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Developing a coordinated regulation schedule to prevent damage to the environment by vehicles and improve the structure of the energy system: evidence from the city of Baku (Azerbaijan)

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Abstract. Problem. *The scale of road traffic is constantly increasing all over the world, which is the basis and indispensable condition for sustainable economic growth, on the one hand, and the source of a complex of transport and environmental problems, on the other. One of the most pressing problems is the congestion of road networks.* ***Goal.*** *The purpose of the article is the analysis of the way to organize the creation of an effective system that controls traffic in an urban agglomeration.* ***Methodology.*** *This article analyzed the case of one of the main avenues of Baku to develop a coordinated regulation schedule for reducing vehicles damage to the environment by waiting at a red light, as well as for improving the structure of the energy system in the developing countries, especially in Ukraine, which has been suffering from war.* ***Results.*** *For this reason, in the article a proposal was made to improve the efficiency of traffic management at the main intersection of Matbuat avenue in Baku, the number of vehicles moving on the avenue was studied and the traffic light timings report was made at all intersections, the reports were adapted to the main roadway, and a green wave graph was constructed.* ***Originality.*** *The methodology for estimating environmental and economic damage from the impact of motor vehicles on the urban ecosystem, including indexation coefficient has been improved. The methodical bases of the design of a complex of environmental measures to reduce the impact of vehicles on the environment of Baku have been substantiated. The article provides a basis for the design of a complex of environmental measures.* ***Practical value.*** *A set of measures has been developed to reduce pollution from city vehicles, which can be used in regional and municipal programs.*

Key words*: Baku city, intersection, "Green Wave", "off-peak" hours, coordinated regulation system*

Introduction

In very large and large cities, traffic jams are constantly increasing, as well as the coordinated schedule of traffic lights is not determined according to the flow of traffic, vehicles are stuck in traffic jams, or pass through a green light at an average speed at one intersection and turn a red light at another, which in addition to creating traffic jams, causes environmental problems, causing imbalance and increasing the number of carbon emissions [1-3].

As it is known, the main reasons for traffic jams are illegal parking, irregular bus traffic, failure to report on corrective schedules of intersections, and there may be other reasons. However, one of the main causes of traffic delays, smooth traffic flow and, in the absence of traffic jams, meaning less waiting for a green traffic light, is the result of uneven coordination of the daily configuration of the system.

As a result of the correct control of the coordinated regulation system, if cars moving along a certain street or avenue adhere to a given speed, then they enter the “green wave” mode, that is, they fall on the green traffic light on all the passages they pass [4-9].

To prevent vehicles from causing more damage to the environment by waiting at a red light, in this article, an investigation was conducted on the establishment of a coordinated regulation in one of the main avenues of Baku, the capital of the Republic of Azerbaijan [10-14].

Statement of the problem

As in all capitals and big cities of the world, traffic is difficult in Baku. The city is overpopulated. Most people have cars, so the city also has a surplus of cars. In many places, traffic is paralysed and as a result, so-called "traffic jams" are formed. Therefore, measures should

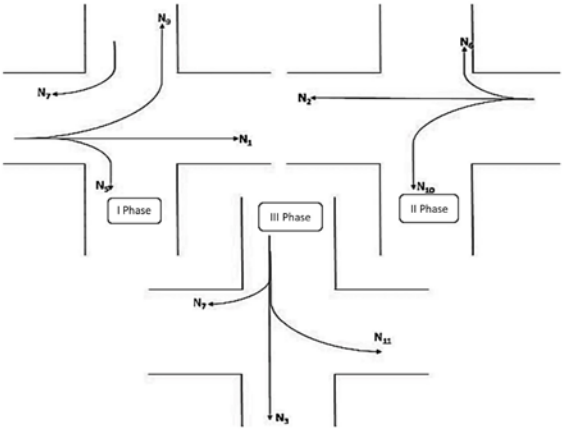
be taken to resolve transport problems on the roads of the capital. In the mentioned Matbuat Avenue, investigations were conducted in order, and a proposal and solution were prepared.

Project proposal for the intersection of Matbuat Avenue and A. Sultanova Street

To create a method of strength and durability testing with the help of modern calculation complexes for the newly designed bearing systems by computer model analyzing with modeling the machine working operations. For this purpose, a created computer model of the loader should be the most relevant to the real machine. To determine the workflow load.

