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Lifecycle cost evaluation of turnouts on a reinforced concrete base for especially heavy-duty track sections

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Abstract. The purpose of this study is to evaluate the economic efficiency of turnouts on a reinforced concrete base under harsh operating conditions by providing a model of their lifecycle and costing their maintenance and repair works. The article analyses failures in turnouts of Projects 2750 and 2768 and the costs of their elimination along two operational railway lines: O-N, V-S. An analysis of the data revealed that 90 % of the costs related to turnout failures were due to speed limit warnings and a mere 10 % of the costs were due to track possessions. The cost of turnout maintenance was calculated for four options (the 1st option was O-N, 1st track; the 2nd option was O-N, 2nd track; the 3rd option was V-S, 1st track; the 4th option was V-S, 2nd track). The calculation revealed that the highest maintenance cost per turnout related to the first track of the V-S direction. The model, cost elements and lifecycle cost for turnouts of Projects 2768 and 2750 from their installation to disposal is justified. While analysing the average annual total lifecycle cost of a turnout, it was concluded that option 3 (the V-S section, 1st track) had the highest lifecycle cost due to excessive operating time and no works on the complete replacement of metal parts. The optimal life cycle length for turnouts of Projects 2768 and 2750 is in the range of 1000-1200 million tons of gross running hours with required replacement of the metal parts of turnouts upon reaching them 0.6 of standard running tonnage.

1 Introduction

A facility lifecycle is an activity that emerges over a period beginning with the conception stage of a facility and ending with its disposal. Lifecycle cost is the total cost of development and maintenance of a facility over its entire lifecycle. Lifecycle costing is the process of economic analysis to evaluate the total lifecycle cost of a facility.

The main purpose of lifecycle costing is to provide input data for cost-effective investment, renovation and maintenance decisions. The lifecycle cost is optimised when a growing increase in the facility cost (renovation) due to increased reliability equals growing savings from reduced maintenance and logistics support costs as well as additional expenses.

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The task of turnout maintenance is to prevent the emergence of track gauge disorders and accumulation of damage to turnout components, to eliminate timely all emergent disorders and faults if the scope of disorders does not require repair work.

The main task of inspections and checks of turnouts is to determine whether the actual technical condition of turnout components meets the requirements established by regulations. Wear and chipping rates are the basis for ordering repairs, replacement of parts in turnouts or traffic speed limitations.

The lifecycle costs are calculated for the options of turnout designs in the Omsk – Novosibirsk (O-N) (first and second track) and Vhodnaya - Srednesibirskaya (V-S) (first and second track) especially heavy-duty railway sections with heavy haul traffic and higher axle loads. The turnouts of 2750 Project in the O-N section and that of 2768 Project in the V-S section are considered.

The study revealed that:

1) Railway turnouts are complex systems designed with complex geometry and a slope, which makes them difficult to control in terms of risk prevention. There is evidence that Building Information Modelling (BIM) can help to reduce risks at the very beginning of a project. BIM is considered to be an information system where tacit knowledge can be stored and extracted from a digital database, facilitating operational decisions as information is ready for analysis [1]
2) To develop an optimal (efficient and cost-effective) design of turnouts a lifecycle costing method can be applied where all the costs during the period under consideration, including those at the turnout purchase stage, are summed up [2]
3) Railway turnouts are an essential part of the railway infrastructure used over the entire network to guide trains along a desired track, thereby providing uninterrupted movement of every train. Therefore, their reliability and availability is an important element of network-wide efficiency [3]
4) Predicting the remaining service life of turnouts is very important to prevent unplanned stops and reduce the labour costs of normal railway operations. A genetic programming algorithm is used to predict the remaining service life [4]
5) The identification of general methodology for studying turnout operation and modelling based on the development of a turnout digital twin has a high potential for detecting faults during the turnout lifecycle [5]
6) A turnout is a multi-component system, and to prevent failures of turnout blocks proactively it is essential to have an ability to predict their condition [5]. Maintenance of turnouts is defined as a factor to reduce the cost of reporting on faults in a turnout [6]
7) Turnouts frequently impose operational limits in terms of speed and maintenance. It is therefore necessary to carry out a lifecycle cost analysis of turnouts from their purchase to disposal, making it possible to find the optimal economic solution [7]
8) The complex design of a turnout reduces the efficiency of its maintenance. It is therefore necessary to use a possibility of information modelling (BIM). 6D BIM provides such a possibility for turnout lifecycle management [8]
9) The innovative results of implementing INNOTRACK (the Innovative Track Systems) are effectively used in addition to the technical analysis in terms of lifecycle costs, reliability and traffic safety. The results reveal that significant cost reductions can be achieved [9]

