

transport, economic effectiveness, simulation

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A MODEL OF THE ECONOMIC EFFECTIVENESS OF THE TRUCK TRANSPORTATION SERVICES

Summary. This paper presents a draw up model for the assessment of the economic effectiveness of vehicle transport services. On the basis of this model, computer calculations have been made, the selected results of which are presented and discussed on in this article.

MODEL EKONOMICZNEJ EFEKTYWNOŚCI SAMOCHODOWYCH USŁUG TRANSPORTOWYCH

Streszczenie. W artykule opisano model oceny ekonomicznej efektywności samochodowych usług transportowych. W oparciu o ten model zostały przeprowadzone obliczenia komputerowe. W niniejszym artykule zaprezentowano i omówiono wybrane rezultaty.

1. INTRODUCTION

The capability to assess the economic effectiveness of vehicle transport services seems to be one of the most important elements in the action strategies of transportation companies [1 - 3]. Such estimation can merely be made using mathematical computational models. These mathematical models must take into consideration many various parameters. These parameters are connected with many legal, technical, and social factors [5, 9]. For example: the purchase price of a new vehicle, the price of fuel, transportation rate, staff salaries, service and repair costs, the inflation rate, taxes and other charges. The number of these factors cause that should to be taken into consideration makes the models for assessing profit gained from transportation services are very complex. Nevertheless, more parameters are included in developing those models, the more efficient will be the final assessment of the economic effectiveness of vehicle transport. This will allow proper planning of the maintenance strategies of a transportation company on the transportation services market [6 - 8].

The author in this paper presents a draw up model for the assessment of the economic effectiveness of vehicle transport services. On the basis of this model, computer calculations have been made, the selected results of which are presented and discussed on in this article. The authors hope that the presented model and the computation results will make it possible to take appropriate action towards minimization of the costs of transportation activity based on vehicle transport.

2. THE BACKGROUND OF THE MATHEMATICAL MODEL OF PROFIT FROM TRUCK MAINTENANCE

The mathematical model of profit ΔZ_R from transportation services the annual gross profit from the maintenance of one truck excluding general costs can be described by the formula [4]:

$$\Delta Z_R = (s - k) \cdot \lambda + z_R - d - K_{\text{avg}}(T) - A_R - P \quad (1)$$

where: ΔZ_R – annual gross profit from the operation of one truck [pln/year], z – annual total income from transportation services including tax (VAT) [pln/year], s – service rate per kilometer [pln/km], λ – annual vehicle operation intensity [km/year], z_R – the part of income contingent upon number of days of vehicle operation [pln/year], d – personal costs [pln/year], $K_{\text{avg}}(T)$ – average annual costs of repair, services and spare parts [pln/year], A_R – annual depreciation allowances [pln/year], P – road tax [pln/year].

The part of income contingent upon number of days of vehicle operation z_R be described by the following equation:

$$z_R = s_R \cdot n \cdot \eta \quad (2)$$

where: s_R – daily vehicle rate [pln/day], n – number of operation days during one year [days/year], η – the availability factor [-]:

$$\eta = (n - \tau) / n \quad (3)$$

where: τ – number of days dedicated to service and repair in one year:

$$\tau = \tau_c(T) / T \quad (4)$$

where: $\tau_c(T)$ – total service time of the vehicle during the whole period of operation [days], T – total operation time of the truck [years]:

$$T = L_{\text{max}} / \lambda \quad (5)$$

where: L_{max} – total life of the vehicle [km]

The intensity of vehicle operation during one year can be described by the following equation:

$$\lambda = \lambda' \cdot n \cdot \eta \quad (6)$$

where: λ – intensity of truck operation [km/year], λ' – daily operation intensity of the serviceable vehicle [km/day]:

The costs of fuel can be combined with the costs of lubricating oil:

$$k = k_p \cdot c_p + k_{ol} \cdot c_{ol} \quad (7)$$

where: k – fuel and lubricating oil costs [pln], k_p – elementary fuel consumption [dm^3/km], c_p – elementary cost of fuel [pln/ dm^3], k_{ol} – elementary consumption of lubricating oil [dm^3/km], c_{ol} – elementary cost of lubricating oil [pln/ dm^3].

