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ALGORITHMIC METHOD FOR THE TRAFFIC LIGHTS REGULATION PROJECT IN THE CITY OF SHKODRA

Abstract.

As the largest center of social, economic and cultural development in Northern Albania, Shkodra has undergone significant changes in the last two decades. Like all Albania, it was also affected by migration and urbanization phenomena, which necessitated profound improvements in road infrastructure, both urban and interurban. The largest artery of the Albanian Road Network, the North-South Corridor, comprising most of its main interurban roads, crosses the territory of the Region.
Demographic changes also conditioned the need to design new transport systems to cope with an increased flow of vehicles. We think that this paper contributes to this goal, which theoretically addresses the problems of improving the traffic lightening of the city of Shkodra, combined with the use of Intelligent Transport Systems.
Based on the experience and literature of European developed countries in this regard, we analyzed some of the most commonly used algorithms to find the most optimal project solution. Comparison between methods and calibration of different values of topology variables serve for engineering calculations of traffic flows. The latter are then part of projects for remedial intervention in the existing infrastructure network.

Keywords: *Algorithmic Methods, Urbanization, Traffic Flows, Intelligent Transportation Systems, Trafic lights regulation.*

1. Transport network project.

In designing the Shkodra city network (with about 114,000 inhabitants), we focused on the central area comprising five neighborhoods with a population of approximately 72,000. On this occasion, the algorithms proposed by the literature for the joint project of topology and traffic lights regulation were tested, with the aim of achieving three objectives:

- Calibration of control parameters used in topology project phase approximations;
- Analysis of the characteristics obtained from different approximations;
- Comparison of topology indicators and configurations dealing with proposed "what to" methods with those of "what if" methods used in practice.

For the calculations of this transport system we considered 2 origin-destination matrices:

- First matrix, referring to peak morning schedule (estimated with a demand model);
- Other matrix, referring to the peak afternoon (approximating the transposed matrix of the previous matrix).

To avoid thet the project configurations being unbalanced, (favoring e.g. access to areas with the highest concentration of activities, to the detriment of exits, if only the peak morning matrix would be used), both matrices were used. The objective function takes into account both simulations performed, ie it is given by the sum of the travel times at the peak of the morning and afternoon.

All refinements start from the solution representing the actual configuration and, with the exception of the Hill Climbing method, stop after exploring a predefined number of topological configurations.

According to the recommendations from the literature, it is best to use this symbology in obtaining application results:

$\boldsymbol{w_0}$ - is the value of the objective function calculated using the initial topological configuration, that is, the actual one with the optimized adjustment;

w* - is the best value of the objective function obtained when executing a processing;

$\Delta \mathbf{w}^{\%}$ - is the percentage reduction of the objective function obtained during processing, that is

$$\Delta \boldsymbol{w}^{\%} = \frac{\boldsymbol{w_0} - \boldsymbol{w}^{*}}{\boldsymbol{w_0}}$$

2. Calibration of parameters.

This section describes and analyzes the experiments performed to calibrate the parameters that regulate the hypotheses in the topology project phase. These experiments also allow for preliminary comparisons between the performances of the different algorithms.

The city transport system was used for calibration, where the study area and the project area correspond to the whole urban area (Fig. 1). We have 22 parts of the project in total and the intersections in the project match the parts (so those nodes are considered which at least one input or output branch belongs to one part of the project).

