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CRITERIA FOR THE ASSESSMENT OF THE EFFECTIVENESS OF PROJECTS RELATING TO THE DEVELOPMENT OF THE TRANSPORT POTENTIAL IN RAILWAY TRANSPORT

Based on the experience from research and development work for railway transport companies, the paper presents the characteristics of selected indices relating to the Cost-Benefit Analysis and the Life Cycle Cost (LCC) Analysis, which can be applied in an assessment of the effectiveness of rolling stock capital projects.

INTRODUCTION

One of the most important aims behind the functioning of a rail transport company in market conditions is to multiply its value by maximising the benefits generated from the transport services it provides. Transport activities involve the allocation of financial resources to the implementation of capital projects in order to, *inter alia*, obtain and maintain means of transport, develop the human resources, organise the technical facilities, construct railway sidings, reloading terminals, gauge change points, warehouses, storage yards and other.

1. ROLLING STOCK CAPITAL PROJECTS IN RAILWAY TRANSPORT

The writings on the subject provide many different definitions of the term “capital project”. They depend on the nature of the activities which are defined as well as the scope of the elements included therein. According to the Lexicon published by the Polish Scientific Publishers (PWN), a capital project means economic outlays the aim of which is to introduce new or develop the existing assets [1]. More general definitions say that a capital project means the involvement of capital outlays in a business project to generate specific effects. In the paper [2], the capital project is defined as any business event burdened with a certain risk in which economic resources are engaged for a specific time in order to generate the intended effects.

From the viewpoint of the impact of capital projects on the potential of transport activities of a railway company, we deal with so-called tangible projects which consist in the acquisition or exchange of its tangible assets and means of transport (railway stock) and equipment and buildings for their maintenance in particular. It can be said that rolling stock capital projects are characterised by:

- the need to make considerable financial outlays,
- a long period of operation (long-term projects),
- high proportion of modernisation projects (extension and modernisation of vehicles in operation),
- decisions on capital projects taken by individual railway companies, and
- a considerable impact on the surroundings, the natural environment in particular.

These factors have a significant influence on the choice of appropriate methods for the assessment of the projects’ effectiveness. Means of railway transport are characterised by a long period of operation, in excess of 30 years. Accordingly, it is necessary to forecast a complex set of variables including such economic figures as outlays, costs and benefits over very long periods of time. A long period of operation determines a relatively long economic life cycle of rolling stock capital projects and has an effect on:

- the determination of the length of the calculation period which should comprise the whole project’s economic life cycle,
- the need to estimate the cash flows over 20 ÷ 35 years (depending in the vehicle type),
- the need to include in the calculation the value of money changing in time, and
- the need to take account of the risk involved in the uncertainty of long-term forecasts.

2. METHODS OF ASSESSING EFFECTIVENESS

The assessment of effectiveness of capital projects relating to means of railway transport is in the nature of a relative, microeconomic calculation – done from the viewpoint of a railway company (railway carrier, manufacturer, modernisation contractor) which makes specific capital outlays to purchase or modernise its rolling stock, the costs of operation and the benefits from the transport services it provides. A reliable assessment of effectiveness requires a comparison of several alternatives for capital projects which correspond to specific technical solutions [3]. The choice of the methods of examining the effectiveness of capital projects developed to date and applied in practice depends on the individual project’s characteristics [2]. Based on the experience acquired in the performance of research and development work for Polish railway carriers, [4] for example, the following methods can be applied to assess the effectiveness of rolling stock projects:

- Cost-Benefit Analysis,
- Life Cycle Cost Analysis.

These are methods recommended in international standards, including the UIC 345 *Environmental specifications for new rolling stock,* the standard PN-EN 60300-3-3:2017 *Reliability management. Part 3-3: Guidance on applications – Estimation of the life cycle cost*, recommended by the World Bank and the United Nations Industrial Development Organisation (UNIDO).

