Juliusz Engelhardt
prof. zw. dr hab.
Uniwersytet Szczeciński
Wydział Zarządzania i Ekonomiki Usług
juliusz.engelhardt@wzieu.pl

DOI: 10.35117/A_ENG_17_07_04

Methodical basis for comparative analysis of rolling stock modernization economic effectiveness

Abstract: The article is dedicated to the analytical and methodological issues related to the economic effectiveness appraisal of rolling stock modernization. It is a very current topic because rail carriers often take up decision on comprehensive modernization of the rolling stock, especially locomotives, passenger carriages and multiple units. There was pointed out in the article the necessity of conduction of rolling stock modernization feasibility studies considering three different assumptions: a) assuming the same annual transport efficiency and expecting benefits at the exploitation costs side, b) assuming the same exploitation costs of the new and modernized carriage and expecting benefits at the transport efficiency side, c) assuming varied exploitation costs and varied transport efficiency of the new and modernized rolling stock. Feasibility study should be conducted by the means of discounted cash flow method - increase version, because that method allows best to capture the benefits resulting from the rolling stock modernization.

Keywords: Camp Railway; Economic analysis; Eficiency of investment

In Polish economic practice, rail carriers quite often decide on a comprehensive modernization of rolling stock, in particular locomotives, passenger coaches, and traction units. In such cases, investing in modernization does not lead to an improvement in the age structure of the rolling stock (lowering the average age), which is an obvious conclusion. Modernization of rolling stock, however, leads to favorable qualitative changes in the rolling stock structure, provided that these are cost-effective projects.

The overall cost-effectiveness of retrofitting rolling stock can be calculated in three options:[1]

I. Assuming the same annual transport performance and expecting benefits on the part of operating costs:

- modernization is profitable when the condition is met;

$$\left(C_{ZAK} - C_{MOD}\right) - \left(K_{EKSP}^{NOWY} - K_{EKSP}^{MOD}\right) \times t_{EKSP}^{MOD} > 0 \quad [1]$$

- modernization is unprofitable, it is better to buy a new vehicle when;

$$\left(K_{EKSP}^{NOWY} - K_{EKSP}^{MOD}\right) \times t_{EKSP}^{MOD} - \left(C_{ZAK} - C_{MOD}\right) > 0 \quad [2]$$

where: C_{ZAK} - the purchase price for a new rolling stock unit,

C_{MOD} - the price for the modernization of the rolling stock unit,

K_{EKSP}^{NOWY} - the annual operating cost (excluding depreciation) of the new rolling stock unit,

[1] The methodology is presented on the basis: F. Bławat, Podstawy …, op. cit., p. 205 – 206.

K_{EKSP}^{MOD} - annual operating cost (excluding depreciation) modernized rolling stock unit,

t_{EKSP}^{MOD} - lifetime of the rolling stock after modernization, in years.

II. Assuming the same operating costs of new and modernized vehicle and expecting benefits on the side of increased transport performance:

- modernization is profitable when the condition is met;

$$\left(C_{ZAK} - C_{MOD}\right) - \left(P^{NOWY} - P^{MOD}\right) \times t_{EKSP}^{MOD} > 0 \qquad [3]$$

- modernization is unprofitable, it is better to buy a new vehicle when:

$$\left(P^{NOWY} - P^{MOD}\right) \times t_{EKSP}^{MOD} - \left(C_{ZAK} - C_{MOD}\right) > 0 \qquad [4]$$

where: P^{NOWY} - annual value of revenues realized by the new rolling stock unit,

P^{MOD} - annual value of revenues realized by the modernized the rolling stock unit,

- other designations as in previous formulas.

III. Assuming different operating costs and diversified transport performance of new and modernized vehicle:

- modernization is profitable when the condition is met;

$$C_{ZAK} - C_{MOD} > \left(P^{NOWY} - K_{EKSP}^{NOWY}\right) \times t_{EKSP}^{MOD} - \left(P^{MOD} - K_{EKSP}^{MOD}\right) \times t_{EKSP}^{MOD} \qquad [5]$$

- modernization is unprofitable, it is better to buy a new vehicle when:

$$\left(P^{NOWY} - K_{EKSP}^{NOWY}\right) \times t_{EKSP}^{MOD} - \left(P^{MOD} - K_{EKSP}^{MOD}\right) \times t_{EKSP}^{MOD} > C_{ZAK} - C_{MOD} \qquad [6]$$

where: - markings as in previous formulas.

