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LIFE CYCLE COST OF RAILWAY STRUCTURES

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Abstract

The article deals with problems of Life Cycle Cost (LCC) for railway structures with a particular focus on railway switches. LCC in general evaluates costs connected to primary preparation right through to termination of the construction work itself. It facilitates the search for the optimum variant of a project solution within the whole life cycle. The need to optimize costs for construction and operation is more than ever in demand in the context of increasing energy prices and relentless pressure to find new cost reduction opportunities. The aim of the article is to show what way to proceed in any LCC calculation for this important railway structure. This is placed together with designs directed at total cost reduction which we can carry out in each designated stage.

Keywords

LCC, railway structures, transport constructions.

Introduction

Life cycle costs (LCC) represent currently one of the most frequently addressed topics and not only in transportation engineering. LCC evaluates connected costs from the primary preparation until termination. It facilitates looking for an optimum variant of a project solution within the whole life cycle. The need to optimize cost for construction operations, together with increasing energy prices and persistent pressure for economies in outlays , is ever more demanding. The aim of the article is to show what way to proceed in any LCC calculation involving the railway switch. This is together with necessary steps for its optimization (total cost reduction) in the design stage. The railway switch LCC calculation can be carried out for its full operational life or for individual stages within the life cycle. For the most precise calculation it is necessary to have available selected data about:

* associated legislation,
* costs and prices,
* life operation,
* maintenance,
* accessibility,
* liquidation technology.

Similarly as with the creation of other calculation models there must be set up a complex solving proposal. After collecting the above mentioned information there follows the creation of a series of theories, hypotheses, which have to be verified by a practical application in the real environment. This can be done with the help of a methodological approach based on technical-economic disciplines. [1] For the optimum solution choice itself there are determined tools for utility and price evaluation together with decision making criteria.

Figure 1: Railway transit corridors in the Czech Republic [2].

Life cycle cost of a railway switch

Railway switches belong to one of the most important parts of a railway superstructure. Railway switches and railway structures are track structures ensuring the carrying function and leading a vehicle in whichever chosen direction between the track rails which mutually cross or variously bifurcate. The speed, security and continuity of the railway transport is connected with their construction and ensured performance. Geometrical arrangement of these structures is given by the branching-off angle (or crossing angle), the radius of the curve in individual branches, the length of tangent to the curves, track gauge in curves, total construction and arms length. As it is with the majority of railway structures elements also in railway switches there are innovations and technological improvements in their production. Thus new types of railway switches are created and gradually replace the outdated original ones. Their development is undertaken simultaneously with the development of rail track meaning for the railway switch construction itself as well as in concurrence with the whole railway superstructure.

Life cycle is the time evolution which includes all stages of a railway switch – from its design to its liquidation. It concerns the sum of all repeated but also non - recoverable expenses from the primary one for the acquisition itself, manipulation, instalment, operational maintenance, repairs or reconstructions up to and including liquidation costs. The process of identification and documentation of all costs connected with the whole life cycle LCC can be thus expressed as a relation:

LCC = IN + PN + LN

IN investment costs,

PN operational costs,

LN liquidation costs.

The use value of the work itself originates in all stages of its life cycle. The Inclusion of the amortized value of money is in the form of a discount rate. A classical means for setting LCC is the Net Present Value (NPV), which represents current value of future costs expended during the life cycle of a project. The optimum variant from the selected scenarios is the one which has the lowest resulting current value of future costs. A customary formula for the calculation of the Net Present Value of future costs is:

$$NPV=\sum\_{t=0}^{T}\frac{C\_{t}}{(1+r)^{t}}$$

NPV net present value of life cycle costs (LCC),

Ct total of all relevant costs after deduction of yields created in the period t,

r discount rate,

t analysed period,

T life cycle.