The personal costs of vehicle operation do not depend on vehicle mileage and are a function of the monthly salary of the driver and the escort:

$$d = m \cdot (w_1 + w_2) \cdot b \quad (8)$$

where: d – personal costs [pln/year], m – number of months within one year [months/year], w_1 – gross salary of the driver [pln/month], w_2 – gross salary of the escort [pln/month], b – additional surcharge [-].

The average costs of repairs, technical services and spare parts for a vehicle are calculated from the formula :

$$K_{\text{avg}}(T) = K(T) / T \quad (9)$$

where: $K(T)$ – total cost of all services and repairs [pln].

Depreciation allowances are calculated using the linear formula:

$$A_R = C_R / M_R \quad (10)$$

where: A_R – annual depreciation allowances [pln/year], C_R – price of a new vehicle [pln], M_R – accounting depreciation period established by the Ministry of Finance [years].

In calculation we assume that the investor purchased N new vehicles basing on his own resources. The annual gross profit from the operation of N trucks is calculated as follows:

$$\Delta Z_N = \Delta Z_R \cdot N - Q \quad (11)$$

where: ΔZ_N – gross profit from the operation of N vehicles [pln/year], N – number of vehicles,
 Q – annual general costs of enterprise [pln/year].

The annual net profit from the operation of N vehicles, including the general costs, is described by the following equation:

$$\Delta Z_{RN} = \Delta Z_N \cdot (1 - F) = (\Delta Z_R \cdot N - Q) \cdot (1 - F) \quad (12)$$

where: ΔZ_{RN} – annual net profit from the maintenance of N vehicles [pln/year], Q – annual general costs (administration costs, lease payments) [pln/year], F – income tax rate for legal entities.

In the proposed evaluation method, a cumulative net profit is calculated based on average prices, additionally taking into account the possibility of re-selling used vehicles, according to the equation:

$$Z_{CN} = N \cdot C_s \cdot (1 + p)^{T-1} + \sum_{i \in \{1, \dots, T\}} \Delta Z_{RN} \cdot (1 + p)^{i-1} \quad (13)$$

where: Z_{CN} – total net profit from the period of operation of N vehicles [pln], p – inflation rate [–],
 C_s – the selling price of used vehicle [pln].

After transforming the sum into a product, we ultimately get:

$$Z_{CN} = N \cdot C_s \cdot (1 + p)^{T-1} + \Delta Z_{RN} \cdot ((1 + p)^T - 1)/p \quad (14)$$

This equation (14) is accurate only for the case when $M \geq T$. If the total operation time of the truck T in years is larger than the statutory period M of redemption deduction by the Ministry of Finance expressed in years, then formula (1) has to be altered so that it has no component A_R describing the annual depreciation allowance,

$$\Delta Z'_R = (s - k) \cdot \lambda + z_R - d - K_{\text{avg}}(T) - P \quad (15)$$

where: $\Delta Z'_R$ – annual gross profit from one vehicle after an accounting period of redemption M [pln/year].

The annual net profit from the operation of N vehicles after the period of M years, taking into account the general costs, is described as follows:

$$\Delta Z'_{RN} = (\Delta Z'_R \cdot N - Q) \cdot (1 - F) \quad (16)$$

where: $\Delta Z'_{RN}$ – annual net profit from the operation of N vehicles after the period of M years [pln/year].

For the case when $T > M$, the formula describing cumulative net profit from the operation of N vehicles, with the possibility of re-selling used vehicles, can be written as follows:

$$Z_{CN} = N \cdot C_s \cdot (1 + p)^{T-1} + \Delta Z_{RN} \cdot \sum_{i=1}^M (1 + p)^{i-1} + \Delta Z'_{RN} \cdot \sum_{i=M+1}^T (1 + p)^{i-1} \quad (17)$$

Ultimately, after transformations, the formula for the total net profit for any operation time of a group of N vehicles is:

$$Z_{CN} = N \cdot C_s \cdot (1 + p)^{T-1} + \Delta Z_{RN} \frac{(1 + p)^M - 1}{p} + \Delta Z'_{RN} \frac{(1 + p)^{T-M} - 1}{p} \quad (18)$$

Taking into account equation (18), we can formulate the criteria for the evaluation of the economic efficiency of a vehicle in conditions of a transport company. A repayment of incurred capital expenditures for the purchase of vehicles, considering the inflation, will occur after T years of operation, when total profit Z_{CN} equals zero. This means that to obtain ultimate financial net profit from the operation of vehicles, the income Z_{CN} must be larger than zero.