2 Operational and technical characteristics of the O-N section and the 2750 Project turnout

The O-N section is double tracked, heavy-duty with mixed, predominantly freight traffic. According to the Unified Corporate Automated Infrastructure Management System

(UCAIMS), passenger and freight train speeds are on average 120 km/h and 80 km/h, respectively. The average axle loads of rolling stock on the first track are 190 kN, those on the second track are 127 kN.

68 pairs of freight trains run through the section per day, as well as 28-29 passenger trains and 2-17 commuter trains per day. The section is electrified with direct current. Electric locomotives of 2ES6 and VL10 series provide traction service for freight trains and those of EP2K and 4S2 series for passenger trains.

During 2003-2021, the main track was renovated with the installation of 2750 Project turnouts on reinforced-concrete foundations.

A turnout of 2750 Project, P65 type, 1/11 grade by Design and Technological Bureau for Track and Track Machines (PKTB CP). The turnout is used in the main tracks of railway lines with mixed freight-passenger traffic.

The turnout design features include:
– separate fastening;
– elastic bar terminals, sole plates with flanges;
– further welding of rail joints on the track;
– flexible point blade with welded rail ends;
– welded construction of a crossing;
– a check rail made of angle bars attached to reinforced concrete crossing sleepers.

The maximum speed of passenger trains is 140 km/h along the straight track and 50 km/h along the siding. The standard service life until removal of a point is 320 million tonnes gross, of a crossing is 80 million tonnes gross (not reinforced), 90 million tonnes gross (explosion-reinforced).

As of January 01, 2022, this section contains 275 sets of 2750 Project turnouts. At present, the major repair with installation of an upgraded version of 2750 Project turnouts is being carried out.

3 Operational and technical characteristics of the V-S section and a 2768 Project turnout

The V-S section is double tracked, heavy-duty with mixed, predominantly freight traffic. Passenger and freight train speeds are 120 km/h and 80 km/h, respectively.

The average axle loads of rolling stock on the first track are 218 kN, those on the second track are 76 kN. 70-78 pairs of freight trains run through the section per day, as well as 1-3 passenger trains and 1-3 commuter trains per day. Electric locomotives of VL80S series provide traction service for freight trains and those of EP1 for passenger trains.

During 2003-2021, the main track was renovated with the installation of 2768 Project turnouts on reinforced-concrete foundations.

A 2768 Project turnout, simple, of P65 type, 1/11 grade.

It is used in the main tracks of railway lines with predominantly freight traffic.

The turnout design features include:
– a pivoting point blade with a toe mounting via attachments and fishplates;
– a chair crossing with a cast crossing vee and rail wings;
– a check rail made of angle bars attached to reinforced concrete crossing sleepers.

The maximum speed of passenger trains is 140 km/h along the straight track and 50 km/h along the siding. The standard service life until removal of a point is 320 million tonnes gross, of a crossing is 75 million tonnes gross.

As of January 01, 2022, this section contains 201 sets of such turnouts.

Fig. 1. A turnout of P65 type, 1/11 grade on reinforced concrete crossing sleepers

4 Methodology for costing turnout maintenance

The maintenance cost of a turnout is calculated by using the following formula:

$$C_m(i) = C_{sd}(i) + C_{rep}(i) + C_{mech}(i) \tag{1}$$

where $C_{sd}(i)$ – wage costs, contributions and workwear of track servicemen employed for turnout maintenance, thousand rubles; $C_{rep}(i)$ – costs for the replacement of defective elements of turnouts, thousand rubles; $C_{mech}(i)$ – costs related to the operation of machines and mechanisms, thousand rubles.

Wage costs, contributions and workwear of track servicemen employed for turnout maintenance $C_{sd}(i)$ are calculated by using the following formula:

$$C_{sd}(i) = T + B + C_k + SC + O + W \tag{2}$$

where T – annual wage tariff for the track servicemen of the 3rd labour grade, roubles per year; B – wage bonus, roubles per year; C_k – regional coefficient, roubles per year; SC – social contributions, roubles; O – overhead costs, roubles; W – workwear costs, roubles.

