

Ecological and economic efficiency of the life cycle of railway territorial-industrial complexes

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Abstract. The paper focuses on the development of the life cycle and its corresponding stages for the new concept of railway territorial-industrial complexes (RTIC). The life cycle calculation methodology (LCC) together with traditional methods of evaluating investment projects makes it possible to carry out an in-depth analysis of the effectiveness of investment projects in accordance with the recommendations of international standards. Here we mean such investment projects as RTIC of surface wastewater coming from railway stations purification. The life cycle of RTIC of surface wastewater treatment facilities can be divided into temporary stages with their technical and technogenic parts. The research also provides mathematical calculations done with account of railway territorial-industrial complexes specific character.

1. Introduction

The priority of the authors is the development of the appropriate stages for the life cycle of railway territorial-industrial complexes (RTIC). The construction of RTIC wastewater treatment facilities is a significant investment in the creation of a new modern technical facility intended for nature protection purposes – that is drainage systems from railway stations. The assessment of their feasibility should be based on modern methods of analysis and calculation to determine the effectiveness of investments as well as social, environmental and other consequences of their construction and operation [1].

2. Theoretical study

The life cycle calculation methodology (LCC) together with traditional methods of evaluating investment projects makes it possible to carry out an in-depth analysis of the effectiveness of investment projects in accordance with the recommendations of international standards [2, 3, 4]. Here we mean such investment projects as RTIC structures of surface wastewater coming from railway stations purification. The life cycle of RTIC structures of surface wastewater treatment facilities can be divided into some temporary stages as shown on Figure 1 (see Figure 1).

Technical and economic feasibility study of investments in the construction of RTIC and surface runoff treatment facilities is a critical step in making decisions about the advisability of investing in, designing, construction and exploitation not only of treatment facilities, but of the entire train station. At this stage it is necessary to determine technological and construction solutions, costs for design, construction and operation of the facility. The liquidation period is the end of the life cycle of RTIC and wastewater treatment plants and the beginning of a new stage. At the stage of operation, there may



be stages of reconstruction, modernization, overhaul, allowing extending the life of RTIC structures, including the development of feasibility studies and project documentation.

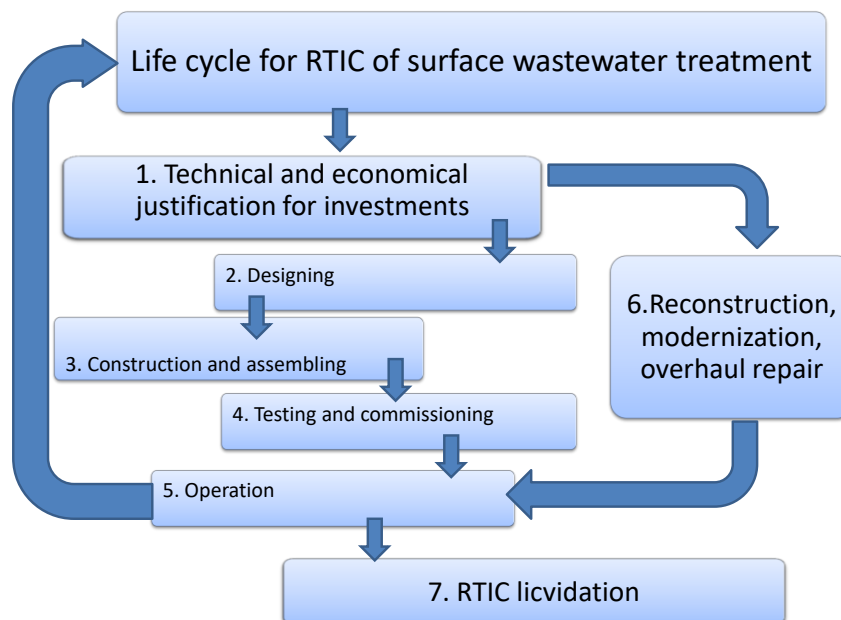


Figure 1. Stages of RTIC life cycle.