3. SELECTED RESULTS OF THE COMPUTER SIMULATION

Using the mathematical model described by formula (18), a computer simulation of profit generated from vehicle operation was made on the basis of a chosen delivery truck. The constant input parameters are described in Tables 1–2. Table 3 presents parameters that were changed during the computer simulation. We assumed that as the price of a vehicle increased, so increased the durability, expressed as the total life of the vehicle L_{max} , and reliability of its engine, expressed as total cost of all services and repairs $K(T)$. Also, a drop in elementary fuel consumption k_p was observed. In addition, various inflation rates p ($p \in \{0.0, 0.05, 0.10, 0.15, 0.20\}$) were adopted for the calculations.

Table 1

Economic and operational input parameters (first part)

Number of trucks N [-]	Rate per kilometer s [pln/km]	Daily vehicle rate s_R [pln/day]	Number of operation days n [days/years]	Cost of fuel c_p [pln/dm ³]	Cost of oil C_{ol} [pln/dm ³]	Total service time $\tau_c(T)$ [days]
10	2.00	100	256	4.0	13.00	30

Table 2

Economic and operational input parameters (second part)

Gross salary of the driver w_1 [pln/month]	Gross salary of the escort w_2 [pln/month]	Additional surcharge b [-]	Selling price of used vehicle C_s [pln]	Period of depreciation M [-]	Road tax P [pln/year]	Annual general costs Q [pln/year]
2 000	1 500	1.50	30 000	5	616	5 000

Table 3

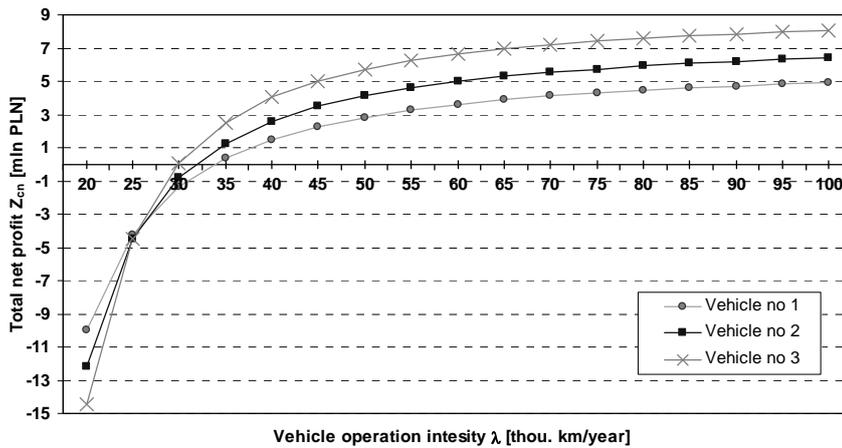
Variable input parameters

Variants	Price of new car C_R [pln]	Total life of the vehicle L_{max} [10 ³ km]	Elementary fuel consumption k_p [pln/km]	Elementary oil consumption k_{ol} [dm ³ /10 ³ km]	Total cost of services $K(T)$ [pln]
Vehicle no 1	60 000	600	0.13	0.003	10 000
Vehicle no 2	70 000	700	0.12	0.002	8 000
Vehicle no 3	80 000	800	0.11	0.001	6 000

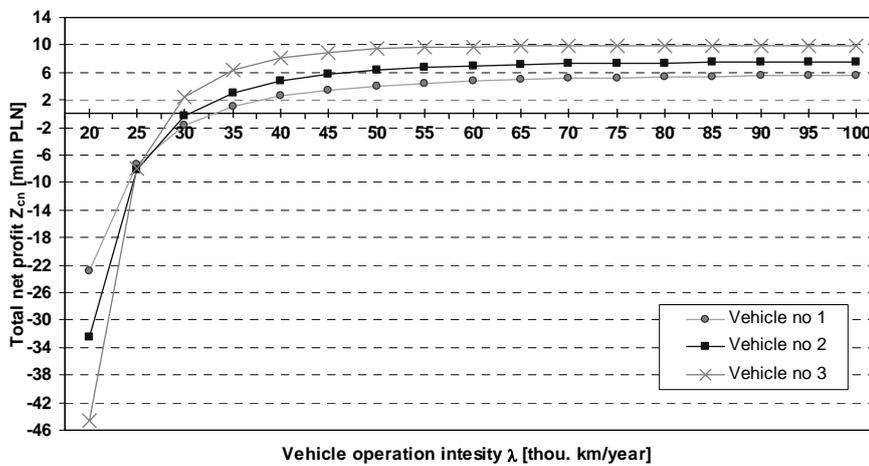
Analyzing the results of the computer simulation of the total net profit Z_{CN} shown in Figs. 1 to 4, we can state that the decisive transport-dependent factor is the vehicle operation intensity λ . As it increases, the obtained profit Z_{CN} grows. There is a limit of operation intensity λ below which a loss is incurred from transport activity.