2.1. Ratios used in the Cost-Benefit Analysis

The assessment of effectiveness with the use of the Cost-Benefit Analysis represents the economic approach thereto. It has a rich theoretical background and offers a number of practical solutions. The theoretical description of the Cost-Benefit Analysis can be found in the extensive writings on the subject, including the papers [2,5,6,7,8]. As part of the Cost-Benefit Analysis for a capital project, calculations are made in which, by means of appropriate mathematical algorithms, the benefits, measured and expressed in figures in pecuniary units, relating to the capital project, are confronted with the capital outlays necessary for creating the project and the future costs of its operation. The benefits, capital outlays and the costs of operation are the basic elements of the Cost-Benefit Analysis and require to be calculated in the particular years of carrying out the project.

The basic ratios used in the function of criterion of the choice of options in the Cost-Benefit Analysis and which are highly useful in the decision-making process of railway carriers, include:

– Payback Period (PP) and the Discounted Payback Period (PP'),
– Net Present Value (NPV),
– Internal Rate of Return (IRR),
– Benefit-Cost Ratio (B/C Ratio).

Payback period

The Payback Period (PP) is understood as the time after which the initial outlays to implement the project are set-off by the benefits generated from the project which has been implemented. The condition for the occurrence of the Payback Period can be presented in short as [2]:

$$NI = \sum_{t=1}^{n} ND_t \tag{1}$$

where:
NI – capital outlays which have been made,
ND – annual financial surpluses from project implementation,
t = 0,1,2,...,n – year in the calculation period.

Like other so-called simple methods, the Payback Period does not comprise the entire project existence period and does not take account of the impact of the time factor. Its value is based on the use of the effects of several years. It enables the choice of an option intended to recover, as soon as possible, the initial outlays on the purchase or modernisation of means of rail transport, thus setting the horizon of the risk of committing capital to the project. An individual project can be carried out if its rate of return is shorter than, or equal to the period adopted by the carrier as permissible, and usually based on the experience with similar projects. A modified method of calculating the Payback Period consists in taking into account the changes in the value of money in time owing to the introduction of the discount rate into the calculations. The basis for determining the Discounted Payback Period is then not the nominal value of future benefits but their net present values.

Net Present Value

The Net Present Value (NPV) depends on the discount methods which, unlike simple assessment methods, take account of the spread over time of the expected benefits and costs involved in the project. This purpose is served by the discount technique which enables the comparability of the outlays and the effects realised over different periods of time. Determination of their present value is the basis for further conclusions. Discount methods make it possible to comprise in the assessment the entire life cycle of the project that is both the capital outlay phase and the operating one when the generation of effects is envisaged. This favours the accuracy of the assessment but involves the necessity to do thorough studies of the estimation of the calculation elements throughout the calculation period.

The NPV is the total of the differences between the inflows (benefits) and expenses (capital outlays and costs) set separately for each year of the calculation period, discounted as of the moment of the capital project's start. If the capital outlays are made in their entirety in year one $t = 0$, then the ratio is calculated from the formula [2]:

$$NPV = \sum_{t=0}^{n} (B_t - C_t) \cdot CO_t - N \tag{2}$$

where:
B_t – total benefits in the year t,
C_t – total costs in the year t,
N – capital outlays,
CO_t – discount ratio for the successive years of the calculation period (relevant for the interest rate which has been adopted),
t = 0, 1, 2, ..., n – successive year of the calculation period.

The NPV defines the scale of the benefits which may be generated by the capital project, expressed in the current value of money (as of the moment when the assessment is made). The Net Present Value method enables the development of an objective decision-making criterion used in the absolute assessment of the effectiveness of capital projects in railway transport. This criterion requires that NPV > 0 which means that the project concerned may be approved because it is profitable [9].

Internal Rate of Return

The Internal Rate of Return (IRR) is defined as the discount rate at which the net cash expenses are set off by the net cash inflow. It is also referred to as a discount rate at which the net value is zero. Its essence may be expressed by means of the following formula [9]:

$$\sum_{t=0}^{n} \frac{CFO_t}{(1+IRR)^t} = \sum_{t=0}^{n} \frac{CFI_t}{(1+IRR)^t} \tag{3}$$

where:
CFO_t – financial expenses in the year t,
CF_{It} – financial inflows in the year t.

