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ASSESSMENT OF VEHICLE EFFECTIVE MODERNIZATION TAKING INTO ACCOUNT THE LIFE CYCLE COST, TECHNICAL AND ENVIRONMENTAL PARAMETERS

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Abstract. *The article deals with the features for determination of the efficiency of vehicle modernization compared to the base one. They propose the model for determining the efficiency of vehicle modernization compared with the base one. The model takes into account technical, economic and environmental parameters of the vehicle.*

Key words: *vehicle efficiency, life cycle, life cycle cost, technical level coefficient, environmental parameters.*

ОЦІНКА ЕФЕКТИВНОСТІ МОДЕРНІЗАЦІЇ ТРАНСПОРТНОГО ЗАСОБУ З УРАХУВАННЯМ ВАРТОСТІ ЖИТТЄВОГО ЦИКЛУ, ТЕХНІЧНИХ І ЕКОЛОГІЧНИХ ПАРАМЕТРІВ

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Анотація. *Приведено модель з відповідними обмеженнями для визначення ефективності від модернізації транспортного засобу порівняно з базовим. Запропоновано відповідний коефіцієнт ефективності від модернізації транспортного засобу, який враховує його технічні, економічні й екологічні показники.*

Ключові слова: *транспортний засіб, ефективність, життєвий цикл, вартість життєвого циклу, коефіцієнт технічного рівня, екологічні показники.*

ОЦЕНКА ЭФФЕКТИВНОСТИ МОДЕРНИЗАЦИИ ТРАНСПОРТНОГО СРЕДСТВА С УЧЕТОМ СТОИМОСТИ ЖИЗНЕННОГО ЦИКЛА, ТЕХНИЧЕСКИХ И ЭКОЛОГИЧЕСКИХ ПАРАМЕТРОВ

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Аннотация. *Приведена модель с соответствующими ограничениями для определения эффективности от модернизации транспортного средства по сравнению с базовым. Предложен соответствующий коэффициент эффективности от модернизации транспортного средства, который учитывает его технические, экономические и экологические показатели.*

Ключевые слова: *транспортное средство, эффективность, жизненный цикл, стоимость жизненного цикла, коэффициент технического уровня, экологические показатели.*

Introduction

Modernization is technical improvement of capital assets in order to eliminate moral depreciation and enhance the technical and economic parameters to the level of advanced equipment

[1]. Usually, determination of efficiency of modernization of the vehicle is viewed from an economic point of view. But this process will improve the technical, economic and environmental parameters of the vehicle.

Analysis of publications

Usually, various methods are used to determination of efficiency of the modernization of the vehicle [1–8]. But they have drawbacks. So [1, 4–7] takes into account only the economic performance of the vehicle. In [2, 3] are only technical and economic indicators. In [8] are considered the economic and environmental performance.

Purpose and problem statement

The aim of the article is in the calculation of efficiency of modernization of vehicle taking into account life cycle, technical and environmental parameters.

There is necessary to use the figure that would take into account all these parameters together in order to assess how much modernization is effective.

Estimation of modernization efficiency

It is proposed to measure the coefficient of efficiency from the modernization of the vehicle according to the procedure which is shown in Fig. 1.

