STRATEGIC ASSESSMENT OF MOTORWAY MAINTENANCE NEEDS IN AZERBAIJAN

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Summary: *Strategic analysis can be used to analyze the whole selected network and to prepare assessment of requirements for development costs and road preservation according to different budget scenarios and in different time intervals. Optimal strategy for Azerbaijan was determined by comparing possible maintenance works for each road segment, depending on current pavement condition and traffic volume. Analysis without budget limitations determined optimal solution for each road class, which implies the solution that minimizes total management costs for the roads and user.*

Keywords: *strategic analysis, maintenance, motorways, pavement condition, traffic volume*

1. INTRODUCTION

Concept of strategic planning of road network medium- and long-term expenses requires to consider needs of the entire road network. Therefore, strategic analysis deals with entire road network or specific parts of network managed by one road agency.

The World Bank model HDM-4 is frequently used for analysis at the strategic planning level. For the purpose of predicting medium- and long-term requirements, HDM-4 applies the concept of road network matrix determined according to key criteria that mostly affect pavement condition indicators and road user costs. In theory, it is possible to model individual road sections through strategic analysis, but since some road agencies manage several thousands of kilometers of roads, such individual modeling makes strategic analysis massive and practically impossible attempt.

Therefore, users define road network matrix in a way that it represents the most important factors which affect road and traffic costs in the country. Typical road matrix is usually divided according to: (i) size of traffic flow or volume, (ii) pavement type and (iii) pavement condition.

Strategic analysis can be used to analyze the whole selected network and to prepare assessment of requirements for development costs and road preservation according to

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different budget scenarios and in different time intervals, which usually range from 5 to 40 years. Typical use of strategic analysis includes:

6. forecast of needs for financing beforehand adopted road maintenance standards;
7. forecast of road network condition in longer period under different financing scenarios;
8. optimal distribution of resources according to defined budget cost types, (i.e. routine maintenance, rehabilitation, reconstruction, construction);
9. optimal distribution of resources for network parts (according to road category/class) or according to administrative division.

For Azerbaijan, optimal strategy was determined by comparing possible maintenance works for each road segment, depending on current pavement condition and traffic volume. Only the part of the main road network, i.e. network of state roads foreseen to achieve motorway standards in the near future was analyzed. In this „theoretic approach”, the entire motorway network was considered, regardless of sections' location. This is achieved through so-called „network matrices”, which means that similar sections are being grouped into same categories, and then optimal strategy is determined for each of them.

2. ROAD DATA ANALYSIS

Complete main road network in Azerbaijan comprises 1.871 km, but only 1.575 km are managed by the state road agency, i.e. AzerYolService. However, only the country's major road corridors (North-South corridor /M1 and M3 roads/ and East-West corridor /M2 and M4 roads/) were considered in this analysis. Besides that, the analysis did not cover the roads, i.e. sections of the motorways that are currently under construction without close completion date and those sections planned to be constructed or rehabilitated/ reconstructed in the near future.

As stated in the introduction, the network has to be considered not with its physical links, but as a statistical spread of different road conditions. This means combining different attributes for road segments, to select classes, and characterising each class by its average conditions. Preliminary work for that is the analysis of road network conditions resulting with the following conclusions:

- network foreseen to achieve motorway standards in the following period is characterized by different cross section details, i.e. number of lanes ranges from two on a single carriageway to more than three on a double carriageway;
- historically used traffic categories can still be used for analysis here, only improvement would be to exclude low traffic classes not being a characteristic of motorways;
- roughness on the network is not widely spread, and at least main network is in fair condition.

In the case of Azerbaijan, three matrices have been set up, distinguishing sub-networks by number of lanes and then further on by traffic volume and condition (IRI value). These matrices and relevant road classes are presented in Tables 1. to 3. Total of these section makes 587,2 km.

Further analysis of road data from the database resulted in general characteristics of the representative sections presented in Table 4.