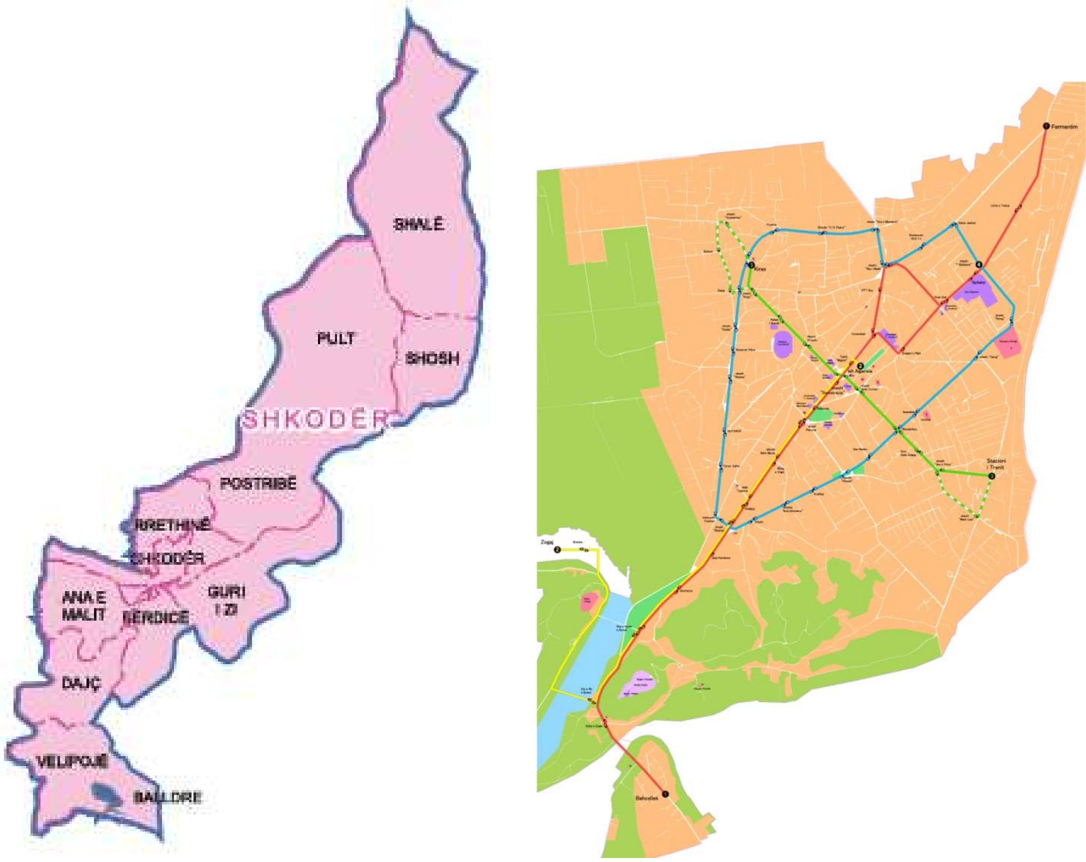

Figure 1. Study area and design area for Shkodra transport system.

The main characteristics of the transport system are given in the table 1.

		Shkodër
	Residents	72.000
	Shift by car (peak hours)	5584 cars/hour
The study area	Origin-destination pairs	320
	Node	72
	Branch	190
	The length of the network	38 km
The project area	Part	22
	Intersections	40

Table 1. Characteristics of the transport system for the city of Shkodra. Below are the results of processing with different parameters for each algorithm. The stopping criterion provides for processing $2x10^4$ topological configurations.

Method with Hill Climbing Algorithm (HC)

This algorithm needs no calibration as it is not controlled by any parameters. The values of the processing results are given in Table 2. 815 topological configurations were processed before the minimum was found (however smaller than the $2x10^4$ limit attempt).

The City	Elaborate configurations	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	815	1456,4	8,41 %	1590,2 [h]

Table 2. HC algorithm processing result

Method with Simulated Annealing (SA) Algorithm

The controlling parameters are:

- Initial temperature τ_0;
- Final temperature τ_p.

The field step length is accepted λ_p=100 and cooling rate α_c is taken as a function of the initial and final temperatures.

Given the recommendations in the literature [3] for similar cases, they are accepted $\tau_0 \cong w_0$ and $\tau_p \cong 10^{-4} w_0$. Table 3 gives the results of refinements performed for changing the calibration parameters.

The City	τ_0 [h]	τ_p [h]	α_c	λ_p	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	1000	100	0,989	100	1564,3	1,63%	1590,2 [h]
	100	10			1556,2	2,14%	
	10	1			1524,7	4,12%	
	1	0,1			1535,9	3,41%	

Table 3. SA algorithm processing result.

Method with Tabu Search Algorithm (TS)

There is only one parameter that controls the specificity proposed by TS [2]: tabu list dimension λ_l.

The results of the processing with the change of the calibrated parameter are given in Table 4.

The City	λ_l	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	0	1521,66	4,31%	1590,2 [h]
	5	1505,60	5,32%	
	10	1495,42	5,96%	
	20	1489,22	6,35%	
	30	1493,03	6,11%	
	35	1519,27	4,46%	
	40	1518,64	4,50%	
	50	1521,50	4,32%	
	55	1515,77	4,68%	
	60	1522,67	4,24%	
	70	1516,09	4,66%	

Table 4. TS algorithm processing result.

Method with Genetic Algorithms (GA)

There are four parameters that control the specificity of Genetic Algorithms:

- entirety coefficient of population, $\mathbf{v_p}$;
- selectivity parameter, $\boldsymbol{\alpha_r}$;
- crossover frequency, $\boldsymbol{\varphi_c}$;
- frequency of change, $\boldsymbol{\varphi_n}$.

In the literature [1], a set of calibrated parameters is given ($\mathbf{v_p} = 40$, $\boldsymbol{\alpha_r} = 70$, $\boldsymbol{\varphi_c} = 0{,}40$, $\boldsymbol{\varphi_n} = 0{,}20$).

The calibration results are given in Table 5.

