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

M. Volodarets, Assoc. Prof., Ph. D. (Eng.), Ukrainian State University of Railway Transport, Kharkov

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.

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 as an indicator by the following formula

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

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]

$$K_1 = \frac{\sum_{i=1}^{i=s} k_n \varphi(i)}{\sum_{i=1}^{i=s} \varphi(i)}, \quad (2)$$

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 $\alpha$ using the following formula [4]

$$LCC_V = \sum_{t=t_0}^{t_0+T} \left( K_t \cdot \alpha_t + I_t \cdot \alpha_t - L_t \cdot \alpha_t \right), \quad (5)$$

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; $t_0$ is the initial year of the vehicle life cycle; $t_a$ is the year of acquisition of the vehicle; $\alpha_t$ is a discount factor.

Discount factor $\alpha_t$ is calculated using the following formula

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

where $r$ is the discount rate; $t_a$ 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 the life cycle cost should be carried in constant (unchanging, basic) prices. Thus, inflation accounting can be achieved either by indexing 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.

$$K_3 = \frac{Y_{b_t}}{Y_{m_t}}. \quad (8)$$

where $Y_{b_t}$ is an assessment damage from the environmental pollution in year $t$ during operation the base vehicle, UAH [8]; $Y_{m_t}$ is an assessment damage from the environmental pollution in year $t$ during operation the modernized vehicle, UAH.

The value $Y_{b_t}$ determined by the formula, UAH,

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

where $\gamma'$ is the unit costs standard, UAH / e.c.; $\delta$ 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; $m_{b_z}$ is average annual mass of of $z$-type pollutant that enter into the atmosphere in year $t$ during operation the base vehicle, kg/h.

Value $Y_{m_t}$ determined by the formula, UAH

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

where $m_{m_z}$ is average annual mass of 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

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

\[
K_e = \frac{\sum_{i=1}^{s} k_i \varphi(i) + \sum_{z=1}^{m} A'_z m'_z}{\sum_{i=1}^{s} \varphi(i) + \sum_{z=1}^{m} A_z m_z}. \quad (12)
\]

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

\[
\begin{align*}
0 < k_n < 3.5, \\
0.02 < \varphi(i) < 2, \\
LLC_{vb} / LLC_{vm} > 0, \\
A_z > 0, m_z > 0, m_mz > 0,
\end{align*}
\quad (13)
\]

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.

References


Рецензент: М.А. Подригало, профессор, д.т.н., ХНАДУ.