It is also observed that the net profit Z_{CN} from transport services increases along with an increase in vehicle life (see Fig. 1), measured as the total life of the vehicle L_{max} , and the total cost of all services and repairs $K(T)$. Although, admittedly, at low annual vehicle operation intensities λ the profit Z_{CN} for more reliable vehicles reaches considerable negative values (i.e. a loss is generated), the profit Z_{CN} shows positive values already at 27 000 – 33 000 km/year. The profit Z_{CN} also depends on the level of inflation. As inflation grows, an increase in the cumulative profit Z_{CN} is observed, as illustrated in Fig. 1b. We can also state that the net profit Z_{CN} gained at inflation level $p = 0.10$ and annual mileage at the level of 40 000 km/year is nearly identical to the one gained at vehicle operation intensity of 100 000 km/year and an inflation rate $p = 0.05$.

The growth of inflation causes also, that we can observe the occurrence of the local maximum, which illustrates drawing 2. The vehicle operation intensity of 40 000 km/year causes the achieved net profit 16.19 mln pln. We can also state that the attained loss from the vehicle no 2 maintenance at vehicle operation intensity of 40 000 km/year and an inflation rate $p = 0.20$ equals -281.85 mln pln.



a



b

Fig. 1. Total net profit Z_{CN} from the operation of the truck as a function of operation intensity λ , the others parameters as shown in Tables 1, 2 and 3; a) the inflation rate $p = 0.05$, b) the inflation rate $p = 0.10$

Rys. 1. Całkowity zysk netto Z_{CN} z eksploatacji samochodu w funkcji intensywności eksploatacji λ ; wartości pozostałych parametrów dane w Tabelach 1, 2 i 3; a) stopa inflacji $p = 0.05$, b) stopa inflacji $p = 0.10$

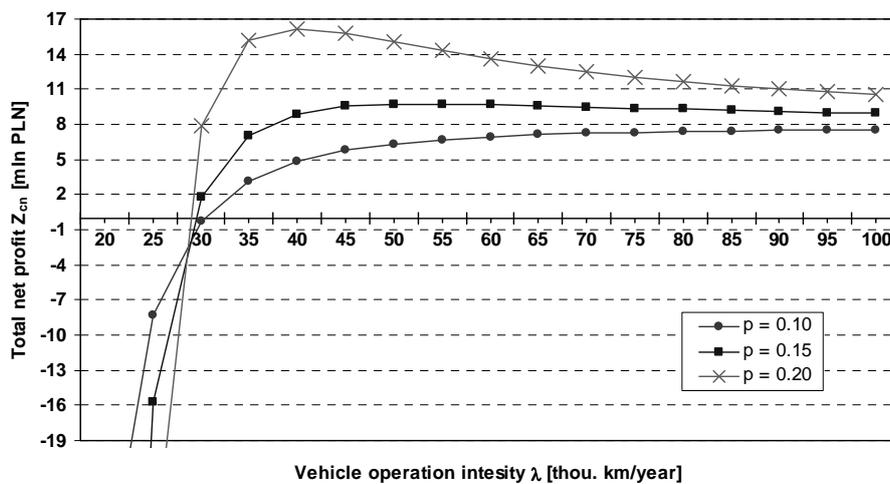
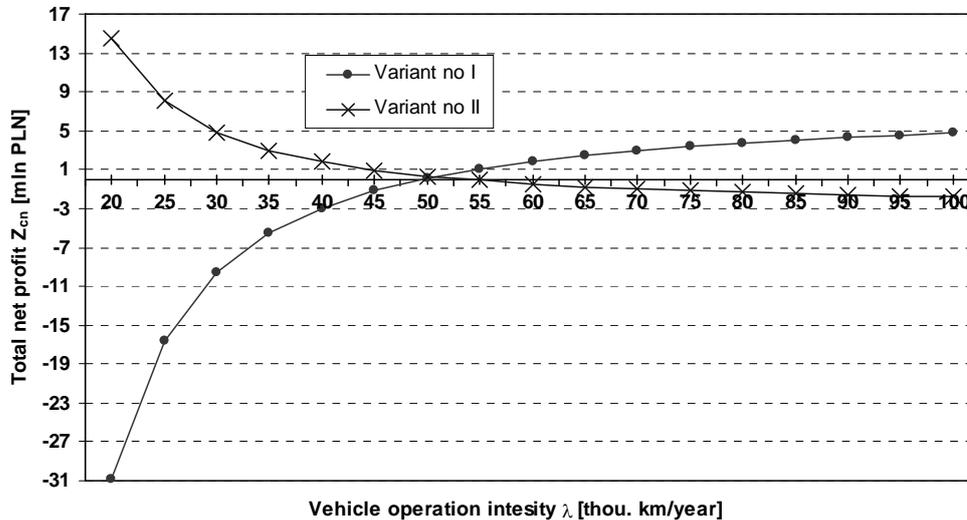