It can be assumed that the formulas [1] - [6] express the theoretical general conditions for the profitability of rolling stock modernization compared to the purchase of a new rolling stock, however, the analysis presented above would be static, not taking into account the value of money in time (discount). For this reason, the above methodology should be modified in such a way as to include in the analysis not only the said discount but also very important for the results of the calculation of the investment efficiency of rolling stock projects, the residual value of projects. Thus, in the case of modernization of the rolling stock owned, the calculation of investment effectiveness should, in principle, be carried out using the discounted cash flow method in the compound (incremental) version, although it can be assumed that in simple situations the straight method can also be used. However, the compound (incremental) method allows to better capture the benefits of modernization due to the possession of an appropriate reference base for the implemented project. What's more, this method allows you to verify two basic decision dilemmas in the form of questions:
A. whether it is profitable or not to modernize the rolling stock,
B. whether it pays to modernize the old rolling stock or purchase a new rolling stock.

Considering the above-mentioned variants of the method analysis NPV in the incremental version, you can exit from the basic general formula of this method:

$$NPV = \sum_{t=0}^{n} \frac{S_t}{(1+r)^t} + \frac{RV_n^{I/II}}{(1+r)^n} \quad [7]$$

where: S_t - the sum of financial (cash) flows generated by a given project in a given year,

r - discount rate,

$RV_n^{I/II}$ - residual value of an investment project after the last year forecasts, appropriate for the variant under consideration.

$$S_t = CF_t - N_t \quad [8]$$

where: CF_t - operational flow of the project in a given year, excluding VAT,

N_t - investment expenditures of the project in a given year, excluding VAT.

Formulas [7] and [8] are general. However, from this point, one should introduce the parameters appropriate for the considered decision-making variants (variant I and II) and indicate the method of calculating the design elements for these variants. For the sake of simplification, the analysis omits income tax and changes in working capital.

Variant I - modernize or not modernize;

$$CF_t^I = \left(P_t^{MOD} - P_t^{NIEM}\right) - \left(Keu_t^{MOD} - Keu_t^{NIEM}\right) \quad [9]$$

where: P_t^{MOD} - revenues from the sale of transport services generated by modernized rolling stock in a given year,

P_t^{NIEM} - revenues from the sale of transport services generated by non-modernized rolling stock in a given year,

Keu_t^{MOD} - operating and maintenance costs of modernized rolling stock in a given year,

Keu_t^{NIEM} - operating and maintenance costs of rolling stock not modernized in a given year.

In the case of options without modernization of rolling stock, there are no investment expenditures, it is assumed that only its maintenance at the level of simple reconstruction, i.e. restoring the original construction and utility properties. You can, therefore, save that investment expenditure in this variant N_t^I they are only as much as they were spent on the modernization of the rolling stock. The residual value of an investment project is calculated in the manner appropriate to the income approach as the difference in the income value of the rolling stock modernized after the last year of the forecast and the liquidation value of the rolling stock not subject to modernization, which can be recorded as follows:

$$RV_n^I = \frac{RV_n^{MOD} - RV_n^{NIEM}}{r} \quad [10]$$

where: RV_t^{MOD} - residual value of modernized rolling stock after the last year of the forecast, calculated using the income method,

RV_t^{NIEM} - residual value of the unmoderated rolling stock after the last year of the forecast, calculated using the liquidation method.

Variant II - to modernize or purchase a new rolling stock;

$$CF_t^{II} = \left(P_t^{NOWY} - P_t^{MOD}\right) - \left(Keu_t^{NOWY} - Keu_t^{MOD}\right) \quad [11]$$

where: P_t^{NOWY} - revenues from the sale of transport services generated by the newly purchased rolling stock in a given year,

P_t^{MOD} - revenues from the sale of transport services generated by modernized rolling stock, in a given year,

Keu_t^{NOWY} - operating and maintenance costs of the new rolling stock in a given year,

Keu_t^{MOD} - operating and maintenance costs of rolling stock modernized in a given year.