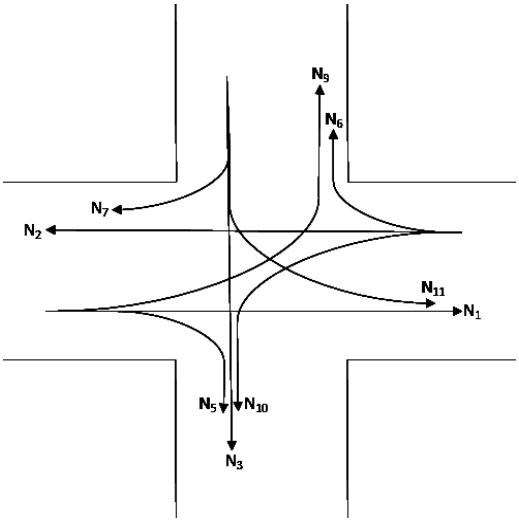
Methods of strength assessment of the bearing system based on the results of virtual tests simulation.

A. Sultanova Street and Matbuat Avenue are 3-phase (Scheme 1, 2), and other intersections are 2-phase, so it is impossible and inefficient to establish a “green wave” schedule on this avenue. Therefore, if the next new project proposal is created at said intersection, then a coordinated regulatory system can be prepared at Matbouat Avenue [15].



Scheme 1. Current traffic light phases at the intersection of Matbuat Avenue and Ayna Sultanova Street

A traffic jam at the intersection of Matbuat Avenue and Abbas Mirza Sharifzade Street is created due to the 3-phase traffic light mode, and at Matbuat Avenue - due to the traffic intensity, which is greater than the traffic capacity of the road, especially during peak hours of the day. As a result of observations, the number of vehicles entering in the direction of Matbuat Avenue and "Badamdar" during peak hours in the morning was 2371 auto/hour, at peak hours in the evening 2058 auto/hour, and the number of cars entering in the direction of the circle "January 20" was 2616 auto/hour during peak hours in the morning and 2952 auto/hour during peak hours in the evening.



Scheme 2. Vehicle traffic patterns at the intersection of Matbuat Avenue with Ayna Sultanova Street

It turned out that two phases of a three-phase traffic light, which is located near the bus stop at the intersection of A.M. Sharifzade Street and Matbuat Avenue, in the direction of Matbuat Avenue, impede the movement of vehicles turning right.

Considering the above, several proposals were developed (Figure 1) to improve the efficiency and safety of traffic at the intersection of A.M. Sharifzade Street with Matbuat Avenue:

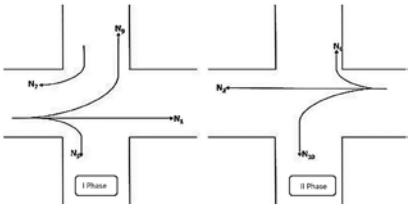
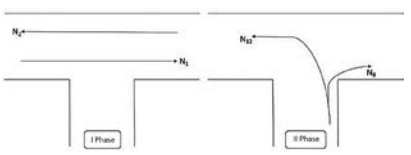
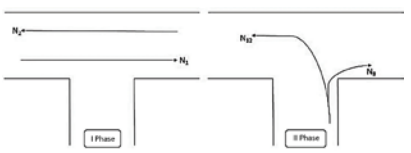
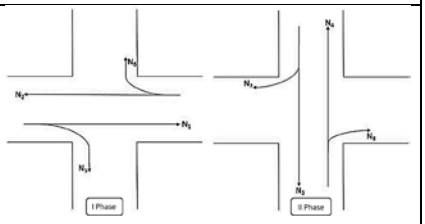
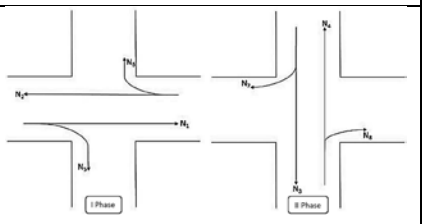
- Create a "pocket", as shown in Figure 1, in the direction of A.M. Sharifzade Street to the right of Matbuat Avenue;
- By directing vehicles moving in the direction from A.M. Sharifzade Street directly to A. Sultanov Street and in the direction from the "Circle of Galaba" to the left to Matbuat Avenue, as shown in Figure 1, to the right (in the direction of Matbuat Avenue and Badamdar) and organizing a turn back after 300 meters (except for trucks) to ensure a turn back;
- Add one lane on the right side of the road in the order shown in Fig. 1 to avoid the obstruction of vehicles by the proposed turn back from Matbuat Avenue in the direction of "Galaba Circle";
- At the specified intersection, by switching the traffic light from three-phase mode to two-phase mode, as shown in Fig.1, it is recommended to manage according to the schedule.