Table 1. Classes of 2-lane roads (total 376,481 km), length/HDM-4 label

AADT [veh/day]	IRI [m/km]			
	< 2,5	2,5 - 3,5	3,5 - 5	> 5
< 3.000	19,426 2_TL_3000-1	N/A	N/A	14,277 2_ TL_3000-4
3.000 - 7.000	45,603 2_ TL_7000-1	N/A	N/A	N/A
7.000 - 12.000	260,796 2_ TL_12000-1	17,984 2_ TL_12000-2	N/A	18,395 2_ TL_12000-4
> 12.000	N/A	N/A	N/A	N/A

Table 2. Classes of 4-lane roads (total 47,660 km), length/HDM-4 label

AADT [veh/day]	IRI [m/km]		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	23,077 4_TL_12000-1	10,226 4_ TL_12000-2	14,015 4_ TL_12000-3
> 12.000	N/A	N/A	0,342 4_ TM_12000-1

Table 3. Classes of roads with more than 4 lanes (total 163,059 km), length/HDM-4 label

AADT [veh/day]	IRI [m/km]		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	15,386 4+_TL_12000-1	N/A	N/A
> 12.000	108,893 4+_TM_12000-1	29,362 4+_TM_12000-2	9,418 4+_TM_12000-3

Table 4. Typical values for motorway network

section	AADT in 2011 [veh/day]	carriageway width [m]	pavement		condition			
			SN	year of previous works	IRI [m/km]	cracked area [%]	potholes [pcs/km]	rut depth [mm]
2_TL_3000-1	2.338	9,6	5,9	2010	1,30	0,90	0,00	1,30
2_TL_3000-4	1.724	9,0	3,5	2006	7,00	26,50	74,10	6,60
2_TL_7000-1	4.257	9,5	4,8	2006	1,50	1,63	0,00	1,40
2_TL_12000-1	8.483	9,8	4,9	2009	1,40	1,29	0,00	1,40
2_TL_12000-2	8.379	8,0	3,7	2009	3,50	3,60	0,00	3,40
2_TL_12000-4	7.511	8,1	3,7	2009	5,30	11,50	0,50	5,10
4_TL_12000-1	9.488	9,3	5,2	2010	1,90	0,35	0,00	1,80
4_TL_12000-2	8.575	9,2	5,6	2010	2,80	0,50	0,00	2,60
4_TL_12000-3	8.341	10,7	3,4	2011	3,70	7,70	0,30	3,50

4_TM_12000-3	19.130	14,0	5,3	2010	4,10	4,10	0,80	4,10
4+_TL_12000-1	7.221	10,1	4,9	2010	1,70	0,00	0,00	1,70
4+_TM_12000-1	26.443	12,4	5,6	2010	2,20	1,61	0,00	2,0
4+_TM_12000-2	38.193	12,9	6,0	2010	3,10	0,00	0,00	3,10
4+_TM_12000-3	38.193	12,9	6,0	2010	6,60	0,00	0,00	6,40

3. MAINTENANCE STANDARDS AND UNIT COSTS

Maintenance standards define maintenance works required to maintain the road network at the target level. Each maintenance standard consists of a set of one or more works items. Each works item is defined in terms of road surface class to which it can be applied, an intervention level and resultant effect on pavement. Rehabilitation and maintenance standards applied in the analysis were determined on basis of expected deterioration in relation to the actual traffic load.
There are at least two alternatives to be tested:
- base option, alternatives with minimum maintenance works (crack sealing, pothole patching and miscellaneous works);
- rehabilitation option, determined as rehabilitation works according to adopted criteria.

In case of strategy analysis, several rehabilitation options are tested, comparing different trigger levels, to answer the question: Should these works on this type of road be carried out NOW or LATER? Adopted standards for further analysis are shown in Table 5.

Table 5. Adopted standards for strategic analysis

No.	maintenance standard	
	works	trigger level
1.	pothole patching	≥ 5 pcs/km
2.	crack sealing	transversal thermal cracks ≥ 15 pcs/km and wide structural cracks ≥ 10 %
3.	miscellaneous works	annual
4.	thin asphalt concrete overlay of 3 cm	IRI ≤ 3
5.	asphalt concrete overlay of 4 cm	3 < IRI ≤ 4,5
6.	milling of 4 cm and asphalt concrete overlay of 4 cm	IRI > 4,5

Prices of individual works, which are included in standards, i.e. analysis, were obtained after detailed analysis of the available documentation (current routine maintenance price list and various contracts for road rehabilitation/reconstruction works). List of unit prices (economic and financial) for all maintenance works was defined as the analysis result.