Due to the fact that any RTIC consists of two main parts which are organic soil, geological formations, surface and underground water sources, atmospheric air, flora and fauna and technogenic or technical (including such stationary objects as railway tracks, electric power supply lines, etc. and such mobile objects as locomotives, wagons, etc.), they should be considered separately [5].

The technical part (both stationary and mobile) of RTIC embraces six stages of its life cycle. They are 1) development of concepts definitions; 2) design and development activities; 3) production of technical means and facilities; 4) introduction of technical means and facilities into operation together with carrying out accompanying actions; 5) operation and maintenance; 6) withdrawal (liquidation and utilization).

The main division into the following two main stages should also be taken into account, (that is 1) costs related to acquisition (Stages I-V); 2) costs related to ownership and disposal (Stages V-VI).

The technogenic part of RTIC (roadbed) has four stages of life cycle. These periods are

1. The period of design, including stages of techno-economic justification of RTIC construction and stages of its structure planning and design.

2. The period of construction, including stages of its erection together with the development of technology, organization and production schedules of manufacture and stages of the RTIC performance development.

3. The period of RTIC operation that makes it possible to ensure the return on funds invested in their creation and development, including stages of structural elements and engineering systems maintenance in normal technical conditions by carrying out regular preventive and major repairs and stages of physical and functional wear (depreciation), requiring modernization and reconstruction of the whole object. If these activities are appropriate, this period precedes the beginning of a new life cycle of the object. Justification of the decision to start a new life cycle of the object must be accompanied by the implementation of works on the feasibility study and development of technical documentation for the reconstruction (modernization) of RTIC and its structures.

4. The period of the end of RTIC life cycle, which is inevitable in case when modernization or reconstruction, restoring the physical, mechanical and operational characteristics of the object to the normal operating level, do not make economic sense. At this stage, RTIC liquidation (demolition) is required. It is possible, however, to recycle and reuse RTIC materials, structures or equipment.

The periods of RTIC life cycle described above can be full or partial [6].

The full life cycle includes all stages of full duration and interstage expectations. Accordingly, the costs also represent the total cost of the entire scope of work.

A partial life cycle differs from a full one in its duration, structure and amount properties. In case of a partial economic life cycle, Russian Railways (considered as an operating organization) can independently carry out works during some stages and arrange carrying-out of work by other enterprises on other stages.

The partial life cycle is reduced to separate stages of the full cycle, for example, it may consist of only manufacturing, operation and disposal stages (or even of one stage only).

An important criterion here is to estimate of efficiency of methods used for RTIC infrastructure development (its ground, underground or combined structures) depending on the location of objects, surface relief and the area to be covered, as well as the need to construct either a main automatic flow tank or another type of surface runoff drainage.

3. Materials and methods. Mathematical description

The cost of maintenance of RTIC facilities should be kept to a minimum. The best here is such a process of wastewater treatment, which requires neither a constant presence of service persons nor regular changes and inspection.

The cost of such consumables as reagents is justified only at medium, large and major railway stations. At village stations and with facilities located on smaller sections between stations, mechanical cleaning methods should be applied. To reduce energy consumption of RTIC facilities, it is required to minimize the number of movable parts and complex automation, which will reduce both the energy intensity and costs of the cleaning process, thereby increasing the reliability of the installation.

For complete assessment of RTIC physical wear it is essential to conduct a detailed examination of its structural elements using modern techniques, equipment and engineering calculation of the residual load capacity of treatment facilities as complex construction systems.

The purpose of the presented LCC calculation is to correct and apply the known technique to the new concept. It is most difficult to estimate operating costs due to the large number of factors affecting them. However, they sometimes make up the bulk of LCC costs [7].