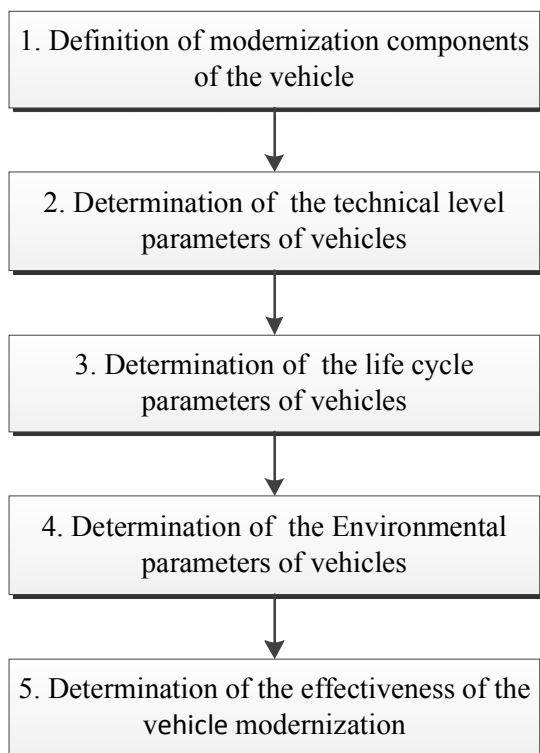


Fig. 1. The procedure for efficiency estimation of vehicle modernization

It is proposed to use the coefficient of efficiency from the modernization of the vehicle K_e as an indicator by the following formula

$$K_e = \frac{\sum_{k=3}^{i=1} K_k \varphi(k)}{\sum_{k=1} \varphi(k)}, \quad (1)$$

where K_1 is the technical level coefficient of the modernized vehicle; K_2 is the life cycle coefficient of the modernized vehicle; K_3 is the environmental parameters coefficient of the modernized vehicle; $\varphi(k)$ is the function which normalize parameters weight in the ranked sequence; k is the parameter number in the ranked sequence.

Calculate the coefficient K_1 as a criterion the technical level using the method of weight coefficients. It describes the new design and engineering development on existing technical objects of the same production purposes. It is calculated using the following formula shown in [2, 3]

$$K_e = \frac{\sum_{i=1}^{i=s} k_n \varphi(i)}{\sum_{i=1} \varphi(i)}, \quad (2)$$

where k_n is the parameter, which is the ratio of the numerical parameters of the new development to the parameters of existing facilities for rational categories (growth of parameter corresponds to the technical progress) and irrational categories (growth of parameter doesn't correspond to the technical progress); $\varphi(i)$ is the function which normalize the parameters weight in a ranked order, $i = 1..s$.

Best of comparable vehicle fits the greater value of coefficient K_1 .

It was on improved method for determining the technical level of the vehicle by the next. Function $\varphi(i)$ was introduced in part of determining the parameters weight in a ranged sequence instead of using the expert method. According to it, this figure determined by the following formula

$$\varphi(i) = \frac{i}{2^{i-1}}, i \geq 2, \quad (3)$$

where i is a number of technical parameter in a ranged sequence (and, by definition $\varphi(1) = 2$ is a singular point).

The coefficient K_2 is determined as the ratio of the life cycle cost of the basic vehicle LLC_{vb} and the modernized one LLC_{vm} using the following formula

$$K_2 = \frac{LLC_{vb}}{LLC_{vm}}. \quad (4)$$

Determining the value of the vehicle life cycle is forecasting costs on stages of its life cycle. The life cycle cost concept (Product Life Cycle Cost – LCC) is widely used abroad to assess the efficacy of investment projects [4, 5].

Today LCC analysis is widely used as a tool in the decision making process when considering plans for the implementation of new investment projects, tendering for rendering the services, manufacture and delivery of technical objects mainly with the high initial cost and the long time of lifestyle. The use of LCC analysis is fixed legislatively in some countries. [6]

The life cycle cost of vehicle LCC_V , which is purchased or upgraded again, is the sum of all costs (non-recurring and current) at all stages and is determined taking into account the discount factor α_t using the following formula [4]

$$LCC_V = \sum_{t_a}^{t_{in}+T} (K_t \cdot \alpha_t + I_t \cdot \alpha_t - L_t \cdot \alpha_t), \quad (5)$$

where K_t is capital investments in the year t of the life cycle, UAH; I_t is current expenses in the year t of the life cycle, UAH; L_t is the residual value of fixed assets, which drop out in the year t of the life cycle, UAH; T is the duration of the life cycle of a vehicle, years; t_{in} is the initial year of the vehicle life cycle; t_a is the year of acquisition of the vehicle; α_t is a discount factor.

