

# Life cycle cost as a criterion in purchase of rolling stock

Jan Raczyński<sup>1,\*</sup>

<sup>1</sup> Railway Research Institute, ul. Chłopickiego 50, 04-275, Warsaw, Poland

**Abstract.** The key parameter in assessing the economic viability of purchasing and operating rolling stock is the total cost incurred by the ordering party, starting from the preparation of the rolling stock purchase plan to the end of its operation, including its disposal. The methodology for calculating these life cycle costs (LCCs) has been developed especially in recent years based on the experience of the next-generation vehicle deployment. In Poland first vehicles purchase using the LCC method was carried out in few recent years - by PKP Intercity and by Lodz Agglomeration Railway. Despite the use of simplified criteria for the economic efficiency of vehicles, optimal offers were selected. This article describes examples of rolling stock purchase based on the low cost of life of the vehicle and the economic and operational results that have been achieved after several years of operation. Further possibilities for optimizing these costs were also indicated. Examples showing the proportion between the cost of vehicle purchase, its technical maintenance and its operation, where the electricity consumption is the main factor are given.

## 1 Introduction

Investment decisions, in it concerning the purchase of rolling stock, require costs and the benefit evaluation of applying different, alternative solutions [2].

They can concern among others technical parameters of rolling stock, expected maintenance costs and operational cost, the reliability or sources of financing among others.

Technical parameters of rolling stock are determining not only investment costs. They have also a significant influence on the level and the deployment of maintenance costs in the life of vehicle [8].

They are also a factor of creating the competitiveness of the public transport, in it railway, towards the individual motorization [6].

In consequence they are determining the competitiveness of states and regions [5], contributing to fulfil the idea of the sustainable development.

Studies and empirical examinations are confirming that correlation between maintenance costs exists and of use of rolling stock, and with level of their technical wear and tear [4]. Along with increasing the accumulated mileage of rolling stock is being increased labour intensity of repairs, resulting in an increase in employment and the fall in the technical available of vehicles. Also a risk of the defects grows and a reliability of providing services is lowering. It next is limiting benefits of the railway operator [3].

The total cost for the contracting authority, from rolling stock purchase project preparation till the end of its operation, including its scrapping (utilization) it the most reliable parameter in assessing the investment decision of rolling stock purchase.

is. The methodology of calculating these costs, defined as life cycle cost (LCC), has been improved in recent years based on experience from the exploitation of new generation vehicles. The presentation of methodological principles of projecting these costs is an essential purpose of this article.

In Poland in recent years took place first purchases of vehicles using the LCC methodology in PKP Intercity and Łódź Agglomeration Railway. Several years of operation of these vehicles allowed verification and assessment of suitability of the applied methodology. These experiences are positive. Even the use of simplified criteria for assessing the economic efficiency of vehicles allowed for the selection of optimal offers

## 2 Vehicle life cycle costs

The investment costs of purchase and operation of rolling stock are significant and amount to approximately 1/3 of the railway carrier's costs. For this reason, when purchasing rolling stock, it is necessary to apply a systemic approach going beyond the simple assessment of the vehicle purchase cost. The construction of the vehicle, its susceptibility to maintenance, accepted reliability and availability indicators, the way the service is organized, determine the total cost of vehicle operation. It is estimated that in the period of 25 - 30 years, the costs of rolling stock maintenance may be equal to the vehicle investment cost. The costs of electricity consumption can be even higher. While preparing specification for the purchase as well as organization management should take into account all aspects necessary to ensure maximum economic efficiency.

\* Corresponding author: [j.raczynski@infotransport.pl](mailto:j.raczynski@infotransport.pl)

Lifecycle costs of a vehicle (LCC) are commonly used for rolling stock investment efficiency analysis in vehicle operation theory.

However, it should be noted that the definition of cost essentially means the purchase price or service during its operation. The actual expenses for purchase of rolling stock is higher than the cost of raising capital. Methodology is simplified because methods and related costs of raising capital for the purchase and operation of the vehicle are different. In the further part of the study will be carried out an analysis of the actual costs of purchase and operation of the vehicle.

