operating materials and components replaced within one month and monthly repair costs k_m. Also, a regression line was plotted in Fig. 1 and a regression equation was given together with 95% confidence intervals for predicted means and individual observations.

Next, a correlation analysis was conducted to see whether the intensity of vehicle use in the i-th month had an impact on the number of replacements of operating materials and components and repair costs in the following month (i+1). The results of this analysis are shown in Matrices a–d in Table 2.

The values of the obtained linear correlation coefficients (presented in Matrices a–d in Table 2) are similar to those in Matrices in Table 1. This allows one to conclude that an increase in the monthly value of intensity of vehicle use has no effect on the monthly number of replaced operating materials and components and monthly repair costs either in the entire investigated population or in the individual groups of vehicles.

Table 2

Linear correlation coefficients for the studied operation parameters taking into account a monthly shift in data; a) for the entire population of vehicles, b) vehicle group I, c) vehicle group II, d) vehicle group III

a)

$$r = \begin{vmatrix} & l_m & k_{m+1} & n_{m+1} \\ l_m & 1.000 & .085 & .160 \\ k_{m+1} & .085 & 1.000 & .516 \\ n_{m+1} & .160 & .516 & 1.000 \end{vmatrix}$$

b)

$$r = \begin{vmatrix} & l_m & k_{m+1} & n_{m+1} \\ l_m & 1.000 & .103 & .127 \\ k_{m+1} & .103 & 1.000 & .694 \\ n_{m+1} & .127 & .694 & 1.000 \end{vmatrix}$$

c)

$$r = \begin{vmatrix} & l_m & k_{m+1} & n_{m+1} \\ l_m & 1.000 & .163 & .252 \\ k_{m+1} & .163 & 1.000 & .515 \\ n_{m+1} & .252 & .515 & 1.000 \end{vmatrix}$$

d)

$$r = \begin{vmatrix} & l_m & k_{m+1} & n_{m+1} \\ l_m & 1.000 & -.125 & .024 \\ k_{m+1} & -.125 & 1.000 & .430 \\ n_{m+1} & .042 & .430 & 1.000 \end{vmatrix}$$

In another correlation analysis, we established whether there were relationships among total yearly vehicle mileage l_s (which is a sum of a vehicle's monthly mileages l_m), the total number n_s of replacements of operating materials and components, and total auto repair costs recorded in the investigated year 2009. The results of calculations of linear correlation coefficients among those parameters are presented in Matrices a–d in Table 3. The level of significance of these coefficients is $p < 0.001$.

Table 3

Linear correlation coefficients of total values of the studied operation parameters; a) for the entire population of vehicles, b) vehicle group I, c) vehicle group II, d) vehicle group III

a)

$$r = \begin{vmatrix} & l_s & k_s & n_s \\ l_s & 1.000 & .241 & .270 \\ k_s & .241 & 1.000 & .693 \\ n_s & .270 & .693 & 1.000 \end{vmatrix}$$

b)

$$r = \begin{vmatrix} & l_s & k_s & n_s \\ l_s & 1.000 & .348 & .475 \\ k_s & .348 & 1.000 & .856 \\ n_s & .475 & .856 & 1.000 \end{vmatrix}$$

c)

$$r = \begin{vmatrix} & l_s & k_s & n_s \\ l_s & 1.000 & .531 & .601 \\ k_s & .531 & 1.000 & .745 \\ n_s & .601 & .745 & 1.000 \end{vmatrix}$$

d)

$$r = \begin{vmatrix} & l_s & k_s & n_s \\ l_s & 1.000 & -.088 & .113 \\ k_s & -.088 & 1.000 & .611 \\ n_s & .113 & .611 & 1.000 \end{vmatrix}$$

An analysis of the values of the correlation coefficients (shown in Matrices a–d in Table 3) shows that there is a statistically significant relationship between the total number n_s of operating materials and components replaced within one year and total auto repair costs k_s. An increase in the number of replaced operating materials and components causes an increase in the repair costs of the test vehicles. Additionally, for cars belonging to groups I and II, a certain correlation can be observed between yearly vehicle mileage l_s and yearly number n_s of replaced operating materials and components as well as total auto repair costs k_s.

