



Determining the Optimized Repair Cycle Structure Considering the Repairing Cost and the Gamma-Percent Lifetime

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Abstract: The paper presents the process of building a computer program to calculate the optimized repair cycle structure while considering the repairing cost and the gamma-percent lifetime. Examples have been taken for the cases of rolling stock details from the Vietnamese National Railway.

Keywords: Repair Cycle Structure, Repairing Cost, Gamma-Percent Lifetime, Lifespan

1. Problem

Currently, maintenance and repair systems for locomotives, wagons remained redundant planned systems. Basic utility of this system is to overcome the gradual deterioration (progressive) of worn and aging parts, which working time is limited by their lifespan. If such a life, in other words, the working period of different parts reached limited states, which overlapped, then the establishment of preventive repair system would be simple: all the parts would be recovered and the same amount of its working time would be recovered too. However, the fact that, every part of the locomotive and carriages are separate lifespans. The lifespan of the same type parts but working in different conditions is different. Even in the same working conditions, it may still propose alternatives, which lead to the difference in the structure of the repair cycle with such as volume, order and distance running between different repair times together.

Optimal structure of a repair cycle depends on many factors, including cost recovery, repair parts, components and their lifespan. When building a system for maintenance and repairing of the rolling stock, we have to focus on logical

targets of cost recovery to every detail, even the smallest parts have their lifespan which must be utilized most thoroughly. Recovery cost for parts will be the target for finding the coefficients of cyclical repairs, thereby allowing the distance recommended by the main engine as well as determines the distance running of parts of locomotive, so that they take advantage of the most affordable lifetime of different parts of different components.

Based on the algorithm relationships between the cost for optimal structure of repair cycle of locomotives and gamma-percent lifetime of their details, we need to conduct a program to reduce the volume of calculations and increase calculation speed.

As the next step of the studies done under the leader of Prof. Do Duc Tuan, from the University of Transport and Communications (UTC) in Hanoi, Viet Nam, this research will cover all the results from the previous works [5-10].

2. The Block Diagrams of Algorithm

The algorithm diagram is shown on Figures 1 and 2.