Annual wage tariff for track servicemen of the 3rd labour grade:

$$Tariff = (labour\ costs)\cdot(hourly\ tariff\ rate) \tag{3}$$

The number of track servicemen employed for the maintenance of one turnout in the main track is calculated using the following formula:

$$N_{turnmt} = N_{turnmt1} \cdot C_{av} \tag{4}$$

where $N_{turnmt1}$ – payroll number of track servicemen who serve turnouts on reinforced concrete crossing sleepers, is calculated using the following formula:

$$N_{turnmt1} = \left(\frac{\frac{(59.778 To_{mt}^{0.2201})(34{,}009 V_{mt}^{0.2292})}{130.7\cdot C_{turnpassti}}}{T_y} \right) \tag{5}$$

where To_{mt} – weighted average tonnage over the past year, million tonne-kilometres gross/km per year; V_{mt} – weighted average speed in the section, km/h; $C_{turnpassti}$ – a coefficient taking into account the passing tonnage, calculated using the following formula:

$$C_{turnpasst1} = 0.3453 \ln(PT_{mt}) - 0.714 \tag{6}$$

where PT_{mt} – weighted average running tonnage, million tonnes gross.

For other design and operating conditions, the weighted average correction coefficient is calculated using the following formula:

$$C_{av}=1+\sum(C_i-1.0) \tag{7}$$

where C_i – a correction coefficient taking into account design and operating conditions.

The calculation is carried out for one turnout in the main track. Turnouts of projects 2750 and 2768 with 4 options (the 1st option is O-N, 1st track, the 2nd option is O-N, 2nd track, the 3rd option is V-S, 1st track, the 4th option is V-S, 2nd track) are considered. Table 1 presents the calculations for the pilot sections.

Table 1. Characteristics of the pilot sections

Section	Passing tonnage, million tonnes gross	Speed, km/h	$N_{turnmt1}$	$C_{turnpasst1}$	C_{av}	N_{turnmt}
O-N, 1st track	1100	102	0.152	1.704	1.69	0.258
O-N, 2nd track	1150	97	0.138	1.720	1.69	0.234
V-S, 1st track	1350	96	0.161	1.775	1.69	0.272
V-S, 1st track	700	95	0.107	1.548	1.69	0.181

Table 2 presents the results of lifecycle costing for the maintenance of one turnout.

Table 2. Lifecycle costing for the maintenance of one turnout (1 section)

Components of costing	Years of the lifecycle										
	0	1	2	3	4	5	6	7	8	9	10
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Tonnage, millio tonnes gross	57.5	172.5	287.5	402.5	517.5	632.5	747.5	862.5	977.5	1092.5	1100
Wage costs, people per year	0.05	0.11	0.15	0.19	0.21	0.23	0.24	0.24	0.25	0.26	0.26
Wage costs, people per hour	99.1	219.6	297.6	375.7	417.6	451.0	468.2	482.9	495.8	507.2	507.9
Annual tariff, thousand rubles	8.9	19.6	26.6	33.6	37.3	40.3	41.9	43.2	44.3	45.3	45.4
Wage bonus, thousand rubles	9.7	21.6	29.3	37.0	41.1	44.4	46.0	47.5	48.8	49.9	50.0
Regional coefficient, thousand rubles	4.3	9.5	12.9	16.2	18.0	19.5	20.2	20.9	21.4	21.9	21.9
Wage fund, thousand rubles	22.9	50.7	68.7	86.8	96.4	104.1	108.1	111.5	114.5	117.1	117.3
Social contributions, thousand rubles	7.0	15.4	20.9	26.4	29.3	31.7	32.9	33.9	34.8	35.6	35.7
Overhead costs, thousand rubles	29.3	65.0	88.0	111.2	123.5	133.4	138.5	142.9	146.7	150.1	150.3
Workwear, thousand rubles	0.5	1.1	1.5	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.5
Total, thousand rubles	59.6	132.2	179.1	226.2	251.4	271.5	281.8	290.7	298.4	305.3	305.7

The total cost of turnout maintenance has been determined for the four options (sections). The highest cost of maintenance of one turnout takes place in the 1st track of the V-S section.