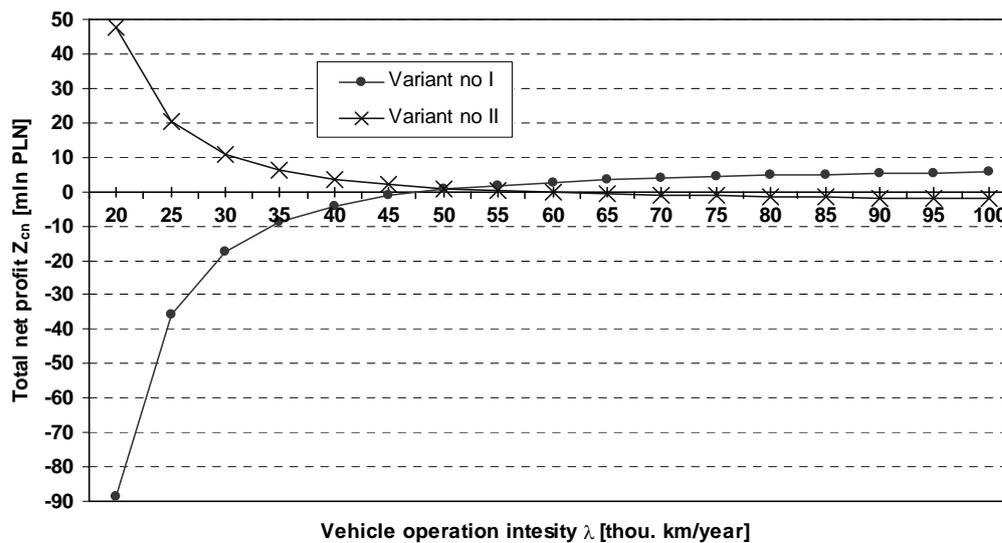
Fig. 2. Total net profit Z_{CN} from the operation of the truck as a function of operation intensity λ ; the inflation rate p was a variable parameter; data for vehicle no 2; other parameters as shown in Tables 1, 2 and 3

Rys. 2. Całkowity zysk netto Z_{CN} z eksploatacji samochodu w funkcji intensywności eksploatacji λ przy zadanych wartościach stopy inflacji p ; wartości pozostałych parametrów dane w Tabelach 1, 2 i 3

Fig. 3 shows a graph of total net profit Z_{CN} as a function of intensity of operation λ of vehicle no. 2 for two calculation variants. In the first variant, it was assumed that the rate per one kilometer was $s = 2.00$ pln/km and a daily vehicle rate $s_R = 0.00$ pln/day. In the second variant, the rate per kilometer was $s = 0.00$ pln/km and the daily vehicle rate $s_R = 400.00$ pln/day.