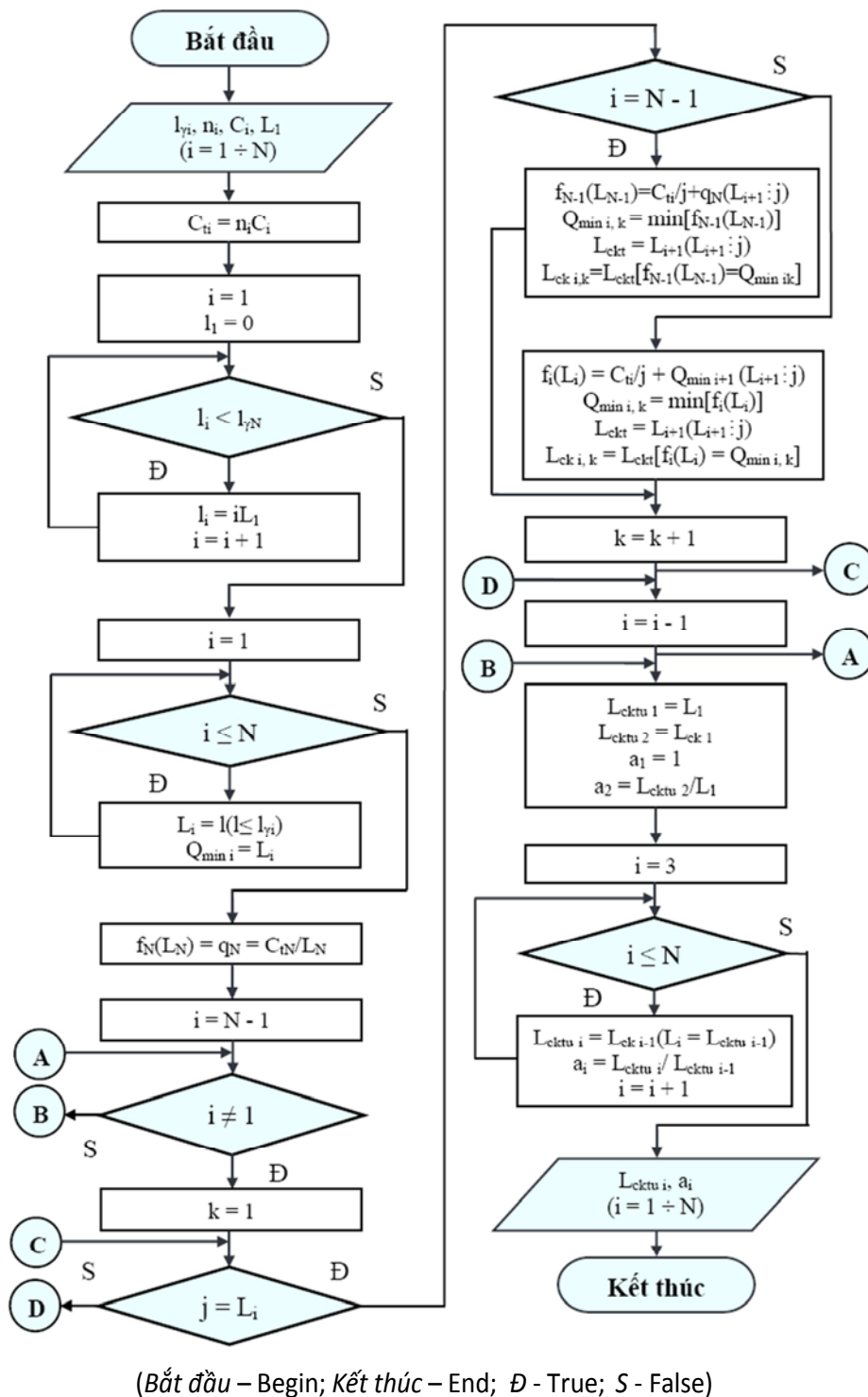


Figure 1. Algorithm for optimization of repairing cycle structure based on the gamma-percent life with a given value L_1 .

3. Building the Calculation Program

Based on the outlined block diagram using MATLAB programming language [4], we conducted programs developed on the following calculations:

1) Enter data for the parameters in accordance with the program guidelines. It can enter each component, which has separate costs or total costs. Then proceeded to arrange the

parameters in the table by ascending value of gamma-percent life;

2) Enter and conduct calculations, draw graphs showing the optimal structure of the intermediate;

3). After the selection, there is a sensible structure for repair parts, which conducts repetitive entire value, which can be adjusted according to the value structure of the original L_1 (L_1 may vary). From there on, the choice is a value at which L_1 total cost of repairs is minimal (optimal).

Finally, based on the calculation results optimal structural repair, recalibration processes cycle repair parts which can be used so that the maximum lifespan of detail that cost is minimal repairs.