The annual costs for a single replacement of defective turnout elements $C_{rep}(i)$ and costs for mechanisation $C_{mech}(i)$ are determined by statistical data of the Infrastructure West Siberian Directorate and presented in four options.

5 Costs of eliminating failures of turnouts

The permissible wear and tear of stock rails, point blades and crossings of turnouts in the main and receiving-departure tracks, depending on the specified running speeds, is given in the Classifier of Defects and Injuries of Turnout Elements.

These rates of wear and tear should be the basis for ordering repairs, replacing metal parts of turnouts, or speed limitations.

The vertical wear and tear of the bolted and rigid crossing vee is measured in the middle of its rolling surface at a cross section where the vee width at the measurement level equals 40 mm (Figure 2).

If the vertical wear and tear of the stock rail or crossing vee is more than 10 mm to 15 mm, the train speed is limited to 25 km/h. If the wear and tear is more than 15 mm, the traffic is closed.

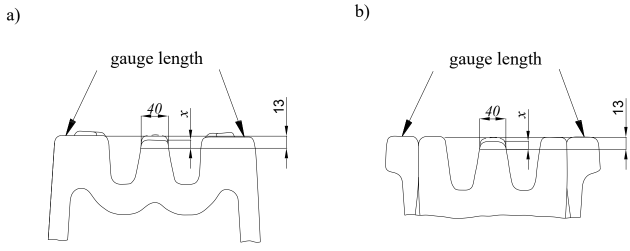

Fig. 2. Measurement of the vertical wear and tear of the bolted (a) and rigid (b) crossing vee *x* (mm)

The relative position of the point blade and stock rail is inspected using the 00316 universal gauge model or the PSI gauge (Point Blade and Stock Rail Inspection). The measurement is made at two reference points: at the point blade toe and at a distance of 200 mm for simple turnouts of 1/11 and 1/9 grades with the PSI gauge installed, as Fig. 3 shows.

If there is a gap between the gauge inclined edge and the stock rail head, immediate measures must be taken to eliminate this gap by removing misadjustment of the point blade to the stock rail and shoe pads or by grinding the point blade profile. If the above measures do not eliminate the gap, a repair kit must be replaced. The turnout is closed to facing movement until the repair kit replacement [10]

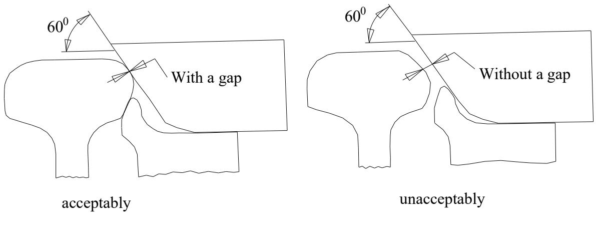

Fig. 3. Inspecting the relative positions of point blades and stock rails with the 00316 universal gauge model and the PSI gauge

The costs related to the elimination of turnout element failures include the costs for acceleration and deceleration of trains due to reduced speeds and the cost of train demurrage during a track possession.

The costs related to the elimination of turnout element failures $C_{fail}(i)$, include the costs for acceleration and deceleration of trains due to reduced speeds C_{rd} and the cost of train demurrage during a track possession C_p:

$$C_{fail}(i)=C_{rs}+C_p \tag{8}$$

The costs caused by reduced train speeds due to warnings are calculated using the formula

$$C_{rs}=\sum n_{warn}(b_1+b_2) \tag{9}$$

where n_{warn} – the number of trains which have passed through the section during the warning period, pieces; b_1 – costs related to the energy loss per train (due to braking and acceleration) when the speed vx is changed to the speed limit vlim, rubles; b_2 – costs related to the time loss due to the delay of a train, rubles.

Number of delayed trains ndem is calculated using the following formula:

$$n_{dem}=\frac{Ndem_{max}}{24} \tag{10}$$

where N_{max} – the maximum number of passenger and freight trains passed during a day; t_{warn} – duration of warning, hours.

The cost of train demurrage due to the track possession:

$$C_p=n_{tr}t_pC_{th} \tag{11}$$

where n_{tr} – number of delayed trains during the track possession, pieces; C_{th} – cost per train hour of demurrage, rubles.

$$n_{tr}=\frac{Np_{max}}{24} \tag{12}$$

Table 3 presents an example of costing due to reduced train speeds at 2750 Project turnouts by warnings in the O-N section, 1st track for the year 2021.