a



b

Fig. 3. Total net profit Z_{CN} from the operation of the truck as a function of operation intensity λ , data for vehicle no 2; in variant no I, rate per kilometer $s = 2.00$ pln/km, daily vehicle rate $s_R = 0.00$ pln/day, in variant no II, rate per kilometer $s = 0.00$ pln/km, daily vehicle rate $s_R = 400.00$ pln/day; other parameters as shown in Tables 1, 2 and 3; a) inflation rate $p = 0.05$, b) inflation rate $p = 0.10$

Rys. 3. Całkowity zysk Z_{CN} z eksploatacji samochodu w funkcji intensywności eksploatacji λ , dane dla pojazdu nr 2; w wariancie I: $s = 2.00$ pln/km, $s_R = 0.00$ pln/dzień; w wariancie II: $s = 0.00$ pln/km, $s_R = 400.00$ pln/dzień; wartości pozostałych parametrów dane w Tabelach 1, 2 i 3; a) stopa inflacji $p = 0.05$, b) stopa inflacji $p = 0.10$

On the basis of the calculations (see fig. 3), it can be explicitly stated that at low vehicle operation intensities it is more economically viable to adopt a rate per day of vehicle operation. However, as the yearly vehicle mileage λ increases, the total net profit Z_{CN} systematically decreases. Comparing the total net profit Z_{CN} between the two variants, one notices that at yearly operation intensity λ exceeding 50,000 kilometers, adoption of the per-kilometer rate is more profitable.

Inflation rate has an influence on the net profit Z_{CN} in variant II (see fig. 3). When inflation rate rises the net profit for vehicle operation intensity of 20 000 km/year increases over threefold. For vehicle

operation intensity of 100 000 km/year the loss in transport service slightly grows up from -1.81 to -2.01 mln pln when the inflation rate changes from $p = 0.05$ to $p = 0.10$. Figure 4 shows the influence of a daily vehicle rate on the total net profit. In calculation three different variants of daily rate were assumed: 400 pln/day in variant I, 350 pln/day in variant II and 300 pln/day. When we analyze the figure 4 we can state that too low daily vehicle rate estimation conducts to permanent loss in transport services.

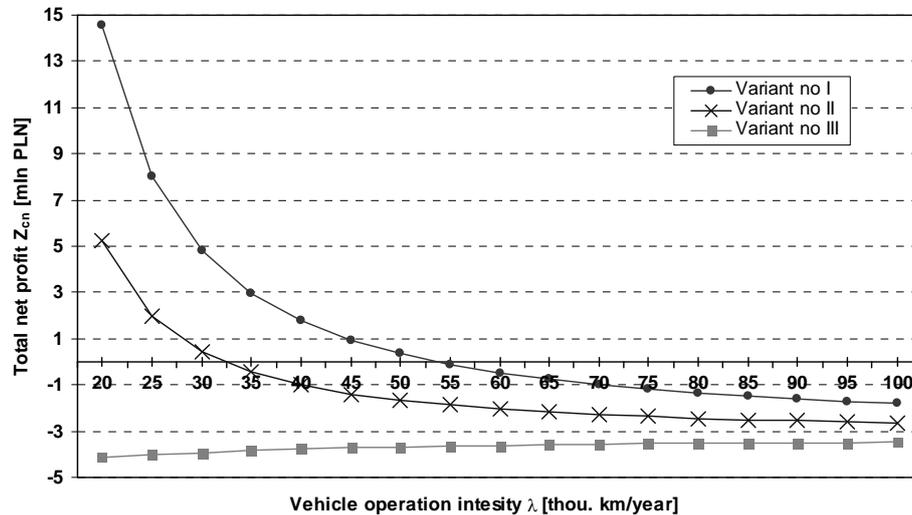


Fig. 4. Total net profit Z_{CN} from the operation of the truck as a function of operation intensity λ , inflation rate $p = 0.05$, data for vehicle no 2; in variant no I, daily vehicle rate $s_R = 400.00$ pln/day, in variant no II, daily vehicle rate $s_R = 350.00$ pln/day; in variant no III, daily vehicle rate $s_R = 300.00$ pln/day, other parameters as shown in Tables 1, 2