3.1. The Main Interfaces

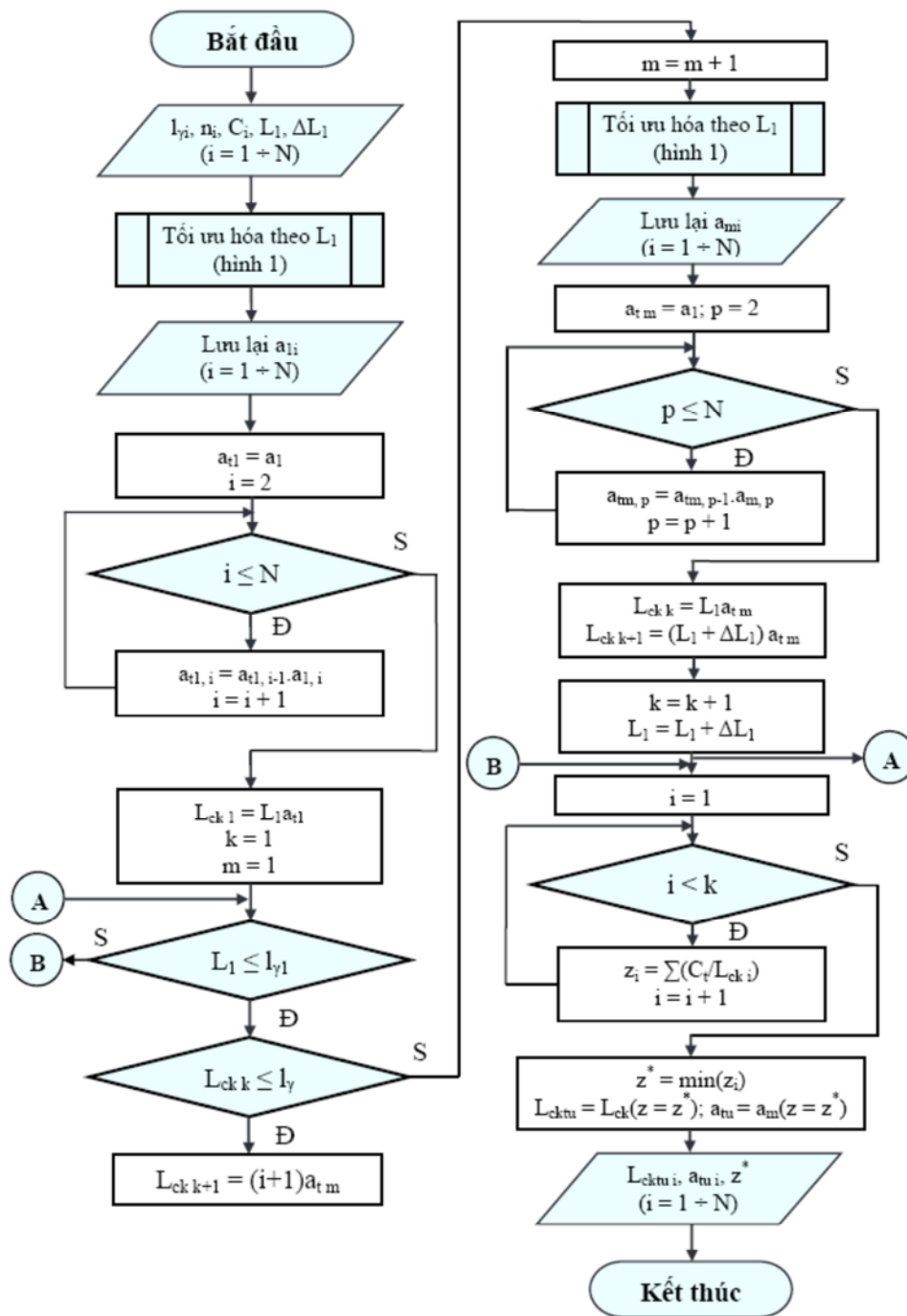
To run the program, we use the input data including gamma-percent life and repair costs of 5 parts damaged by wear and tear on the engine VL80K [3] to run at a fixed distance $L_1 = 40,000$ km. The input data of the parts are

given in Table 1.

The number of parts taken into account can exceed wear parts because they can have multiple test parameters with different life values.

In 5 parts above, electric drive motors had the biggest life value ($l_{\gamma 5} = 730,000$ km), so all calculations can be started from this part.

Running distance of initial survey is $L_1 = [(0,5 \times 77)+1] \times 10^3 = 39,500 \approx 40,000$ km.



(Bắt đầu – Begin; Kết thúc – End; Đ - True; S - False)

Figure 2. The adjustment algorithm optimization of the cycle structure repairs according to the gamma-percent life.