A last correlation analysis concerned the relationships among initial mileage l_0, the total number n_s of replaced operating materials and components, and total auto repair costs k_s. It should be noted here that due to "organizational shifts" of the test vehicles between delivery offices of the Polish Mail in the Lublin Voivodeship during 2009, the analyses took into account only those vehicles for which full-year information was available. This is why the number of cases in groups I, II, and III fell to 39, 58, and 20, respectively.

Table 4

Linear correlation coefficients among the total value of repair costs, the total number of replaced parts, and initial mileage; a) for the entire population of vehicles, b) for vehicle group I, c) for vehicle group II, d) for vehicle group III

a)

$$r = \begin{vmatrix} & l_0 & k_s & n_s \\ l_0 & 1.000 & .549 & .521 \\ k_s & .549 & 1.000 & .659 \\ n_s & 0.521 & 0.659 & 1.000 \end{vmatrix}$$

b)

$$r = \begin{vmatrix} & l_0 & k_s & n_s \\ l_0 & 1.000 & .426 & .420 \\ k_s & .426 & 1.000 & .801 \\ n_s & .420 & .801 & 1.000 \end{vmatrix}$$

c)

$$r = \begin{vmatrix} & l_0 & k_s & n_s \\ l_0 & 1.000 & .290 & .378 \\ k_s & .290 & 1.000 & .667 \\ n_s & .378 & .667 & 1.000 \end{vmatrix}$$

d)

$$r = \begin{vmatrix} & l_0 & k_s & n_s \\ l_0 & 1.000 & .791 & .828 \\ k_s & .791 & 1.000 & .650 \\ n_s & .828 & .650 & 1.000 \end{vmatrix}$$

An analysis of the values of the linear correlation coefficients shown in Matrices a–d in Table 4 shows that for vehicles from group III the value of initial vehicle mileage l_0 has a very strong effect on the total number n_s of replaced operating materials and components and total auto repair costs k_s. The level of significance of these coefficients is $p < 0.001$. Similar (though weaker) relationships are observed for vehicles from group I as well as the entire population of test vehicles. The results confirm the observation that the higher the mileage of a vehicle, the worse its technical condition.

Fig. 2 shows scatter plots of initial vehicle mileage l_0 and total vehicle repair costs k_s. Also, a regression line was plotted in Fig. 2 and a regression equation was given together with 95% confidence intervals for predicted mean and individual observations.

An analysis of the scatter plots in Fig. 2 indicates that the lack of a relationship between initial mileage $\boldsymbol{l_0}$ and total auto repair costs $\boldsymbol{k_s}$ in vehicles of group II results from a greater scatter of cost values. However, information obtained from the Polish Mail does not provide an answer to the question of what may have been the cause of this situation.