Discount factor α_t is calculated using the following formula

$$\alpha_t = (1+r)^{t_c-t}, \quad (6)$$

where r is the discount rate; t_c is calculated year of the life cycle; t is the life cycle year, which costs are reduction to calculated year.

If it is impossible to predict the dynamics of prices (inflation) for the entire life cycle, defining of the life cycle cost should be carried in constant (unchanging, basic) prices. Thus, inflation accounting can be achieved either by index-

ing the price, or by adjusting the discount rate. In this case, instead of the value of r (in the formula (6)) is used the modified discount rate d [7], which is calculated using the following formula

$$d = \frac{1+r}{1+\frac{p}{100}} - 1, \quad (7)$$

where p is the projected annual inflation rate, %.

Coefficient K_3 is calculated as the ratio estimates of damage from environmental pollution in year t during the operation accordingly of the base vehicle to the modernized one.

$$K_3 = \frac{Yb_t}{Ym_t}, \quad (8)$$

where Yb_t is an assessment damage from the environmental pollution in year t during operation the base vehicle, UAH [8]; Ym_t is an assessment damage from the environmental pollution in year t during operation the modernized vehicle, UAH.

The value Yb_t determined by the formula, UAH,

$$Yb_t = \gamma' \delta f \sum_{z=1}^n A'_z m_{bz}, \quad (9)$$

where γ' is the unit costs standard, UAH / e.c.; δ is an indicator of the relative danger of air pollution on the different types territories; f is a coefficient that takes into account the nature of the scattering of impurities in the atmosphere; A'_z is an indicator of the relative activity of z -type impurities; m_{bz} is average annual mass of z -type pollutant that enter into the atmosphere in year t during operation the base vehicle, kg/h.

Value Ym_t determined by the formula, UAH

$$Ym_t = \gamma' \delta f \sum_{z=1}^n A'_z m_{mz}, \quad (10)$$

where m_{mz} is average annual mass of z -type pollutant that enter into the atmosphere in year t during operation the modernized vehicle, kg / h.

Given the formulas (9) and (10) we have

$$K_3 = \frac{\sum_{z=1}^n A'_z m_{bz}}{\sum_{z=1}^n A'_z m_{mz}}. \quad (11)$$

The model of determine the effectiveness of the modernized vehicle

If we assume that parameters K_k affect the coefficient of efficiency K_e equally and take into account mentioned above dependence, then the model of determine the effectiveness of the modernized vehicle compared to the base one will be in general form as follows

$$K_e = \frac{\sum_{i=1}^{i=s} k_n \varphi(i)}{\sum_{i=1}^{i=s} \varphi(i)} + \frac{LLC_{Tb}}{LLC_{Tm}} + \frac{\sum_{z=1}^n A'_z m_{bz}}{\sum_{z=1}^n A'_z m_{mz}} \quad (12)$$

The model limitations form can be represented in general as the following system

$$\begin{cases} 0 < k_n < 3,5, \\ 0,02 < \varphi(i) < 2, \\ LLC_{vb} / LLC_{vm} > 0, \\ A_z > 0, m_{bz} > 0, m_{mz} > 0, \\ s = 1 \dots 3, \\ i = 1 \dots s, \\ z = 1 \dots n. \end{cases} \quad (13)$$

The foregoing dependence can be used when designing new vehicles and modernization of existing ones. There were calculated parameters modernization of Lanos car with a hybrid transmission by applying the methodology that was described above. K_e ratio was equal to 1,4, which fully confirms the efficiency of such modernization.

Conclusions

The analysis of existing methods of estimation of vehicle efficiency was performed.

It was developed dependences which allow to determine the effectiveness of the modernization of the vehicle.

It was shown general appearance of the model of determining the effectiveness of the modernized vehicle compared with the base one.

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