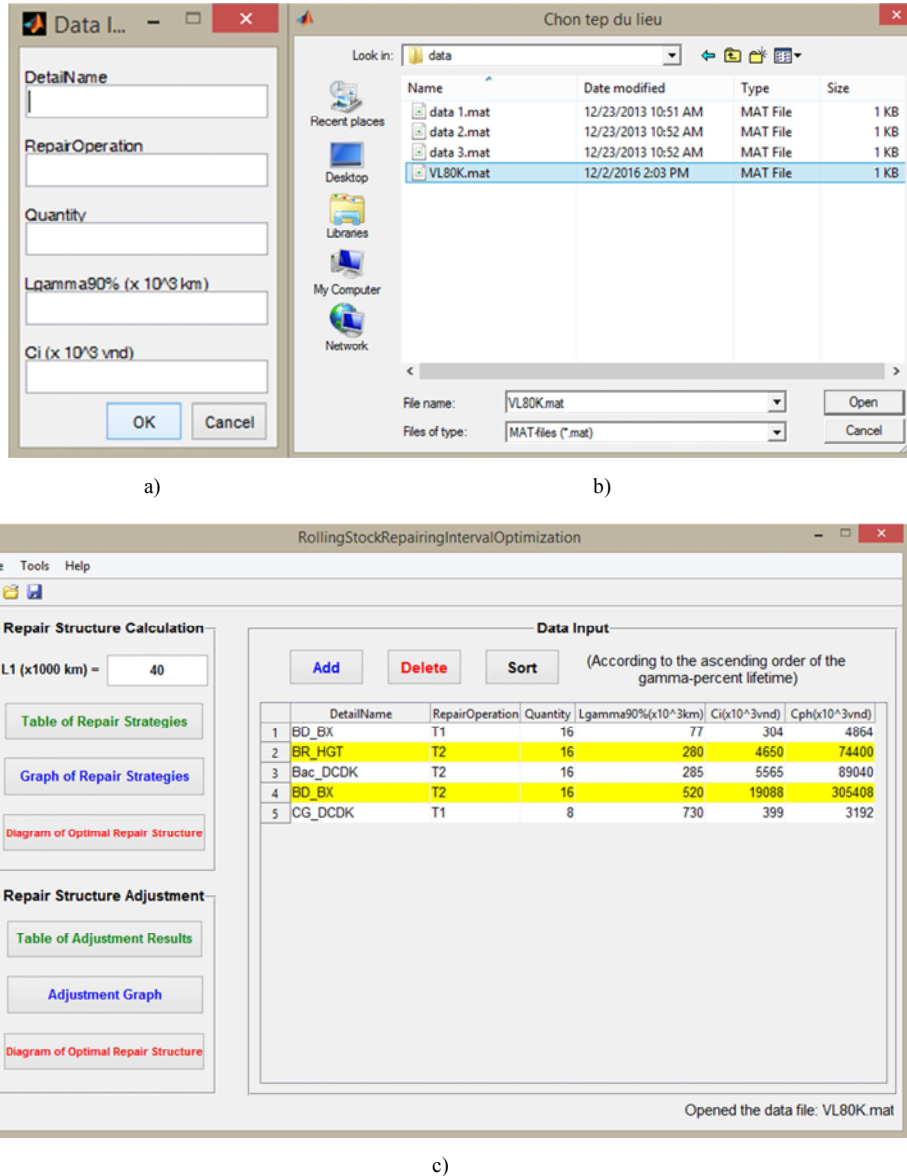
Table 1. Life expectancy gamma percent and the cost of repairs of parts on locomotives.

TT	Part /Component name	Qty,m	Repairing works	Life span%, (10 ³ km)	Cost for repair, 10 ³ VND	
					For 1 pcs, C_i	Fos all pcs of one serie, $C_{ph}=m.C_i$
1	Wheel flange	16	lathe	77	304	4.864
2	Gearsof redutor	16	replace	280	4.650	74.400
3	Support bearing of drive motor	16	replace	285	5.565	89.040
4	Wheelflange	16	replace	520	19.088	305.408
5	Electric drive motor	8	lathe	730	399	3.192

3.1.1. Initial Data Entry

The initial data of the life percent gamma and repair costs of the parts (Table 1) is entered into the program from the

keyboard (Figure 3(a)) or open the test data in the library file (Figure 3(b)). The interface displays the original data shown in Figure 3(c).

**Figure 3.** Interface to initial data entry (a); open database file (b) and display the initial data (c).

3.1.2. Calculation of Repair Strategies for Identified Running Distance L_1

At here we conducted calculation of available repair strategies for distance running $L_1 = 40,000$ km. Calculation interface is shown in Figure 4a. Calculation results are given in Table 2.

3.1.3. Plotting the Repair Strategies for Identified Running Distance L_1

The plot of repair strategies for running distance $L_1 = 40,000$ km is shown in Figure 4b.