Life cycle vehicle cost (K) can be defined as follows [7]:

$$K = K_i + K_m + K_u$$

where:

$K_i$  – investment costs of vehicle purchase

$K_m$  – technical costs of vehicle maintenance

$K_u$  – vehicle operation costs

The investment costs of  $K_i$  include the vehicle purchase cost, spare parts (the first batch for current maintenance), workshop and diagnostic tools, technical documentation, instructions for use and maintenance, modernization and additional investments in the workshop facilities. This group also includes withdrawal and utilization costs.

The costs of the  $K_m$  maintenance process include implementation costs, vehicle preparation, maintenance costs (planned and scheduled repairs as well as ongoing repairs).

$K_u$  use costs include, in particular, power supply from network costs – catenary and other purposes as well as costs incurred as a result of the vehicle's impact on the track (this costs are usually omitted).

$K_m$  maintenance costs and  $K_u$  operating costs are the costs of vehicle operation.

The cost group  $K_m$  and  $K_u$  should refer in principle to the entire vehicle life. Calculation periods are usually defined for 20 to 30 years, with a practical indication for 30 years period.

### 3 Cost costs of vehicle maintenance

The total cost of vehicle maintenance during its 30-year lifetime is generally similar to the cost (price) of a vehicle purchase. This could mean that the average annual maintenance cost amount at 3.3% of the vehicle purchase cost. This should be considered as a starting point for further analysis. The cost of vehicle maintenance can be adjusted up or down depending on the following factors:

- the size of the fleet park (the smaller it is, the higher the unit maintenance costs);
- the technical complexity of vehicles;
- the cost of maintaining technical facilities (different depending on the region, land costs and other charges);
- labour cost (depending on the region).

These costs are not evenly distributed over the entire lifetime of the vehicle. The costs of back office preparation and the first period costs related to spare parts, materials and IT systems purchase as well as staff training are high.

In terms of rolling stock technical maintenance management there are two possible solutions:

- maintenance own workshops by operators, with possibility of shorter periods contracts with the rolling stock provider for the maintenance services provision;
- maintenance contract together with the contract for the rolling stock purchase for the first major repair period (about 15 years).

The second solution is the more advantageous for carriers without own technical depot developed and lack of an experienced staff. It transfers the risk of design and other errors to the rolling stock manufacturer. Such contract should require from the contractor to provide for peak hours a given quantity of rolling stock. In case of less than 20 vehicles two of them should be in reserve. In case of failing to meet the requirements, the supplier must provide replacement rolling stock with similar characteristics at their own cost along with a possible contractual penalty.

Rolling stock maintenance takes place in a manufacturer depot or the one lent to him by the carrier but with equipment provided at the expense of the supplier.

Usually are concluded 15-year maintenance contracts as such period is necessary for cost stabilisation due to their long-term predictability. In recent years appeared maintenance contracts for 30 years which means for the vehicle lifetime.

There are also in Poland contracts for periods shorter than 15 years, in example until first inspection repair (maintenance level P4). Such contract doesn't solve fundamental problems related to the maintenance costs for the ordering party. The first inspection repair means the warranty period for the vehicle and subassemblies. Higher maintenance costs may appear later, especially in 10 years from the date of purchase of the vehicle.

### 4 Rolling stock operational costs

Power supply costs are the key element of operational costs. They can be significantly different in individual countries, due to the differentiation of energy unit prices.

While choosing technical solutions it is possible to reduce power supply by changing such factors as:

- reduction of the train's weight;
- using drive devices with high energy efficiency;
- an effective recuperation system and the use of energy lost in braking for auxiliary purposes;
- optimization of energy consumption for auxiliary purposes (heating, air conditioning, lighting).

Energy consumption information may be required in the declaration provided by the rolling stock manufacturer.

In modern vehicles are being introduced more and more advanced methods of energy saving. Power supply from network is used for:

- traction purposes, i.e. for vehicle drive;
- auxiliary purposes and to ensure comfort for passengers and drivers.