The Internal Rate of Return method enables the development of an absolute and a relative criteria necessary for making decisions on capital projects. The absolute assessment consists in comparing the internal rate of return i_{gr} expressing an alternative engagement of capital in capital projects with a similar risk profile. It may also reflect the cost of the capital which has been engaged. The general form of the absolute decision-making criterion can be formulated as follows: IRR > i_{gr} which means that the capital project is profitable, returns the capital outlays and contributes benefits equal to the rate of return expected by the investors [9].

Benefit-Cost Ratio

The benefit-cost index also referred to as the B/C Ratio is the quotient of discounted benefits from the calculation period and discounted total project costs. It is calculated from the formula [9]:

$$PI = \frac{\sum_{t=0}^{n} \frac{CFI_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{CFO_t}{(1+r)^t}} \tag{4}$$

where:

CFO_t – financial expenses in the year t,
CFI_t – financial inflows in the year t,
r – discount rate.

A ratio higher than one demonstrates that the project is effective and should be accepted. In the relative assessment, the basis for the selection of the most efficient project is to maximise the ratio. A project with a B/C Ratio which is the highest is deemed to be most advantageous.

The Cost-Benefit Analysis which presents an economic approach to the assessment of effectiveness of rolling stock projects, has major limitations and does not take full account of one of the most important characteristics of means of railway transport which is reliability referred to as the RAMS (Reliability, Availability, Maintainability, Safety). The above limitations may be eliminated by the other of the methods – the Life Cycle Cost (LCC) Analysis presenting an engineering approach to the assessment of effectiveness.

2.2. Life Cycle Cost Analysis

The LCC are the total costs comprising the full life cycle of a vehicle from concept to write-off. The LCC may be divided into three components: costs of purchase, possession and write-off.

$$LCC = K_N + K_P + K_L \quad (5)$$

where:
K_N – costs of purchase,
K_P – costs of possession,
K_L – costs of write-off.

Based on the methods for performing the LCC Analysis proposed in the writings, a universal procedure can be proposed to assess the effectiveness of means of railway transport. Such procedure comprises six stages and is described in Fig 1.

In the proposed method, Stage 1 means the development of assumptions, preparation of input data and identification of the aims to be provided by the analysis. The output data relate to:
– identification of the vehicle's construction data,