Investment expenditures in this variant N_t^{II} are calculated as the difference between capital expenditure for the purchase of a new rolling stock and expenses for rolling stock modernization, i.e.:

$$N_t^{II} = N_t^{NOWY} - N_t^{MOD} \quad [12]$$

where: N_t^{NOWY} - investment outlays for purchases of new rolling stock in a given year,

N_t^{MOD} - investment outlays for modernization of rolling stock in a given year,

The residual value of an investment project in this variant is calculated as the difference between the income value of the new rolling stock after the last year of the forecast and liquidation or income (depending on the age of the rolling stock and its performance after the forecast period) of the rolling stock subject to modernization, which can be recorded as follows:

$$RV_n^I = \frac{RV_n^{NOWY} - RV_n^{MOD}}{r} \quad [13]$$

where: RV_t^{NOWY} - residual value of the new rolling stock after the last year of the forecast, calculated using the income method,

RV_t^{MOD} - residual value of modernized rolling stock after the last year of the forecast, calculated using the income or liquidation method.

Economic inference based on the analyzes carried out is, in principle, simple. Each positive value NPV means that the profitability rate of a given project is higher than the border rate, i.e. the discount rate, and therefore the project is economically viable. With positive values NPV for two variants, the higher value of this indicator determines. Projects for which the value NPV is negative are unprofitable from an economic point of view, while projects with NPV equal zero are treated as acceptable because their profitability is equal to the threshold. In addition, the above calculations can be supplemented by the calculation of the so-called internal rate of return of the project IRR. If this ratio is higher than the adopted discount rate, which is the interest rate, it means that the project is profitable, while at IRR lower discount rate than the considered one, the project is unprofitable and should be rejected.

One of the most important substantive issues related to the analysis of the efficiency of rolling stock projects in railway undertakings according to the above methodology is the proper estimation of revenues and costs, which will be directly attributed to the investment variants under consideration. It should be noted that railway undertakings sell transport services to customers by generating revenues from the sale of tonne-kilometers or passenger-kilometers and rolling stock generates costs, some of which are fixed and the remaining part related to operational work.

The total operating and maintenance costs of rolling stock appearing in the formulas presented above can be mapped using the following formula:

$$Keu_t = K_t^{ST} + \left(k_t^{Jzm} \times pr_t^{EKSP}\right) \quad [14]$$

where: K_t^{ST} - the total fixed costs of rolling stock maintenance and maintenance in a given year,

k_t^{Jzm} - unit cost of rolling stock calculated per unit of exploitation work,

pr_t^{EKSP} - operation work performed by the rolling stock in a given year.

Operation work pr_t^{EKSP} from the formula [14] is determined in a manner appropriate to the type of rolling stock. It is generally expressed in the following measures:

- for locomotives - in locomotives-kilometers or gross-tonne-kilometers made respectively in passenger or freight traffic,
- for wagons - in wagons-kilometers made respectively in passenger or freight traffic,
- for passenger trainsets or combined trains - in train-kilometers.

Estimation of the total costs of rolling stock maintenance and maintenance in a given year for the purpose of analyzing the efficiency of rolling stock projects should not pose major difficulties. Railway companies run because of the development of cost records and extensive statistics of operation work. In this situation, in particular, in the analysis of rolling stock modernization projects, the company usually has an extensive historical database, which, when properly prepared, is the starting point for financial projections. In the case of projects involving the purchase of new, previously unexploited rolling stock, projections of total operating and maintenance costs may contain a higher risk of inaccuracy, due to lack of experience and historical output database, but in this case, for example, various benchmarks or the results of comparable contracts may be helpful which are currently very often combined with additional obligations of the rolling stock provider to ensure the maintenance of this rolling stock (with an indication of the unit rate) for a specific, several or sometimes several-year period.

The total revenue from the sale of rolling stock transport services in the formulas [9] and [11] can be recorded as follows:

$$P_t = p_t^{Jtkm} \times tkm_t \quad \text{lub} \quad P_t = p_t^{Jpkm} \times pkm_t \qquad [15]\,[16]$$

where: p_t^{Jtkm} - unit revenue in PLN per tonne-kilometer of transport performance,

p_t^{Jpkm} - unit revenue per passenger-kilometer in PLN of transport performance,

tkm_t - transport performance performed by freight rolling stock (locomotives, wagons), in a given year, in tonne-kilometers,

pkm_t - transport performance performed by passenger rolling stock (locomotives, wagons, traction units, combined trains), in a given year, in passenger-kilometers.