The discount rate serves for the conversion of future relevant costs to the present value. For the assessment of the effectiveness of public project investments in railway infrastructure there is usually used 5 per cent of the discount rate value. [3]

Investment costs

Investment (acquisition) costs usually include engineering activities, delivery and assembly of the railway switch. The highest possible attention should be given to the project solution, because it will obviously influence the whole life cycle of the railway switch. For example if the railway switch is placed in a loaded rail with a mounted crossing frog, it will wear out or possibly destruct quickly (and it will be necessary to replace it fully). Whereas if there is put a railway switch with a monolithic crossing frog made from a better material and also with camber wing rails thus improving the passage of the wheel through the crossing frog, it will resist much longer before any possible exchange (it is similar with switch tongues). [4] A particular sum of costs for delivery and switch assembly is set up by a supply firm. For setting up total costs for a definite unit of measurement in the Czech environment (e.g. pc, m2) there is a costing model:

* Material costs
	+ Costs for a switch and an auxiliary material for its assembly
	+ Costs for transport of the material
* Wage costs
	+ Costs connected with workers who will install the railway switch (gross hourly/piecework wage)
* Machine costs
	+ Costs for machines serving the switch assembly (costs for operational materials and transport of a machine to the site)
* Other direct costs
	+ Costs determined for transfer for social and health insurance for the workers who directly deal with the switch assembly
	+ Costs for technological transport of a railway switch (associated with materials transport etc.)
* Overhead costs and profit
	+ This category serves to place all indirect costs associated with the railway switch delivery and assembly (e.g. a firm operation, THP workers wages, machines purchase etc.)

Total resulting acquisition costs are influenced by many factors. For example the type of sleepers used, length of a railway switch, using crossing frogs, rectification of rail materials etc. It also depends on whether it is a standard geometry switch or a switch transformed into an arc (in the case of transformation which has not been used, it is necessary to carry out a drawing documentation-a cost increase).

Operational costs

Railway switches involve the checking of costs status, maintenance (grinding work, packing, lubrication, minor interventions such as partial equipment adjustment), restoration, reconstruction, engineering activity (monitoring, planning, project preparation, assembly supervision etc.). From the investor´s plan it is a very complicated matter to find and evaluate all the necessary data in creating a model. This is why there are used professional assessments gained from specialists with appropriate experience. [4]

Costs at the liquidation stage

This usually represents costs connected with disassembly, transport, ecological liquidation and administration. [4]

Case Study of an LCC switch

For the creation of an example for a switch LCC calculation with the construction of a new rail stretch there was used information gained both from representatives of private firms and from the public agency RIA (SŽDC). The necessary information about various categories of costs appear in the calculation as expert estimates. The inputs for the LCC model calculation are summarized in Table 1.

Table 1: Inputs for LCC railway switch calculation (source: authors)

|  |  |  |  |
| --- | --- | --- | --- |
| Evaluating period | 30 years | Type of switch | J60E2 1:14-760, concrete, sleepers |
| Discount rate | 5,0 % | Number of operation of switches  | 100 – 150/ day |
| Design speed  | 200 km/h | Type of transport  | combined |
| Annual wage growth | 2,0 % | Inflation | 1,1 % annual growth by 0,2 % |
| Construction length  | 14 days | Number of general repairs | 2 |

* Investment costs

a. Acquisition cost of the switch - from the supplier

Type J60-1:14-760 price 3, 349, 800 CZK

b. Transport to the site - expert estimate

50, 000 CZK

c. Switch assembly by the crane wagon - expert estimate

2, 322, 900 CZK

d. Engineering activity - expert estimate

8 % from acquisition costs of the switch 457, 816 CZK

* Operational Costs
1. Restoration costs

Ministry of Transport of the Czech Republic states life operation of the railway superstructure 30 years = 0 CZK

1. Maintenance costs

i. Lubrication - expert estimate

Annual average consumption for a loaded switch (lubrication 1 x in 9 days) is roughly 1,2 kg of lubricant = 110, 000 CZK/year

ii. Status check - expert estimate

Measuring wagon for railway superstructure 17, 000 CZK/year,

employees ensuring switches measurement 30, 000 CZK/year

iii. Treatment, cleaning and adjusting of switches parts - expert estimate

40, 000 CZK/year

c. General repair costs (reconstruction) - expert estimate

i. Engineering activity - expert estimate

15 % of the construction work costs 85, 841CZK/repair x 2 = 171, 682 CZK

ii. Construction work - expert estimate (supported by several construction budgets)