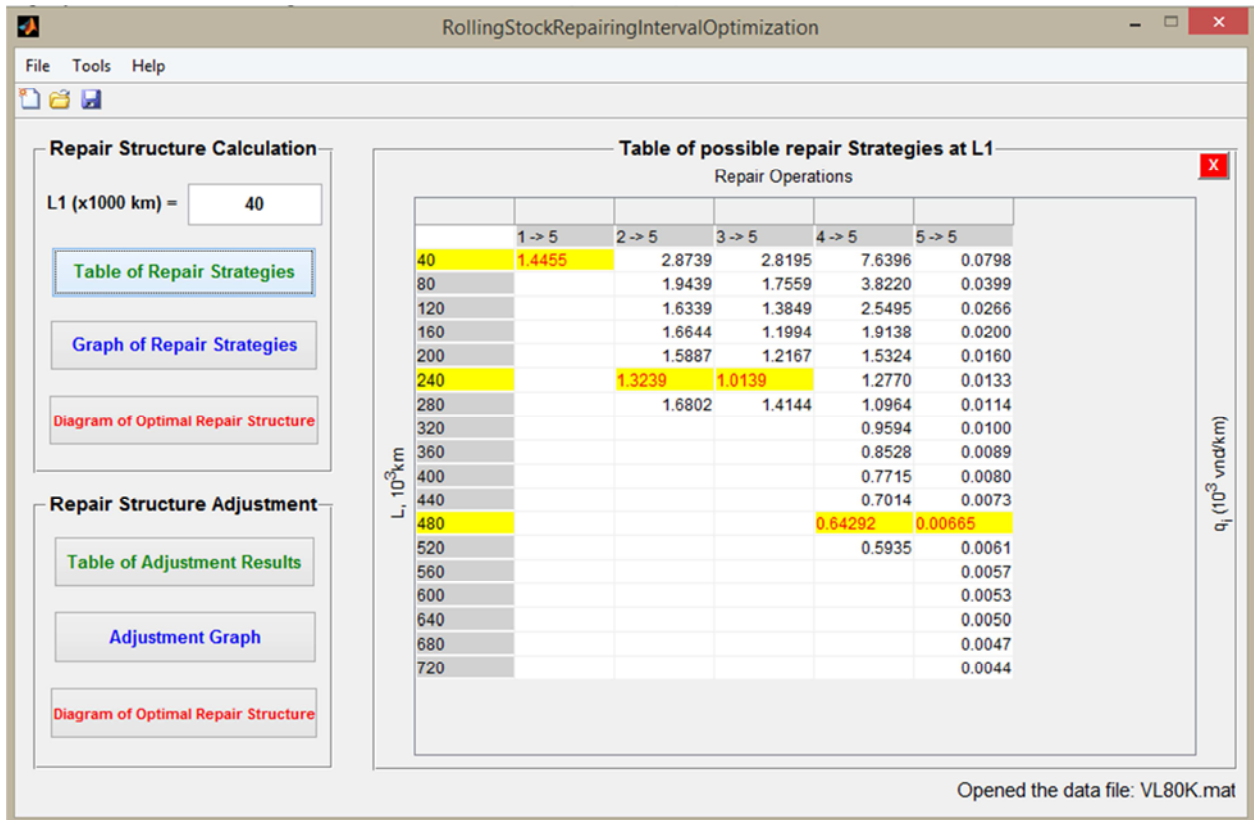


Figure 4a. Calculation of repair strategies for identified running distance $L_1 = 40,000$ km.