The energy consumption for auxiliary purposes and ensuring comfort is relatively high in modern vehicles and may amount to 20 - 30% of the total energy consumption of the vehicle. For this reason, the effective use of energy for purposes (i. e. air conditioning control) is becoming more and more important. It is also important to ensure the highest energy recuperation. This energy can be:

- distributed directly to the traction supply network;
- stored in the vehicle (in batteries or capacitors) and re-used for traction or auxiliary purposes, when needed;
- directly used for auxiliary purposes.

The use of energy management systems can provide savings at standstill amounting to 3 - 5% of total energy used (15 - 20% for devices that provide comfort to travellers).

The energy consumption assessment method may be direct or indirect. The direct method consists in estimating the energy consumption under certain conditions (theoretical transfers), and the value declared by the manufacturers then verified in practice at rolling stock delivery. This methodology is defined in the document CLC-TSI 50591, Technical Specification for verification of energy consumption of railway rolling stock [1]. This methodology is still not widely disseminated because of difficulties in its application. More simplified is an indirect evaluation methodology using specific mass index. It is the subject of the UIC 345 leaflet. The specific mass is defined in it as follows [9]:

**Table 1.** Definition of specific mass.

Type of rolling stock	Indicator
Locomotives	Vehicle weight
Multiple units and passenger cars	Vehicle weight per one seat
Freight cars	Vehicle weight per load

For passengers vehicles is used a following formula:

$$P = S + A \times B$$

where:

P – passengers number in vehicle

A – defined standing places per 1 m<sup>2</sup> of available vehicle space

B – available vehicle space for standing passengers [m<sup>2</sup>]

The A indicator of standing places per 1 m<sup>2</sup> depends on the type of traffic. In long distance service it is equal to zero, and for agglomeration railways even the value of 4 is used.

The method recommended in UIC 345 leaflet in a modified version was applied in several tenders in Poland: in which the mass per meter of vehicle length in a part available for passengers instead of mass per seat was used. This was justified by defining by ordering parties a minimum value of the seat pitch.

However, this indicator does not take into account all elements affecting the energy consumption of the vehicle. Vehicles with the same specific mass may also have other technical solutions that affect their energy consumption. These are, for example:

- vehicle resistance movement related to its construction, e.g. aerodynamics;
- way of controlling drive train;
- so called intelligent energy consumption management for auxiliary purposes in the vehicle (air conditioning, heating, lighting, auxiliary equipment).

In order to take these factors into account in an accurate and objective manner it is necessary to perform in comparable conditions vehicle tests on selected routes.

## 5 Taking into account life cycle costs in tenders

Selection of the best offer for passenger rolling stock should be the result of a multi-criteria analysis taking into account all or at least the most important factors affecting the cost of the entire life cycle of the rolling stock.

The main factors to be taken into account and their possible weight in offers evaluation based on the example of selected tenders in Poland are as follows:

- rolling stock cost – 40 – 50% of value;
- cost of rolling stock maintenance in a cycle of at least 15 years (that is till the first major repair but without its cost) – 40 – 50% of value;
- energy consumption (can be calculated in few ways, i.e. by vehicle mass per one passenger indicator) – 15 – 20% depending from the character of the route which are to be operated by the new rolling stock.

Adopting specific percentage depends on the specificity of the rolling stock ordered, the conditions of its use and the expected economic results to be achieved. These values should be defined on the basis of technical and economic analyses in a feasibility study for each rolling stock purchase.

## 6 Summary

Using vehicle life cycle costs method is the most reliable for rolling stock purchase or modernization tender's offers assessment. This method up to date implementation in Poland have allowed gathering positive experience which allows its further improvement. There are still some problems to be solved particularly whose concerning methodology development in case of rolling stock maintenance by the operator or when it is partly subcontracted by the rolling stock manufacturers. Up to date cases concerns only rolling stock purchase with long term maintenance contracts. Also it should be considered taking into account vehicle energy efficiency based on the CLC-TSI 50591 specification [1]. This should particularly apply to agglomeration and regional traffic vehicles.

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