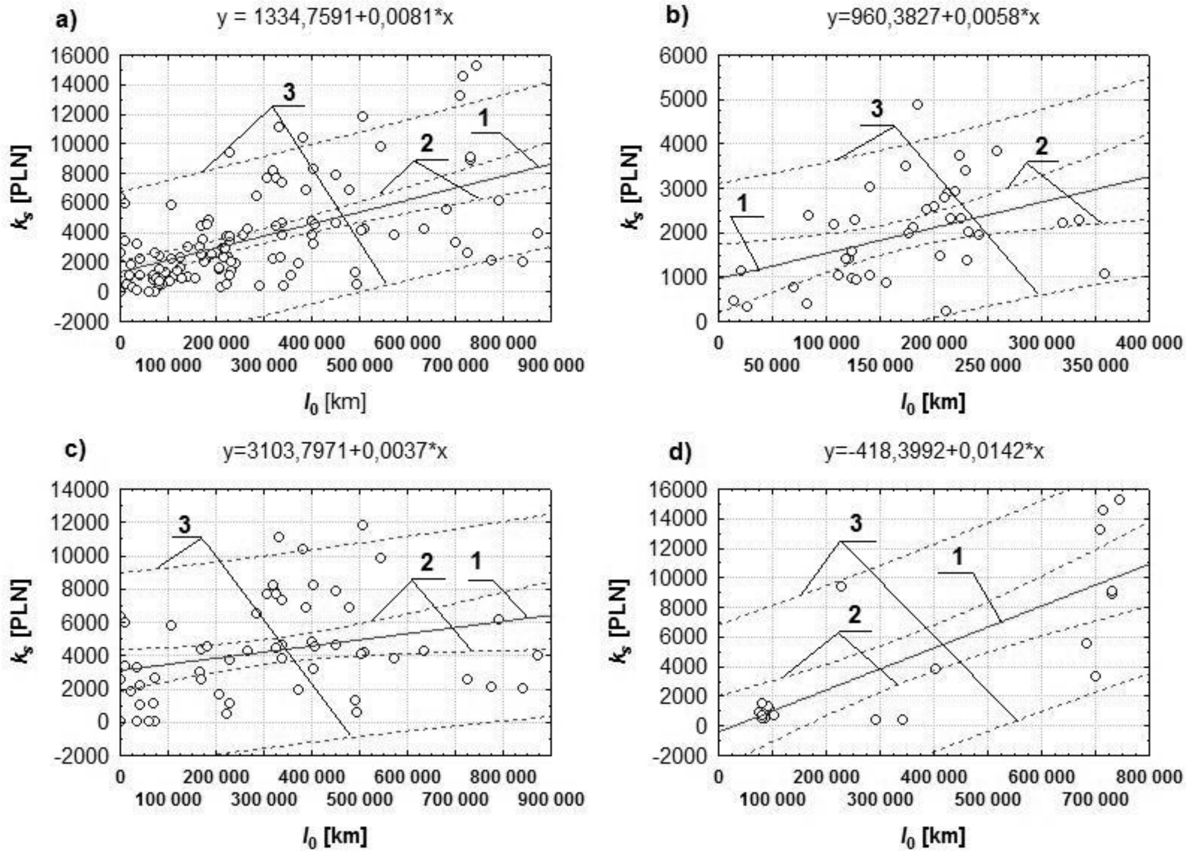

Fig. 2. A scatter plot of vehicle mileage l_0 and total vehicle repair costs k_s; 1 – regression line, 2 – confidence interval for the predicted mean observation, 3 – confidence interval for the predicted observation; a) the test population of vehicles, b) group I vehicles, c) group II vehicles, d) group III vehicles

Rys. 2. Wykres punktowy zależności przebiegu początkowego l_0 oraz całkowitych kosztów k_s napraw; 1 – linia regresji, 2 – przedział ufności dla prognozowanej średniej obserwacji, 3 – przedział ufności dla prognozowanej obserwacji, a) cała populacja, b) pojazdy grupy I, c) pojazdy grupy II, d) pojazdy grupy III

4. CONCLUSIONS

On the basis of the results obtained in correlation analyses of real-life data related to the intensity of use, repair costs and the number of replaced parts or assemblies for delivery vans of the Polish Mail company in Lublin during one year of operation, it can be concluded that

1) No relationship was observed between the monthly intensity of vehicle use and the monthly number and costs of replacements of operating materials and components.
2) There is a relationship between the yearly number of replaced operating materials and components and yearly repair costs of the test vehicles. An increase in the number of replacements causes an increase in costs.
3) The technical condition of a vehicle has a significant effect on the yearly number of replaced operating materials and components and thereby on yearly repair costs. The higher the mileage on a vehicle, the greater the costs that a user has to expend for its repairs and services.

Finally, it should be noted that the correlation analyses were conducted for data related to the process of vehicle operation spanning one calendar year. Therefore, it cannot be unequivocally determined whether the obtained relationships among the investigated operational parameters would also be valid in other years. To confirm these relationships, analyses should be carried out for data covering at least a few years of vehicle operation. The authors hope to explore this issue in their future research.

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