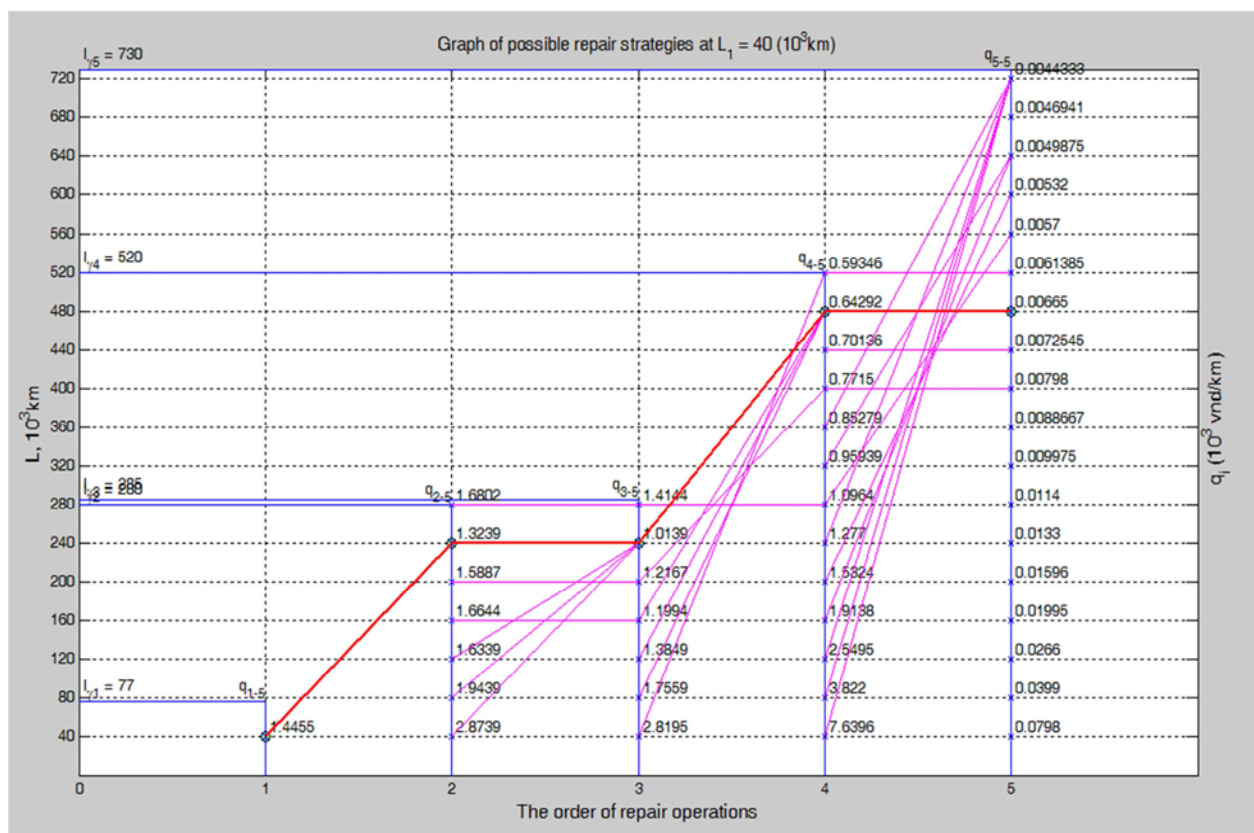


Figure 4b. Plot of repair strategies for identified running distance L_1 of the locomotive VL80K.

Table 2. The calculation result of repair strategies for identified running distance $L_1 = 40,000$ km.

No.	Running distance, $L \cdot 10^3$ km	Order of repaired items				
		1 \rightarrow 5	2 \rightarrow 5	3 \rightarrow 5	4 \rightarrow 5	5 \rightarrow 5
		Chi phí sửa chữa đơn vị, $q_i, 10^3$ VND/km				
1	40	1,4455	2,8739	2,8195	7,6396	0,0798
2	80		1,9439	1,7559	3,8220	0,0399
3	120		1,6339	1,3849	2,5495	0,0266
4	160		1,6644	1,1994	1,9138	0,0200
5	200		1,5887	1,2167	1,5324	0,0160
6	240		1,3239	1,0139	1,2770	0,0133
7	280		1,6802	1,4144	1,0964	0,0114
8	320				0,9594	0,0100
9	360				0,8528	0,0089
10	400				0,7715	0,0080
11	440				0,7014	0,0073
12	480				0,6429	0,0067
13	520				0,5935	0,0061
14	560					0,0057
15	600					0,0053
16	640					0,0050
17	680					0,0047
18	720					0,0044

3.1.4. Charting the Repair Structure for the Identified Running Distance L_1

From the chart of repair strategies of locomotive parts [3] for $L_1 = 40,000$ km, we find the repair structure of the 5 above parts. This interface is shown in Figure 5.