The City	$\mathbf{v_p}$	$\boldsymbol{\alpha_r}$	$\boldsymbol{\varphi_c}$	$\boldsymbol{\varphi_n}$	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	40	70	0,40	0,20	1536,92	3,35%	1590,2 [h]
	20	70	0,40	0,20	1528,34	3,89%	
	80	70	0,40	0,20	1524,20	4.15%	
	40	30	0,40	0,20	1531,99	3,66%	
	40	140	0,40	0,20	1535,33	3,45%	
	40	70	0,20	0,20	1549,17	2,58%	
	40	70	0,80	0,20	1437,24	9,62%	
	40	70	0,40	0,10	1491,44	6,21%	
	40	70	0,40	0,40	1540,58	3,12%	

Table 5. GA algorithm processing result

Hybrid Method 1 (TS + GA)

The parameters that control the specificity of the hybrid method are six:

- Tabu Search parameter - λ_l.
- Parameters of Genetic Algorithms - ν_p; α_r; φ_c; φ_n.
- The parameter that determines the part of the solutions considered with TS, denoted by $\tau_{\%}$.

Being too many parameters to be calibrated, the best values obtained from the calibrations by particular methods are accepted. Part of the solutions considered with TS is accepted $\tau_{\%} = 75\%$ and the one with GA: 1- $\tau_{\%}$ = 25%. The processing results are given in Table 6.

The City	Hybrid Method 1	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	TS→GA GA→TS	1489,22 1437,24	6,35 9,62	1590,2 [h]

Table 6. Result of processing with hybrid method 1 (TS + GA)

Hybrid Method 2 (TS + PR)

The only parameter that controls the specificity of this hybrid method is the tabu list dimension λ_l. From the literature recommendations, it is best to obtain a value that is close to the values of the parts of the project. The processing results are given in Table 7.

The City	λ_l	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	0 5 10	1510,21 1500,51 1494,94	5,03 5,64 5,99	1590,2 [h]

	20	1492,56	6,14	
	30	1490,49	6,27	
	35	1510,05	5,04	
	40	1481,27	6,85	
	50	1511,96	4,92	
	55	1502,26	5,53	
	60	1509,25	5,09	
	70	1503,37	5,46	

Table 7. Result of processing with hybrid method 2 (TS + PR)

Double Round Hill Climbing Method (HC2)

This method is not adjusted by any parameters and therefore does not need to be calibrated. Table 8 gives the results after processing 3145 topological configurations before the local minimum was found, (even in this case, less than the recommended $2 \cdot 10^4$ limit).

The City	Processing configurations	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	3145	1475,70	7,20 %	1590,2 [h]

Table 8. Double Climbing Hill Climbing Algorithm (HC2) Processing Result

In conclusion, let's look at the analysis of the comparison of the results obtained with each of the methods. To this end, Table 9 gives the best recorded values.

The City	Algoritmi	The best value, w* [h]	Decrease $\Delta w^{\%}$	Initial value w_0 [h]
Shkodër	HC	1456,4	8,41 %	1590,2 [h]
	SA	1524,7	4,12%	
	TS	1489,22	6,35%	
	GA	1437,24	9,62%	
	TS+GA	1489,22	6,35%	

	TS+PR HC2	1481,27 1475,70	6,85% 7,20 %	

Table 9. Comparison of the best results, obtained with all algorithms.

3. Conclusions.

Given the different number of applications for different methods, and because different sets of parameters were used for each method, the results obtained should be considered preliminary.

It results that the percentage reduction of the objective function is included in the range (4.12% -9.62%), which is considered wide [4] and indicates the need to use the best algorithms with the optimal parameters. The reduction intervals of the objective function, for each method and with the change of the parameters used, are given in Fig. 2.

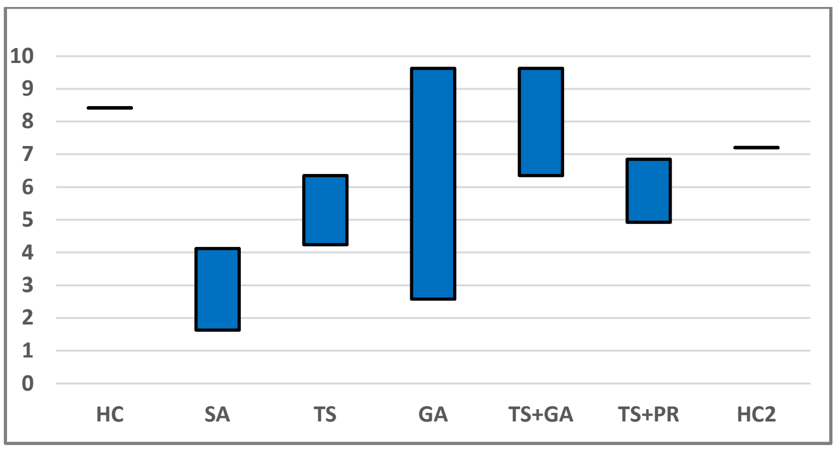

Figure 2

Interpreting the graph, the best algorithm comes out Hybrid Method 1 (TS + GA).

The purpose of this paper is to analyze the algorithms used to calibrate the parameters for the project phase of the traffic light regulation project. To make a comparison as close to reality as possible, the same transport system can be used, but it is recommended to study a city with approximate parameters.

4. Bibliography.

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