10 % of acquisition costs of a switch 572, 270 CZK/repair x 2 = 1, 144, 540 CZK

iii. Ensuring traffic closure - expert estimate

Together with the switch repair there will also be carried out repair work on other railway structure elements. From the total schedule there will be devoted three days for the switch itself. Ensuring the substitute transport for the shorter distance on the less loaded rail track the costs per day are 115, 000 CZK.

115, 000 CZK/day x 3 = 345, 000 CZK

* Liquidation costs
1. Disassembly - expert estimate

Rail on concrete sleepers 1, 590 CZK/m, switch length is roughly 25 m, 25 x 1, 590 = 39, 750 CZK

1. Carrying away - expert estimate

20, 000 CZK

It is possible to calculate the LCC from the above expressed values for individual stages of the LCC switch. Individual input and output values are summarized in the Table below.

Table 2: Total costs in the LCC of the switch calculation (source: authors)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| LCC stage | Type of a switch cost  | Frequency of occurrence | Total cost [CZK] | Discount sum of costs in  LCC [CZK] |
| Investment costs | Acquisition  | 1 x operation life | 3, 349, 800 | **6, 080, 401** |
| Transport  | 1 x operation life | 50, 000 |
| Assembly  | 1 x operation life | 2, 322, 900 |
| Engineering activity | 1 x operation life | 457, 816 |
| Operational costs | Maintenance  | 1 x year | 110, 000 | **3, 921, 789** |
| Status check | 1 x year | 47, 000 |
| Treatment, cleaning and adjusting  | 1 x year | 40, 000 |
| Engineering activity (repair) | 1 x 15 years | 171, 682 |
| Construction work (repair) | 1 x 15 years | 1, 144, 540 |
| Ensuring traffic closure (repair) | 1 x 15 years | 345, 000 |
| Liquidation costs  | Disassembly  | 1 x operation life | 39, 750 | **14, 562** |
| Carrying away  | 1 x operation life | 20, 000 |

On the basis of calculated values there was created a graph with proportions for individual stages in the LCC of a switch. The investment stage manifested itself as a dominant one which is typical for engineering works. This is why it is appropriate to pay great attention to this stage of LCC costs.

Figure 2: Graphic calculation of LCC switch (source: authors)

Conclusions and Recommendations

In several chapters there has been summarized and shown a method in the railway switch LCC calculation. In comparison with building constructions where there is usually dominant the category of operational costs there has been confirmed that with engineering structures it is just the opposite. Investment costs are dominant and these are in general enormously high. A very narrow group of specialists deals with this segment of transport structures and as has been several times mentioned in the text, the access to information is very difficult. Nevertheless, there was some success in coming to several conclusions and recommendations. The summary itself and recommendations are presented in several points below:

* When designing construction it is necessary that the project engineer deals with the complex economic aspect of a project and not only with acquisition costs.
* The switch increases the track price for 1 km and its insertion is necessary.
* If the switch is in a loaded rail, before the problems start e.g. with corrosion, it comes to be unusable due to wearing out.
* If the switch is in low loaded rails, it can result in degradation due to the influence of atmospheric influences – e.g. wooden sleepers have a life operation 20 – 60 years, if the switch is located in worse climatic conditions it can result in sleepers rotting earlier than for wearing out or degradation of a steel material.
* Higher investments are justifiable if gaining the longer life operation – especially so with an elastic switch.
* Investments enable lowering of operational costs and costs for maintenance.
* Higher annual costs for control and maintenance are compensated by the prolongation of operational life.
* After the monitored operational life the preferences can turn due to inclusion of the repair and maintenance cycles – more expensive acquisition costs will offer a return over the life cycle.

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