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Evaluation of effectiveness of separating layers in railroad track structure using life cycle cost analysis

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Abstract

This article deals with the problem of evaluation of effectiveness for separating layers in railway track structure. The statistical analysis of railway track characteristics in this study was carried out for sections of railways with separating layers in track structure and without such layers. Evaluation of effectiveness was done by means of life cycle cost calculation and failure rate prediction, using the life cycle model based on reliability analysis.
Parameters of trends between intensity of failure accumulation and operating time of track structure (in years or tons) were calculated on the basis of railway infrastructure automated system database. Source data for calculations are characteristics of operational condition, features of track construction, values of failure rate, statistics on track geometry and maintenance of way works, performed on railroad section. Values of failure rate were calculated using the life cycle model based on reliability analysis. This model describes changes of railway track technical condition for all periods of its life cycle: period of infant mortality, useful life period and wear out period.
As a result, values of economic effect for separating layers in different operation conditions are given.

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Keywords: railway track structure, separating layers, life-cycle costs analysis, effectiveness evaluation

The railway track structure may include separating and protective layers that perform various functions.

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Firstly, it is the most commonly used layer of geotextile laid on the solid subgrade under the layer of ballast. The role of this protective layer is to prevent mixing of soil subgrade and ballast. Along with that there shall be provided water filtering from the ballast to subgrade.

Secondly, it is a layer of polystyrene plates, placed as a heat protection material for prevention of railway track blow-ups due to freezing of water-saturated subgrade soil.

Thirdly, it is the geogrid layer used for underballast layer strengthening.

Other variants of protective layers suggests using of various polymeric films, layers of bitumen, and finally, the use of standard track structure that contains in its structure a protective layer as a mixture of sand, gravel and crushed stone.

When selecting the optimal track structure for different operating conditions, the question arises: by what criterion this choice is to be made.

The use of economic criteria in decision-making in maintenance of way on Soviet railways began in 1930th.

The task of maintenance cost analysis was investigated by Shakhunyants [1], Shulga [2], Andreyev [3].

The most correct way to determine the effectiveness of various technical objects and systems is the analysis of the life cycle cost (hereinafter – LCC). Life cycle is a set of processes from the phase of creation of an object concept through stages of requirements determination, design and creation of the object, its using and utilization.

Initially, the use of LCC theory for the railway track was developed by such researchers as Coenraad and Zoeteman [4, 5, 6], then RAMS methodology was added to the LCC, for example, by Patra [7].

On Russian railways the LCC calculations and RAMS methodology are presently also in use. RZD had officially introduced enhanced methodology «URRAN». These researches are developing under the direction of Gapanovich [9].

For the track structure, life cycle is a period from one overhaul (renovation, renewal) to the next. The frequency of overhauls is regulated by «Specifications for the reconstruction (modernization) and repair of railway track « [10].

The purpose of the life cycle cost calculating is optimization of resource assignment. There are two types of life cycle cost in this methodology: the life cycle cost in case when the object is to be replaced and life cycle costs in case when the object is continuing its operation. In both cases, LCC is calculated using forecasting techniques comparison and selection of the optimal ways to continue the life cycle. Therefore, assessment of costs at all stages of the life cycle is the task, which allows managing resource assignment within a life cycle.

The costs are determined using the economic model of behavior of the object at stages of the life cycle. In economic terms, the cycle consists of five types of costs that characterize individual stages. The scheme of costs over the life cycle is shown in Fig. 1.

The expression for LCC calculation is as follows:

$$S_{\mathrm{lcc}} = S_{\mathrm{rk}} + S_{\mathrm{mr}} + S_{\mathrm{mow}} + S_{\mathrm{util}} - S_{\mathrm{ret}} \tag{1}$$

where S_{lcc} is life cycle cost between overhauls

S_{rk} is overhaul costs;

S_{mr} is midlife repairs costs (medium ballast cleaning repair, raising repair, surfacing repair and so on);

S_{mow} is track maintenance costs, including failure repairs

S_{util} is track structure materials utilization costs during the next overhaul;

S_{ret} is returnable amounts for permanent-way materials.

Due to possible insufficiency of railway track technical conditions data, calculation of costs for track maintenance works can be calculated in various ways: based on results of simulation of track and rolling stock interaction, based on results of field tests and observations with measuring of state parameters, based on results of analysis of direct maintenance of way costs.