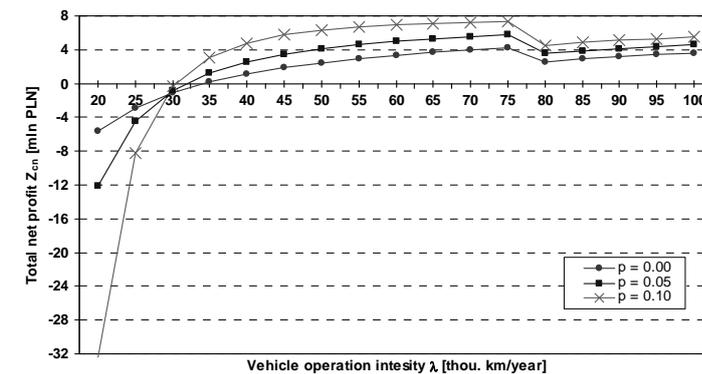
Rys. 4. Całkowity zysk netto Z_{CN} z eksploatacji samochodu w funkcji intensywności eksploatacji λ , stopa inflacji $p = 0.05$, dane dla pojazdu nr 2; w wariacie I: $s_R = 400.00$ pln/dzień; w wariacie II: $s_R = 350.00$ pln/dzień; w wariacie III: $s_R = 300.00$ pln/dzień; wartości pozostałych parametrów dane w tabelach 1, 2

Figure 5a shows the case of vehicle no 2, in which, with the value of yearly mileage being in the order of 75 thousand kilometers, a second driver is employed. Figure 5b shows the case of vehicle no 2, in which, with the value of yearly mileage being in the order of 50 thousand kilometers, a second driver is employed and additionally the third driver is employed after 75 thousands kilometers. This follows from regulations related to a driver's working time. This follows from regulations related to a driver's working time. As it appears from Figure 5, at any level of inflation, employing the second and third driver causes an abrupt decrease in the total net profit Z_{CN} . It should be added that when second driver has been employed (fig. 5a), the largest decrease in profit is observed at an inflation level $p = 0.10$. When we first employ the second driver and next the third driver we can observe (inflation rate $p = 0.00$) that the net profit Z_{CN} in transport services fluctuates near zero.

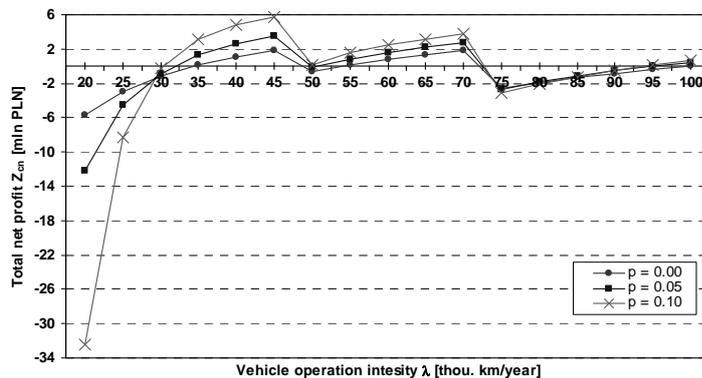
4. SUMMARY

When we analyse the results from calculation basing for the presented model for the assessment of profit from vehicle transport services in this article, we can conclude that the purchase of a more expensive, but also a more durable and reliable vehicle is more profitable. The durable vehicle is cheaper to operate at increasing yearly operation intensity.

The results show either that if we plan to use a vehicle at low operation intensities, we should primarily apply charges per day of vehicle operation. Road traffic regulations, by imposing the requirement of extra personnel recruitment, significantly affect the value of the total profit gained from transportation services. When the number of drivers increases, a company decreases its profit from transport services. The level of inflation has an effect on the value of the profit gained. Its increase contributes to the growth of the profit.



a



b

Fig. 5. Total net profit Z_{CN} from the operation of the truck as a function of operation intensity λ ; the inflation rate p and the number of drivers were variable parameters; data for vehicle no 2; other parameters as shown in Tables 1, 2 and 3; a) variant with two drivers, b) variant with three drivers

Rys. 5. Całkowity zysk netto Z_{CN} z eksploatacji samochodu w funkcji intensywności eksploatacji λ , wariantowe stopa inflacji p oraz liczba kierowców; dane pojazdu nr 2, wartości pozostałych parametrów pokazane w Tabelach 1, 2 i 3; a) wariant z dwoma kierowcami, b) wariant z trzema kierowcami

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