Table 3. Costs due to the reduced train speeds at 2750 Project turnouts by warnings in the O-N section, 1st track for the year 2021

Train type		passenger				freight			
Turnout specia-lisation		traffic control cross-overs		branches onto a side track		traffic control cross-overs		branches onto a side track	
limited speed, km/h		number of delayed trains, pieces	costs due to the reduced train speeds, thousand rubles	number of delayed trains, pieces	costs due to the reduced train speeds, thousand rubles	number of delayed trains, pieces	costs due to the reduced train speeds, thousand rubles	number of delayed trains, pieces	costs due to the reduced train speeds, thousand rubles
In 1st T	15	0.06	0.15	1.43	3.35	0.14	0.94	3.25	21.20
	25	2.17	4.50	0.19	0.39	4.91	28.64	0.42	2.47
	40	3.40	6.24	6.34	11.63	7.71	36.48	14.37	67.95
	50	0.02	0.03	0.02	0.03	0.04	0.17	0.05	0.18
	60	3.14	4.77	7.55	11.45	7.13	19.56	17.12	46.98
	70	0.07	0.09	-	-	0.16	0.23	-	-
	80	2.94	3.31	3.11	3.51	6.65	0.39	7.06	0.41
	100	-	-	0.59	0.38	-	-	1.33	0.04
Total		-	19.10	-	30.76	-	86.41	-	139.24

6 Lifecycle cost model of a turnout

The life cycle of a turnout begins with its major repair MR_T, followed by its operation and maintenance, including maintenance, complete replacement of metal parts R_M, scheduled preventive adjustments A and disposal of obsolete turnout elements MR_T (Figure 4).

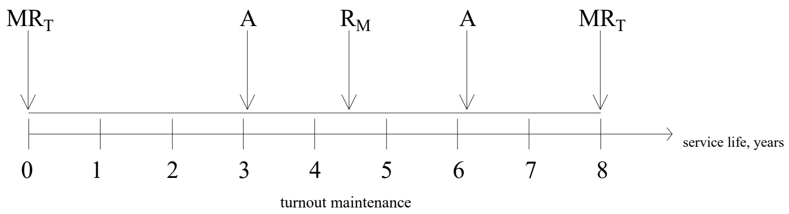

Fig. 4. Lifecycle cost model of a turnout on reinforced concrete crossing sleepers

Also, at regular intervals, grinding is carried out and crossings are completely replaced in dependence on their condition. At the end of the lifecycle, defective parts are disposed of with the return value. The next major repair is then carried out, which is the beginning of a newly mounted turnout's lifecycle (Figure 5).

7 Methodology for lifecycle cost evaluation of a turnout

To evaluate the lifecycle costs of a turnout, it is necessary to divide it into the cost component elements. On this basis, we assume the following turnout value model:

$$\begin{cases} \overline{TLC} = \dfrac{MR_t + \sum_{i=1}^{n} (C_{cm}(t) + C_r(t) + C_{fail}(t)) - C_{dis}(n)}{n} \rightarrow min \\ \eta(t) \leq P \end{cases} \quad (13)$$

where $\overline{\mathrm{TLC}}$ – average annual life cycle cost per turnout, rubles; MR_t – major repair cost, rubles; $C_{cm}(t)$ – maintenance cost per year *t,* rubles; $C_{fail}(t)$ – cost of eliminating failures per year *t,* rubles; $C_{dis}(t)$ – cost of disposing a facility (at the end of its service life), rubles; n – lifecycle length in years; η(t) – failure function (reliability index); P – required reliability level.

The amount of major repair costs MR_t and present operating costs (taking into account the time lag of the latter by a coefficient $\eta=\frac{1}{(1+d)^i}$) can be calculated by the following expression:

$$\mathrm{TLC} = MR_t + \sum_{i=1}^{n} \frac{C_{cm}(t)}{(1+d)^i} + \sum_{i=1}^{n} \frac{C_r(t)}{(1+d)^i} + \sum_{i=1}^{n} \frac{C_{fail}(t)}{(1+d)^i} + \sum_{i=1}^{n} \frac{C_{dis}(t)}{(1+d)^i} \quad (14)$$

where TLC – total life cycle cost of one turnout over its entire service life, rubles; d – discount rate; *t* – year of expenditure.