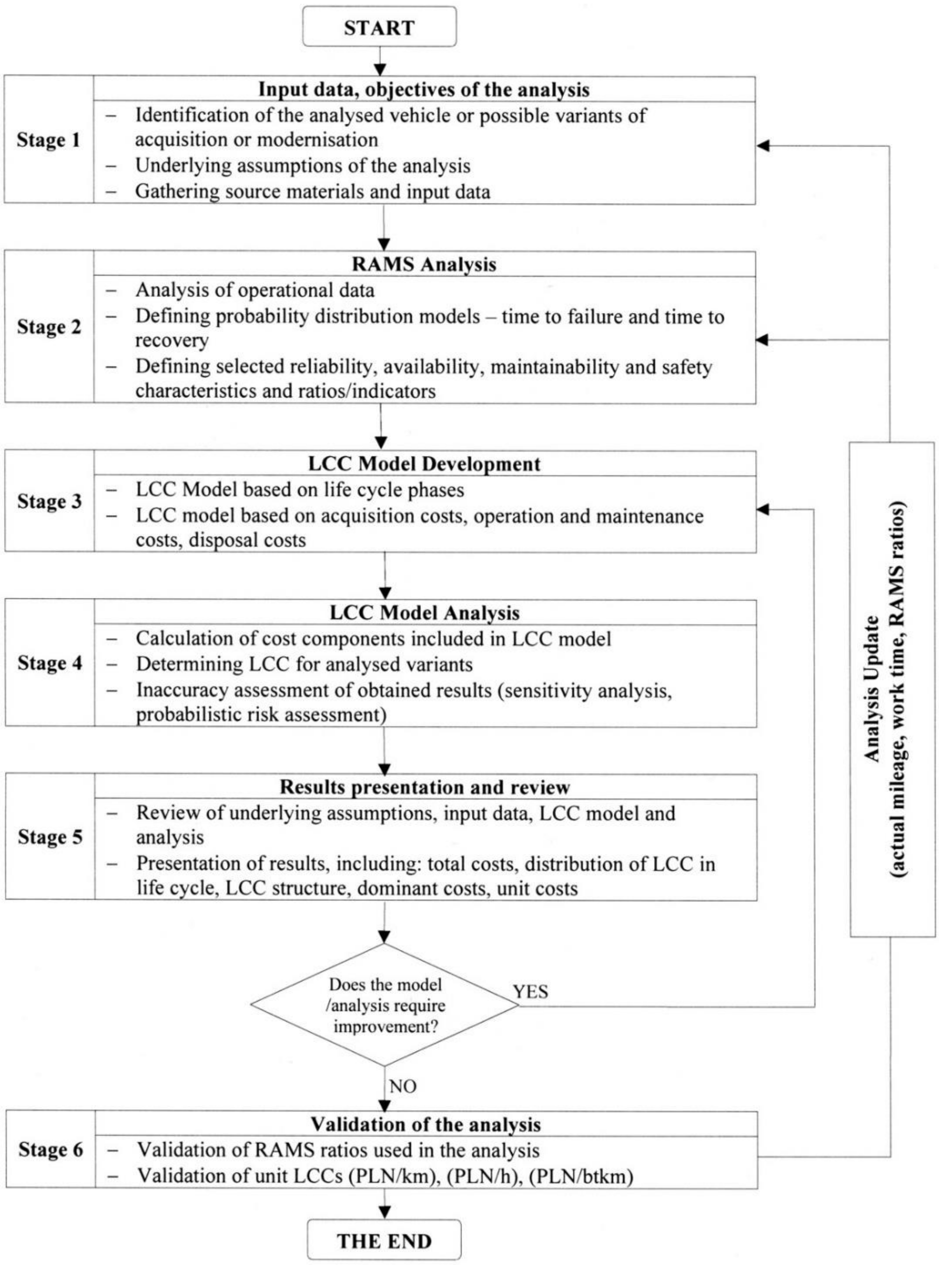

Fig. 1. LCC analysis and RAMS algorithm for rail transport vehicles [12]

– estimation of the vehicle's durability,
– identification of the conditions, duration and intensity of the vehicle's operation (diesel engine's operation time, transport work done during the year, etc.),
– requirements following from the vehicle's maintenance records (time to preventive maintenance, expected maintenance duration, etc.).

Examples of the aims of the LCC analysis include:
– comparative assessment of the total costs or the costs generated at the stage of vehicle's operation,
– identification of prevailing costs,
– identification of the cost elements and parameters which have the greatest influence on the LCC.

Stage 2 involves the conduct of the vehicle's reliability analysis, defined in the writings as the RAM (reliability, availability, maintainability) analysis. As required by the standard PN-EN 60300-3-3, a reliability assessment of a technical object should be an integral part of the process of LCC calculation. Ratios enabling a quantitative description of reliability, as well as methods of performing reliability examinations can be found in the extensive writings on the field, e.g.: [10, 11].

The choice of reliability ratios depends on the degree of detail and aim of the analysis. Examples of ratios applied to means of railway transport to:
– renewal function H(t),
– intensity of failures z(t),
– mean time to failure MTTF,
– mean time between failures MTBF,
– technical availability A,
– mean time to repair MTR,
– mean time to renewal MTTR.

A vehicle's reliability, comprising such characteristics as dependability, durability, maintainability and technical availability, is the basis for developing the cost model.