$L_1 = 40,000$ km; $L_2 = 240,000$ km;

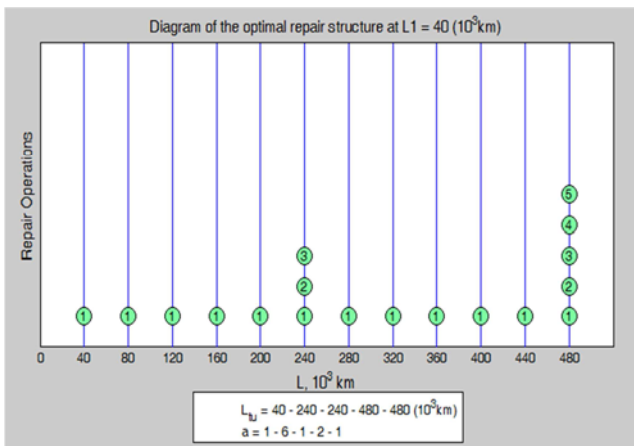
$L_3 = 240,000$ km; $L_4 = 480,000$ km;

$L_5 = 480,000$ km

corresponding multiple coefficients as:

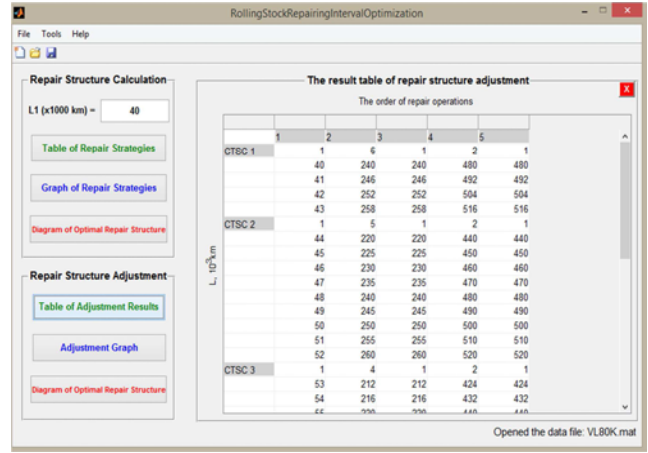
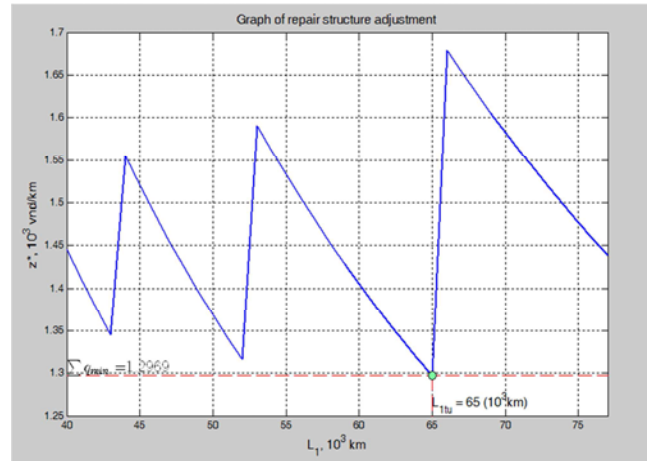
$a_1 = 1; a_2 = 6; a_3 = 1; a_4 = 2; a_5 = 1$

From this structure, we can see the underutilized parts of his life, even the first division with the lowest life expectancy. So proceed with structural adjustment coefficients according to the multiple target of this optimization of lowest recovery cost that has set the objective function by keeping the repair structure and increasing the distance running between repairs of the first part.

**Figure 5.** Diagram of primary repair structure.

3.1.5. Adjustment Calculation of Repair Structure

The interface of adjustment calculation of repair structure is shown on Figure 6.a. The plot of the relationship of total unit cost for the restoration of the locomotive parts with running distances is shown in Figure 6.b. The calculation results are presented in Figure 6.c.

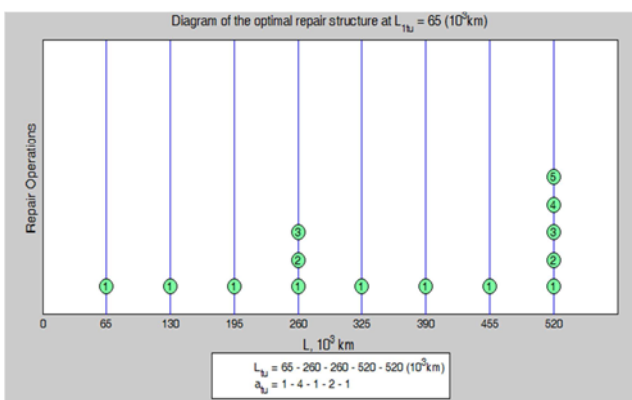
**Figure 6a.** Adjustment calculation of repair structure.**Figure 6b.** Relationship plot of total unit cost for the restoration of the locomotive parts with running distances