8 The results of lifecycle costing for turnouts

The lifecycle costs of turnouts on reinforced concrete crossing sleepers have been calculated for especially heavy-duty track sections of the Trans-Siberian Railway: O-N (1st track and 2nd track), where 2750 Project turnouts are installed, and V-S (1st track and 2nd track), with heavy-haul traffic and higher axle loads, where 2768 Project turnouts are installed (Table 4).

Table 4. Options of railway sections for lifecycle costing

Section	Passing tonnage, million tonnes gross	Service life, years	Average axle load, kN	Weighted average speed, km/h
O-N, 1st track	1100	10.5	190	102
O-N, 2nd track	1150	15	127	97
V-S, 1st track	1350	10	218	96
V-S, 1st track	700	17	76	95

Table 5 provides the results of cumulative life cycle costing for two options (the O-N section, 1st track and the V-S section, 1st track), and Figure 5 provides the results for the four options with discounting.

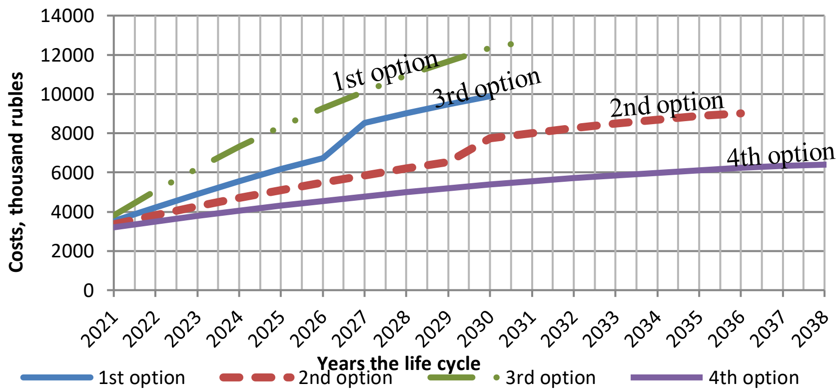

Fig. 5. Cumulative total costs per years over the life cycle of turnouts by options (with the discount rate)

The highest total costs are for the 3rd option (the V-S section, 1st track) with the highest axle loads and traffic density (Table 5), while the lowest lifecycle cost was for the 4th option (the V-S section, 2nd track) with the lowest axle loads and traffic density.

Table 5. Lifecycle costing

Components of TLC costing		Number of years											
		0	1	2	3	4	5	6	7	8	9	10	Total
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	
O-N, 1st track	Rehabilitation works, thousand rubles	3000	-	-	-	-	-	2209	-	-	-	-130	5079
	Maintenance, thousand rubles	377.6	461.1	515.3	569.7	602.2	629.6	647.2	663.4	678.5	692.7	693.6	6530.9
	Failures, thousand rubles	149.8	299.6	299.6	299.6	299.6	299.6	299.6	299.6	299.6	299.6	149.8	2995.6
	Subtotal, thousand rubles	3527.4	760.7	814.9	869.3	901.8	929.2	3155.8	963.0	978.1	992.3	713.4	14605.5

	Discount rate (d = 10 %)	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.466	0.424	0.386	-
	Total	3527.4	691.52	673.4	653.07	615.90	576.9	1781.4	494.2	456.3	420.8	275.0	10165.9
V-S, 1st track	Rehabilitation works, thousand rubles	3000	-	-	-	-	-	-	-	-	-	-130	2870
	Maintenance, thousand rubles	368.5	479.2	529.9	570.2	604.3	633.1	651.8	668.9	684.9	700.0	708.4	6599.2
	Failures, thousand rubles	442.4	884.80	884.8	884.8	884.8	884.8	884.8	884.8	884.8	884.8	442.4	8848
	Subtotal, thousand rubles	3810.9	1364	1414.7	1455	1489.1	1517.9	1536.6	1553.7	1569.7	1584.8	1020.8	18317.2
	Discount rate (d = 10 %)	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.466	0.424	0.386	-
	Total	3810.9	1240.01	1169.11	1093.14	1017.06	942.46	867.41	797.36	732.27	672.11	393.52	12735.4

Formulas (13, 14) are used to calculate the average annual life cycle cost of a turnout and its total service life cost taking into account the discount rate d = 10 %. The following is a calculation for the 1st section:

$$\overline{\mathrm{TLC}}=\frac{5079+6530.9+2995.6}{10}=1460.55 \quad \text{thousand rubles}$$

Table 6 and Figure 6 present the results of $\overline{\mathrm{TLC}}$ calculations for the other sections.