4. ALTERNATIVES

Analyzed alternatives differ in costs of investment to apply defined technical measures and in savings which are realized by application of those measures. Favorable

consequences of pavement condition maintenance and improvement on the network are increase of network functionality, increase of safety and driving comfort. Savings in user costs are expected as consequence of these improvements.
Two basic options were considered in this analysis:
- do minimum (DM);
- do something (DS).

DM is "zero" alternative and it is used as the basic one in comparison process and, in general case, it does not predict investment in pavement maintenance (do nothing). During analysis period it is realistic to expect pavement deterioration for each network section, but at different speed, which depends on existing condition, pavement characteristics, as well as volume and structure of future traffic volume. It is more realistic to predict minimal investments in pavement maintenance during analyzed period with the purpose of slowing down its deterioration (DS), than to presume that there will be no investments in routine maintenance which would lead to considerable network condition deterioration (do nothing). Basic alternative in this analysis presumes costs and effects of routine maintenance during analysis period. DS alternative consists of set of maintenance standards which are adequate for individual representative sections, with purpose to keep and improve their existing condition in analyzed period. Description of alternatives and applicable works for pavement maintenance are presented in Table 6.

Table 6. Review of alternatives for road network strategic analysis

alternative	description
routine maintenance	- pothole patching when their number is ≥ 5 pcs/km - crack sealing when number of transversal thermal cracks is ≥ 15 pcs/km and when wide structural cracks area becomes ≥ 10 % of total area - miscellaneous works
thin overlay 30 mm	routine maintenance + thin asphalt concrete overlay of 3 cm for IRI ≤ 3
overlay 40 mm	routine maintenance + asphalt concrete overlay of 4 cm for 3 < IRI ≤ 4,5
mill and replace 40 mm	routine maintenance + milling of 4 cm and asphalt concrete overlay of 4 cm for IRI > 4,5

5. MODEL OUTCOMES

This section presents the outcomes of model runs, after analysing the matrix cells (each cell is modelled as a road section, candidate for maintenance). Results are twofold:
- the optimal strategy to be adopted for each cell (each type of road) maximizing the NPV;
- the priority of each cell (based on comparing IRR or NPV/cost between cells).

Analysis of the results consists in generalising the outcomes into a global strategy and recommendations. The optimal strategy for each of the road classes is presented in tables below (Tables 7. to 9).

Table 7. Optimal strategies for classes of 2-lane roads (treatment in year/NPV)

AADT [veh/day]	IRI [m/km]			
	< 2,5	2,5 - 3,5	3,5 - 5	> 5
< 3.000	routine maintenance 0,00	N/A	N/A	mill and replace 40 mm in 2013 3,55
3.000 - 7.000	thin overlay 30 mm in 2018 0,92	N/A	N/A	N/A
7.000 - 12.000	thin overlay 30 mm in 2019 22,88	overlay 40 mm in 2013 10,34	N/A	mill and replace 40 mm in 2013 16,49
> 12.000	N/A	N/A	N/A	N/A

Table 8. Optimal strategies for classes of 4-lane roads (treatment in year/NPV)

AADT [veh/day]	IRI [m/km]		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	thin overlay 30 mm in 2014 2,89	thin overlay 30 mm in 2013 and 2015 3,94	overlay 40 mm in 2013 11,02
> 12.000	N/A	N/A	overlay 40 mm in 2013 0,44

Table 9. Optimal strategies for classes of roads with more than 4 lanes (treatment in year/NPV)

AADT [veh/day]	IRI [m/km]		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	thin overlay 30 mm in 2018 1,31	N/A	N/A
> 12.000	thin overlay 30 mm in 2013 209,39	overlay 40 mm in 2013 271,45	mill and replace 40 mm in 2013 118,12

Reading the tables above, the main outcomes are:
- maintenance cost is exceeding user benefits that can be expected for low traffic on 2-lane roads, which is unacceptable for motorways (or even for other main roads), whatever their traffic is;
- an overlay thickness around 30-40 mm, is enough to maintain good condition if the roads are not yet deteriorated and maintenance is carried out relatively often (preventive maintenance);
- for roads in poor condition IRI>4,5/5, heavy rehabilitation works (milling and replacement of 40 cm), will improve the condition to a maintainable level.