Fig. 1. The proposed project for the intersection of Matbuat Avenue and A.Sultanova Street

Methodology: (Scheme 1) **[16-22]**

In order to prevent vehicles from causing more damage to the environment by waiting at a red light, in this article, an investigation was conducted on the establishment of a coordinated regulation in one of the main avenues of Baku, the capital of the Republic of Azerbaijan.

Table 1 Phases of traffic lights at the intersections of Matbuat Avenue:

At the intersection with Aina Sultanova street	
At the intersection with M. Rahim street	
At the intersection with V.Vahabzade street	
At the intersection with A. Hagverdiyev street	
At the intersection with A. Abbasov street	

Because of this, this article offers a project proposal to improve traffic on Matbuat Avenue. There is a project proposal for the intersection of Matbuat Avenue and A. Sultanova Street. Because A.Sultanova Street and Matbuat Avenue are 3-phase, as well as other intersections are 2-phase, it is both impossible and inefficient to establish a “green wave” schedule on this avenue. Therefore, other measures must be taken.

Then, there are reports of time regimes (taking into account the first section) on Matbuat Avenue, namely the phases of traffic lights at the intersections of Matbuat Avenue, the actual intensity of traffic in directions at the intersections of Matbuat Avenue, as well as calculations of the reduced traffic intensity, traffic flow in directions, phase coefficient on the phases, the sum of the maximum phase coefficients, lost time, the duration of the intermediate cycle by phases, the control cycle, the main regulated cycles, the walking path, the correction of the duration of the main regulated cycles, the walking path, as well as the duration of the adjusted cycle.

At last, there is given an application of coordinated regulation (“Green Wave”), namely, a report on the construction of a schedule of coordinated regulation and a schedule of coordinated regulation is carried out.

Table 2 Actual intensity of traffic in directions at the intersections of Matbuat Avenue

	A.Sultanova street			M. Rahim street			B.Vahabzade street			A.Hagverdiyev street			A.Abbasov street		
	car	truck	bus	car	truck	bus	car	truck	bus	car	truck	bus	car	truck	bus
N_1	599	20	44	1412	8	10	1241	30	21	1371	19	4	963	9	6
N_2	885	16	36	1305	30	10	1005	12	8	940	3	8	1131	10	9
N_3	-	-	-	-	-	-	-	-	-	725	30	6	543	12	27
N_4	-	-	-	-	-	-	-	-	-	780	14	4	381	6	9
N_5	80	0	2	-	-	-	-	-	-	157	0	0	126	0	0
N_6	192	20	15	-	-	-	-	-	-	-	-	-	432	0	13
N_7	388	32	14	-	-	-	-	-	-	95	0	0	30	0	0
N_8	-	-	-	144	0	0	192	0	4	153	4	1	228	0	8
N_9	435	16	12	-	-	-	-	-	-	-	-	-	-	-	-
N_{10}	294	0	4	-	-	-	-	-	-	-	-	-	-	-	-
N_{11}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N_{12}	-	-	-	142	2	2	123	18	3	-	-	-	-	-	-

Calculation of reduced traffic intensity

$$N_{rt} = N_c \cdot K_c + N_t \cdot K_t + N_b \cdot K_b \text{ unit/hour} \quad (1)$$
$$K_c = 1, K_t = 2, K_b = 4$$

Table 3

	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}
A.Sultanova street	771	1025	-	-	86	277	494	-	503	306	-	-
M.Rahim street	1458	1395	-	-	-	-	-	144	-	-	-	152
B.Vahabzade street	1364	1053	-	-	-	-	-	204	-	-	-	168
A.Hagverdiyev street	1421	970	803	820	157	-	95	164	-	-	-	-
A.Abbasov street	999	1169	648	420	126	471	30	252	-	-	-	-

Calculation of traffic flow in directions:

$$M_{dir} = 1800 \cdot n_c \cdot \frac{N_{dir} + N_{right} + N_{left}}{N_{dir} + 1.25 \cdot N_{right} + 1.75 \cdot N_{left}} \quad (2)$$

units/hour

Table 4

A.Sultanova street		M.Rahim street		B.Vahabzade street		A.Hagverdiyev street		A.Abbasov street	
$M_{dir1,5,9}$	5568	M_{dir1}	5400	M_{dir1}	3600	$M_{dir1,5}$	3513	$M_{dir1,5}$	3502
M_{dir7}	2880	M_{dir2}	3600	M_{dir2}	3600	M_{dir2}	3600	$M_{dir2,6}$	5038
$M_{dir2,6,10}$	4554	$M_{dir8,12}$	2389	$M_{dir8,12}$	3659	$M_{dir3,7}$	5261	$M_{dir3,7}$	3561
						$M_{dir4,8}$	5184	$M_{dir4,8}$	4937