Table 6. Results of life cycle costing as per options

Lifecycle length, years	Actual tonnage before repairs, million tonnes	TLC, thousand rubles			
		without taking into account discounting		taking into account discounting	
		total	average annual	total	verage annual
10	1100	14605.5	1460.55	10165.9	1016.59
15	1150	15175.4	1011.691	9016.087	601.07
10	1350	18317.2	1831.72	12735.35	1273.54
17	700	10265.8	603.8706	6399.882	376.46

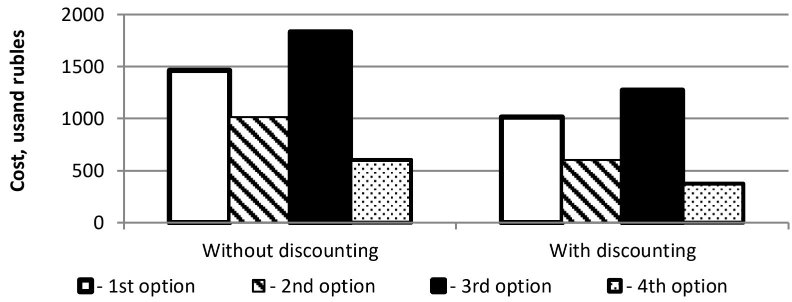

Fig. 6. Average annual life cycle cost for one turnout by the four options

An analysis of the result from the lifecycle costing of turnout as per options (Figure 7) revealed that the cost of rehabilitation works (turnout repairs) for the 3rd and 4th options is 1.8 times less as compared to options 1 and 2. This is due to the fact that there was no complete replacement of the turnout metal parts in the V-S section along the 1st and 2nd tracks. This resulted in tripling the costs for eliminating faults in turnouts as per the 3rd option as compared to the 1st option (Figure 7).

The total costs of turnout maintenance as per the 2nd option were 13 % higher as compared to the 1st option. This is due to 1.5 times longer service life of turnouts in years as compared to the 1st option.

An analysis of the average annual total lifecycle cost of turnouts (Figure 6) revealed that the 3rd option (the V-S section, 1st track) had the highest TLC due to high costs for eliminating faults in turnout elements, resulting from overkeeping 2768 Project turnouts in operation until they had run 1350 million tonnes gross and no replacing metal parts of the turnout in the middle of its lifecycle.

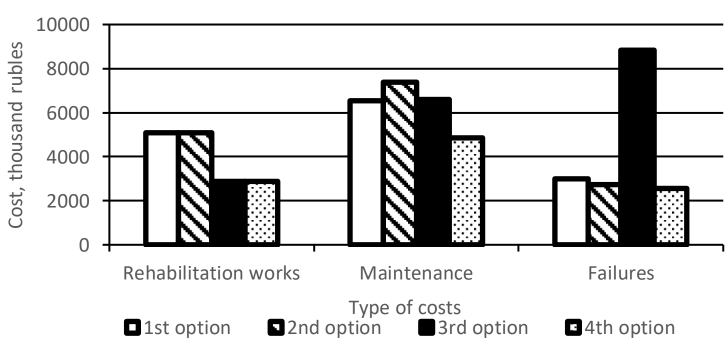

Fig. 7. Maintenance and repair costs as per four lifecycle options

9 Discussion

Calculations based on operational data have demonstrated that the greatest effect in terms of reducing the average annual lifecycle cost of turnouts is achieved by extending their service life due to complete replacement of metal parts followed by turnout alignment. In this case, the lifecycle of turnouts almost doubles.

In summing up the results of this study, it should be noted that the optimal lifecycle of turnouts of Projects 2750 and 2768 is in the range of 1000-1200 million tons of gross running hours, depending on the value of average rolling stock axle load with the required replacement of the metal parts of turnouts upon reaching 0.6 of standard running tonnage.

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