Priorities, considering NPV/C and IRR, are presented in Tables 10. to 15.

Table 10. Priority segments for classes of 2-lane roads, ranked by NPV/C

AADT [veh/day]	IRI [m/km]/label			
	< 2,5	2,5 - 3,5	3,5 - 5	> 5
< 3.000	- 0,241	N/A	N/A	2,727
3.000 - 7.000	1,838 overlay 40 mm	N/A	N/A	N/A
7.000 - 12.000	7,023 overlay 40 mm	17,869	N/A	10,914
> 12.000	N/A	N/A	N/A	N/A

Table 11. Priority segments for classes of 2-lane roads, ranked by IRR

AADT [veh/day]	IRI [m/km]/label			
	< 2,5	2,5 - 3,5	3,5 - 5	> 5
< 3.000	3,9	N/A	N/A	31,0
3.000 - 7.000	44,4 overlay 40 mm	N/A	N/A	N/A
7.000 - 12.000	84,3 overlay 40 mm	96,1	N/A	76,4
> 12.000	N/A	N/A	N/A	N/A

Table 12. Priority segments for classes of 4-lane roads, ranked by NPV/C

AADT [veh/day]	IRI [m/km]/label		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	7,977 overlay 40 mm	15,532 overlay 40 mm	17,141
> 12.000	N/A	N/A	22,187

Table 13. Priority segments for classes of 4-lane roads, ranked by IRR

AADT [veh/day]	IRI [m/km]/label		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	66,2 overlay 40 mm	98,0 mill and replace 40 mm	108,9
> 12.000	N/A	N/A	155,3

Table 14. Priority segments for classes of roads with more than 4 lanes, ranked by NPV/C

AADT [veh/day]	IRI [m/km]/label		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	6,739 overlay 40 mm	N/A	N/A
> 12.000	52,809 overlay 40 mm	143,858	67,03

Table 15. Priority segments for classes of roads with more than 4 lanes, ranked by IRR

AADT [veh/day]	IRI [m/km]/label		
	< 2.5	2,5 - 3,5	3,5 - 5
< 12.000	109,1 overlay 40 mm	N/A	N/A
> 12.000	185,8 mill and replace 40 mm	326,2 mill and replace 40 mm	286,5

The ranking is slightly different between the method considering NPV/C and IRR (which is often the case, due to the calculation detail).

6. CONCLUSION

By comparing total costs (maintenance costs for the road agency and road user costs) and the road user effects, for a situation in which only minimum maintenance works are carried out and a situation where a particular form of maintenance standard is applied, it is possible to determine the net economic benefits of investing in different forms of road maintenance projects, concerning achieved road user effects at the same time.
Optimal strategy for the motorway network in Azerbaijan was determined by comparing possible maintenance works for each road segment, depending on current pavement condition and traffic volume.
Analysis without budget limitations showed optimal solution for each road class, i.e. the solution that minimizes total management costs for the roads and user, having the following tendency:

- focus on segments with high traffic and bad condition;
- second priority are segments with high traffic and good/medium condition (to maintain them in good condition) and segments with medium traffic, but deteriorated condition.

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STRATEŠKA ANALIZA POTREBA ODRŽAVANJA AUTOPUTEVA U AZERBEJDŽANU

***Rezime**: Strateška analiza može da se koristi za analizu kompletne odabrane mreže i procenu finansijskih zahteva razvoja i očuvanja puteva prema različitim budžetskim scenarijima i u različitim vremenskim intervalima. Optimalna strategija za Azerbejdžan je određena poređenjem mogućih radova održavanja za svaki segment puteva, u zavisnosti od trenutnog stanja kolovoza i obima saobraćaja. Analizom bez ograničenja budžeta je utvrđeno optimalno rešenje za svaku klasu puteva, što podrazumeva rešenje koje minimizira ukupne troškove upravljanja za puteve i korisnika.*

***Ključne reči**: strateška analiza, održavanje, autoputevi, stanje kolovoza, obim saobraćaja*