According to the graphics in figures 6, the repair structure of 5 above parts may lead to the following: in the 3rd stage of the plot, the total value of the costs for recovery of parts with the most logical expression (maximum value point not much different from the previous period. Furthermore, at the 4th stage worth the cost recovery soared parts. If you look at the values in the table of results, (in Figure 6.c) we can see in the period from 54,000 to 65,000 km of running, corresponding to the 4-1-2-1 structure, take optimal use of gamma-percent lifetime of damaged parts. Once beyond the value, the parts had to bring to repair to restore their features.

Currently, the majority of the parts is repaired mainly in planned regular repairs, or new replaced in unplanned repairs (for irregular damages).

Cấu trúc sửa chữa (Số đồ gián cách các lần sửa chữa)	TT	Thứ tự các bộ phận hay nguyên công sửa chữa				
		1	2	3	4	5
		Quãng đường chạy giữa các lần sửa chữa của bộ phận, 10 ³ km				
I		$a_1=1$	$a_2=6$	$a_3=1$	$a_4=2$	$a_5=1$
	1	40	240	240	480	480
	2	41	246	246	492	492
	3	42	252	252	504	504
	4	43	258	258	516	516
II		$a_1=1$	$a_2=5$	$a_3=1$	$a_4=2$	$a_5=1$
	5	44	220	220	440	440
	6	45	225	225	450	450
	7	46	230	230	460	460
	8	47	235	235	470	470
	9	48	240	240	480	480
	10	49	245	245	490	490
	11	50	250	250	500	500
	12	51	255	255	510	510
	13	52	260	260	520	520
III		$a_1=1$	$a_2=4$	$a_3=1$	$a_4=2$	$a_5=1$
	14	53	212	212	424	424
	15	54	216	216	432	432
	16	55	220	220	440	440
	17	56	224	224	448	448
	18	57	228	228	456	456
	19	58	232	232	464	464
	20	59	236	236	472	472
	21	60	240	240	480	480
	22	61	244	244	488	488
	23	62	248	248	496	496
	24	63	252	252	504	504
	25	64	256	256	512	512
	26	65	260	260	520	520
IV		$a_1=1$	$a_2=3$	$a_3=1$	$a_4=2$	$a_5=1$
	27	66	198	198	396	396
	28	67	201	201	402	402
	29	68	204	204	408	408
	30	69	207	207	414	414
	31	70	210	210	420	420
	32	71	213	213	426	426
	33	72	216	216	432	432
	34	73	219	219	438	438
	35	74	222	222	444	444
	36	75	225	225	450	450
	37	76	228	228	456	456
	38	77	231	231	462	462

Figure 6c. The corrected calculation result of repair structure.

Figure 7. Plot of adjusted optimal structure of repair cycle of the locomotive for $L_1=65.000$ km.

3.1.6. Plotting of Corrected Optimal Repair Structure of Parts and Components

For 5 parts mentioned above, according to actual use, 3rd group was fully replaced with the 45,000 km of running.

Then these parts were not taking full advantage of life, and wasting it. Thus, according to the calculation results, to ensure the most rational use of parts and fully exploit operation lifespan of parts, the adjustment of repairing cycle can be conducted as proposed distance running of first part, $L_1 = 65.000$ km, as follows:

$$L_{1u} = 65-260-260-520-520.10^3 \text{ km and}$$

$$a_{1u} = 1 - 4 - 1 - 2 - 1$$

This interface is shown in Figure 7.

3.2. Comment

In summary, the proposed repair system not only ensures the use of a better way of life of different parts, such as bang da banh xe, but also allows enhancing working reliability of the other parts, such as gears of electric drivemotors; moreover, the costs to recover these parts are more reasonable.

4. Conclusion

To minimize the repairing cost while ensuring the reliability of parts and components, from the algorithm [1, 2], a program was developed and tested according to data referred in [3].

The program ensures calculating functions and plotting graphs of rational structure of repair cycle, which takes into account for the repair cost and gamma-percent lifetime of parts and components of locomotives and carriages. The program has friendly interface, easy to use, matches the purpose and content of the study.

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Biography



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