As demonstrated by the analyses, the reliability characteristics have the greatest influence on the costs of operation and maintenance. In most studies on this issue, the losses caused by the unreliability of a vehicle are treated as a figure which is determined and defined by the costs of stoppage and the costs of repairs, if any. In actual fact, losses are also generated which link to the direct effect of unavailability, resulting, for instance, from the loss of benefits produced during the period of the vehicle's availability, the costs involved in the loss of reputation and prestige or the loss of customers. The interdependencies between reliability, costs and economic effects of a rail vehicle are not easy to identify. However, once identified, they enable a comparison of the effectiveness of objects with different reliabilities. It is one of the advantages of the LCC Analysis compared with the traditional economic methods for the assessment of effectiveness.

Like any other model, the LCC model developed during Stage 3 is a simplified presentation of the reality. It identifies the vehicle's characteristics and aspects, transforms them into figures relating to costs. In order to make the model realistic, it is recommended to reflect the characteristics of the vehicle under analysis, including the expected scenarios of use, concepts of operation and all other assumptions defined at Stages 1 and 2. The model should be simple enough to be easy to understand and enable its future use, updates and modifications. It should be designed in such a way as to enable an assessment of the specific LCC elements independently of other ones. The development of the cost model includes:
– the cost division structure,
– the vehicle division structure,
– an estimate of the cost elements and parameters.

One of the most important tasks in LCC modelling is to define the cost division structure which consists in decomposing the cost categories at the highest level: costs of purchase, possession and write-off into the component costs. In accordance with the standard PN-EN 60300-3-3:2017-07, each cost category should be divided until the lowest level, i.e. the so-called cost element is reached [13, 14]. The cost element is a figure which cannot be expressed as the total of other costs. It is defined by means of mathematical formulae containing functions, constant values and parameters, e.g.: intensity of failures, man-hour cost of periodical repairs and maintenance, labour intensity of technical operations, discount rate and other. One of the approaches to defining the required cost elements consists in separating the lower identification levels relating to the division of the vehicle's structure, cost categories and durability cycle phases. The advantage of such an approach is that it is systematised and organised, thus providing a high level of confidentiality that all cost elements of great importance in the LCC model have been taken account of. The concept of defining the cost elements in a multi-dimensional matrix was proposed in one of the programmes of US' Department of Defence, Integrated Logistics Support (Directive DOD 4100.35 1968) and in the standard PN-EN 60300-3-3:2017-07.

During Stage 4, the LCC model analysis is about:
– calculating all cost elements incorporated in the model,
– identifying the costs which dominate in the LCC.

Additionally, at this stage, it is proposed to perform a sensitivity analysis in order to examine the influence of changes in the parameters and elements of the cost on the LCC. It should include in the first place the dominating costs and the reliability parameters, e.g.: the mean number of failures, duration of technical maintenance, etc.

Stage 5 in the proposed procedure is a review and presentation of the results. The review intended to confirm the correctness of the results and conclusions includes:
– aim and scope of the analysis: whether they have been correctly formulated and interpreted,
– assumptions made during the process of analysis: to make sure they are reasonable,
– model: making sure that it suits the aim of the analysis and that all necessary cost elements are included.

Where errors are found in the model, it is necessary to rectify and supplement the preliminary concept. A presentation of the results should contain a clear specification of the results obtained from the calculation.

During Stage 6, the model and the analysis itself are verified. The verification is possible only on the basis of the vehicle's actual operation within a specific time range during which operational data are collected on:
– vehicle's reliability and durability,
– duration of current repairs and preventive maintenance,
– labour intensity and consumption of materials in current repairs and preventive maintenance,
– consumption of power or fuel,
– use of consumables and other.

The assessment of the correctness and accuracy of the calculations of the costs defined in the LCC model is based on the operational data. This forms the basis for any claims against and contractual penalties from the vehicle's supplier.