The above formulas show that for the calculation of sales revenues generated as a result of the implementation of a given investment project by a given type of rolling stock, it is necessary to know the volume of net transport performance performed by the rolling stock in a given period. For this purpose, appropriate conversion of the operating parameters for net transport performance should be performed, known from statistics or assumed ex ante.

In the case of locomotives involved in the service of freight or passenger traffic, a universal way of estimating the volume of transport performance in net tonne-kilometers or in net passenger-kilometers can be used, according to the formula:

$$tkm/pkm_t^{LOK} = \frac{w_{t-NETTO}^{U} \times Q_t^{BRUTTO} \times l_t^{DOB} \times il_t^{INW} \times L_t^{D}}{w_t^{K}} \qquad [17]$$

where: tkm/pkm_t^{LOK} - transport performance in tonne-kilometers of the given locomotive number, respectively in freight or passenger traffic,

$w_{t-NETTO}^{U}$ - an index expressing the ratio of the average net weight of a train to its average gross weight, respectively for freight or passenger traffic,

Q_t^{BRUTTO} - the average gross weight of a freight train in a given type of transport or the average gross weight of a passenger train in a given type of transport,

l_t^{DOB} - the daily course of the locomotive in a given type of traffic,

il_t^{INW} - inventory quantity of locomotives, respectively in freight or passenger traffic,

w_t^{K} - index expressing the ratio of locomotives-kilometers to train-kilometers in a given locomotive group, suitable for freight or passenger traffic,

L_t^{D} - number of days of the calculation period (365 days a year).

Calculation of net transport performance performed by freight wagons covered by a given investment project can be made according to the following formula:

$$tkm_t^{WAGtow} = Z_t^{DYN} \times w_t^{CAŁ} \times km_t^{WAGtow} \times il_t^{INWwag} \times w_t^{ROB/INW} \qquad [18]$$

where: tkm_t^{WAGtow} - Transport performance in tonne-kilometers of a given inventory plan of freight wagons made in a given period (year)),

Z_t^{DYN} - dynamic loading of a freight wagon, in a given period,

$w_t^{CAŁ}$ - utilization rate of the total freight wagon, calculated as the ratio of wagon-kilometers loaded to a total wagon-kilometer,

km_t^{WAGtow} - total mileage of 1 wagon of inventory, in a given period,

il_t^{INWwag} - Inventory number of freight wagons,

w_t^{K} - index expressing the average share of the workload of freight wagons in inventory, in a given period.

Calculation of net transport performance performed by passenger wagons, multiple units or combined trains covered by a given investment project can be made according to the following formula:

$$pkm_t^{WAGpas} = q_t^{WAGprzec} \times km_t^{WAGpas} \times il_t^{INWwag} \times w_t^{CZY/INW} \qquad [19]$$

where: pkm_t^{WAGpas} - transport performance in passenger-kilometer net of a given inventory plan of passenger coaches (multiple units, combined trains) made in a given period (year),

$q_t^{WAGprzec}$ - average number of passengers in a passenger wagon (in a traction unit, on a combined train), in a given period,

km_t^{WAGpas} - total mileage of 1 passenger car (trainset, combined train) inventory roster, in a given period,

il_t^{INWwag} - Inventory roster of passenger coaches (traction units, combined trains)),

$w_t^{CZY/INW}$ - index expressing the average share of the active stock of passenger wagons (multiple unit trains, combined trains) in the inventory plan, in a given period.

After calculating the net transport performance for individual types and groups of rolling stock in a given period (year) and adopting unit revenue indicators and other forecasting assumptions relevant for the investment variant under consideration, the forecasted revenues are calculated in accordance with the formula [9] or [11].

The presented methodology for a comparative analysis of the economic effectiveness of rolling stock modernization concerns only the economic and financial aspects of projects related to the rolling stock modernization processes. Obviously, it does not include extensive issues of all technical and operational conditions related to the maintenance of rolling stock by carriers, the impact of rolling stock on railway infrastructure, and many other aspects, such as the impact of rolling stock on the environment, railway traffic safety standards, meeting TSI conditions and many other issues.