The presented calculation of LCC of RTIC and its treatment facilities is designed to cover a fairly long period of operation of building structures that is about 40-50 years. In connection with such a long period, it is necessary to take into account the factor of inflation and differences in similar costs at different times. It is advisable to apply the principles of compounding (future value) to determine the amount of money that the investor will possess at the end of the life cycle. In general, the formula for calculating LCC costs is as follows:

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d, \quad (1)$$

where: C_{ic} is the costs for construction works and purchase of equipment, rub; C_{in} is the costs for installation and commissioning, rub; C_e is the costs of energy resources, rub; C_o is currents costs, rub; C_m is the maintenance service costs, rub; C_s is costs which is due to downtime or loss of productivity, rub; C_{env} is the costs for environmental protection and prevented damage, rub; C_d is costs for disposal and calculation of residual value, rub.

It is also important to take into account the time factor of subsequent years dependence from the first year: according to calculations presented in Paper [8], the calculations were made for 40 years; the costs of the next 39 years are reduced to the first base-year through the discount coefficient.

$$Kd=1/(1+L)n, \quad (2)$$

where L is the interest rate of banks of the highest category of reliability, $L=0,1$; n is the period of reduction in years, $n=39$ years. The increase in prices and tariffs can be taken into account by the inflation coefficient. The costs of subsequent years, respectively, are reduced to the first base-year by the formula:

$$Cn=Cp[(1+m)/(1+L)]^n, \quad (3)$$

where, Cp is the costs of the future period; m is the annual rate of inflation, $m=0.0644$.

The calculation of LCC of RTIC and its treatment facilities is done according to the recommended variant for each category of stations and according to the previous calculations given in Table 1 (see Table 1).

The application of costs to calculate LCC goes as follows: C_{ic} is the costs for construction works and acquisition of equipment, these costs are referred to the first year only and are not subject to indexing; C_{in} is costs for installation and commissioning, these costs are referred to the first year only and are not subject to indexing; C_E is the costs of energy and thermal resources, these costs are referred to Option 4 (that is cleaning to MAC); C_o is the current costs consisting of wages, land lease (not required in railroad right-of-way) treating agent costs, active coal change and regeneration; C_m is maintenance service costs and costs of planned replacement of spare parts and their maintenance; C_s is the costs which is due to downtime or loss of productivity (not taken into account in these calculations because they are not a commercial object); C_{env} is the costs for environmental protection and prevented damage made up of the fee for the negative impact on the environment and by discharges of harmful substances into water bodies; C_d is the costs for disposal and calculation of residual value (not taken into account).

Table 1 presents the results of calculations for RTIC and its wastewater treatment facilities.

Table 1. Results of LCC calculation for RTIC.

Characteristics, thousand rubles	Symbol	Option 3 – 70% purification			Option 4 – purification according to MAC	
		bridges and bridge crossings	small-scale stations	small stations	middle stations	major stations
Costs of construction and installation works and equipment	C_{ic}	215.7	719.1	1438.1	35354.5	179772.3
Costs of testing and commissioning	C_n	7.15	23.8	47.7	1192.1	5960.4
Costs of energy resources	C_e	0	0	0	132.56	662.8
Current costs	C_o	47.7	159.2	318.3	8260.9	39304.5
Service and maintenance costs	C_m	23.85	79.5	159.6	4130.4	19652.3
Costs due to downtime	C_s	0	0	0	0	0
Costs of environment protection	C_{env}	174.9	182.9	1058.3	3292.1	40764.2
Disposal costs	C_d	0	0	0	0	0
LCC (1 year)	LCC	469.3	1164.5	3022	52362.56	286116.5
LCC (2-40 years)	LCC	366.054	908.31	2357.16	40842.7968	223170.87
LCC life cycle costs	LCC	835.354	2072.81	5379.16	93205.3568	509287.37

4. Conclusions

In this paper the methodology of LCC estimation for the efficiency of investment projects of surface wastewater treatment facilities has for the first time been adapted for railway territorial-industrial complexes. It is mentioned that this methodology can be successfully implemented and used in further investigations.

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