CONCLUSIONS

The characteristics of the ratios used in the assessment of effectiveness of capital projects in rolling stock in rail transport presented in this paper is synthetic in its nature. In practice, the methodology of assessment of effectiveness is more complex which is confirmed in the writings on the subject. The methods presented in the paper: Cost-Benefit Analysis and Life Cycle Cost Analysis complement each other, e.g.: the LCC analysis makes it possible to find optimum relations between the costs of purchase and operation of a rail vehicle whilst the Cost-Benefit Analysis offers the possibility to identify the outlay limits and safety margins for the particular purchase option. As a tool serving the purpose of assessing alternative solutions, the LCC is, in many countries, an instrument legally required to carry out new projects, open competitive tenders to provide service or construct technical facilities – usually with considerable opening value and long durability. These include means of rail transport.

LITERATURE

1. *Leksykon PWN*, pod red. B. Kaczorowskiego, *PWN*, Warszawa 2004.
2. Sierpińska M., Jachna T., *Ocena przedsiębiorstwa według standardów światowych, PWN*, Warszawa 1994.
3. Dębniewski G., Pałach H., Zakrzewski W., *Mikroekonomia*, *Wydawnictwo UWM,* Olsztyn 2000.
4. *Analiza efektywności inwestycyjnej projektu nabycia przez PKP Cargo S.A. nowych elektrycznych lokomotyw wielosystemowych do obsługi międzynarodowych przewozów towarowych*, Praca nr M-8/297/2012, Politechnika Krakowska Instytut Pojazdów Szynowych, Kraków 2013.
5. Borowiecki R., *Efektywność przedsięwzięć rozwojowych*, *AE w Krakowie*, Warszawa-Kraków 1995.
6. Hawranek P.M., Behrens W., *Poradnik przygotowania przemysłowych studiów feasibility*, *UNIDO*, Warszawa 1993.
7. Manikowski A., Tarapata Z., *Ocena projektów gospodarczych*, *Difin*, Warszawa 2001.
8. Ministerstwo Infrastruktury i Rozwoju*: Wytyczne w zakresie zagadnień związanych z przygotowywaniem projektów inwestycyjnych, w tym projektów generujących dochód i projektów hybrydowych na lata 2014-2020*, Dokument nr MIiR/H/2014-2020/7(01)03/2015, Warszawa, 18 marca 2015
9. Dyr T., Kozubek P.R., *Ocena transportowych inwestycji infrastrukturalnych współfinansowanych z funduszy Unii Europejskiej*, *Instytut Naukowo-Wydawniczy Spatium,* 2013.
10. Szkoda M., *Assessment of Reliability, Availability and Maintainability of Rail Gauge Change Systems, „Eksploatacja i Niezawodnosc* - Maintenance and Reliability" 2014, nr 3, s. 422-432.
11. Szkoda M., *Wskaźniki niezawodności środków transportu szynowego*, „Logistyka" 2012, nr 2.
12. Szkoda M., *Kształtowanie potencjału przewozowego przedsiębiorstw transportu kolejowego*. Monografia, *Wydawnictwo Politechniki Krakowskiej*, Kraków 2017, ISBN: 978-83-7242-925-4.
13. Szkoda M., Satora M., *Ocena efektywności inwestycji infrastrukturalnych na linii kolejowej Wieliczka – Lotnisko Kraków Balice*, „Autobusy – Technika, Eksploatacja, Systemy Transportowe" 2017, nr 12, s. 1604-1609.
14. PN-EN 60300-3-3:2017-07 *Reliability management. Part 3-3: Guidance on applications – Estimation of the life cycle cost*.

Kryteria oceny efektywności przedsięwzięć związanych z kształtowaniem potencjału przewozowego w transporcie kolejowym

W artykule na podstawie doświadczeń zdobytych podczas realizacji prac badawczo-rozwojowych dla przedsiębiorstw transportu kolejowego, przedstawiono charakterystykę wybranych wskaźników związanych z analizą korzyści kosztów i analizą kosztu cyklu istnienia, które można zastosować przy ocenie efektywności inwestycji taborowych.

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