Determination of the phase factor on the phases:

$$Y_i = \frac{N_{rt}}{M_{dir}} \quad (3)$$

Table 5

A.Sultanova street		M.Rahim street		B.Vahabzade street		A.Hagverdiyev street		A.Abbasov street	
$Y_{1,5,9}$	0.24	Y_1	0.27	Y_1	0.38	$Y_{1,5}$	0.45	$Y_{1,5}$	0.32
Y_7	0.17	Y_2	0.39	Y_2	0.3	Y_2	0.27	Y_2	0.33
$Y_{2,6,10}$	0.35	$Y_{8,12}$	0.12	$Y_{8,12}$	0.1	$Y_{3,7}$	0.17	$Y_{3,7}$	0.19
						$Y_{4,8}$	0.19	$Y_{4,8}$	0.14

Determining the sum of the maximum phase coefficients:

$$Y = \sum Y_{\max} \quad (4)$$

Table 6

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
Y	0.59	0.51	0.48	0.64	0.52

Determining the duration of an intermediate cycle by phases:

$$t_{inti} = \frac{v_a}{7.2 \cdot j} + \frac{(B_i + l_a) \cdot 3.6}{v_a} - \sqrt{\frac{2 \cdot l_j}{b}} + 2, \text{ sec} \quad (5)$$

Table 7

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
T_{miI}	4	4	4	4	4
T_{miII}	4	4	4	4	4

Lost Time Calculation:

$$L_i = \sum_{i=1}^{n} (t_{inti} - 1), \text{ sec} \quad (6)$$

Table 8

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
L	6	6	6	6	6

Calculation of the duration of the control cycle:

$$T_c = \frac{1.5 \cdot L + 5}{1 - Y}, \text{ sec} \quad (7)$$

Table 9

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
T_c	58	29	27	39	29

Calculation of the duration of the main adjustable cycles:

$$t_{maini} = \frac{Y_{i\max}}{Y} \cdot (T_c - L) - 1, \text{ sec} \quad (8)$$

Table 10

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
T_{mainI}	20	17	16	22	14
T_{mainII}	30	4	4	9	7

Determining the duration of a pedestrian road:

$$t_{pi} = \frac{B_p}{v_p} + 5, \text{ sec} \quad (9)$$

Table 11

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
T_{pI}	15	14	17	23	22
T_{pII}	24	21	22	21	21

Correction of the duration of the main adjustable cycles, as well as the duration of the walking path:

Table 12

A.Sultanova street	At $t_{mainI} > t_{pI}$ и $t_{mainII} > t_{pII}$, $t_{mainI} = 20\ sec.$ $t_{mainII} = 30$ sec.
M.Rahim street	At $t_{mainI} > t_{pI}$ и $t_{mainII} < t_{pII}$, takes on the meaning $t_{mainII} = t_{pII} = 21$ sec. Then, $\frac{t_{mainI}}{t_{mainII}} = \frac{Y_{Imax}}{Y_{IImax}}$ $t_{mainI} = 68$ sec.
B.Vahabzade street	At $t_{mainI} < t_{pI}$ и $t_{mainII} < t_{pII}$, takes on the meaning $t_{mainII} = t_{pII} = 22$ sec. Then, $\frac{t_{mainI}}{t_{mainII}} = \frac{Y_{Imax}}{Y_{IImax}}$ $t_{mainI} = 84$ sec.
A.Hagverdiyev street	At $t_{mainII} < t_{pII}$ takes on the meaning $t_{mainII} = t_{pII} = 21$ sec. Then, $\frac{t_{mainI}}{t_{mainII}} = \frac{Y_{Imax}}{Y_{IImax}}$, $\frac{t_{mainI}}{21} = \frac{0.45}{0.19}$ $t_{mainI} = 50$ sec.
A.Abbasov street	At $t_{mainII} < t_{pII}$ takes on the meaning $t_{mainII} = t_{pII} = 21$ sec. Then, $\frac{t_{mainI}}{t_{mainII}} = \frac{Y_{Imax}}{Y_{IImax}}$, $\frac{t_{mainI}}{21} = \frac{0.33}{0.19}$ $t_{mainI} = 36$ sec.

The duration of the corrected cycle:

$$T_c = t_{mainI} + t_{inI} + t_{mainII} + t_{inII}, \text{ sec} \quad (6)$$

Table 13

	A.Sultanova street	M.Rahim street	B.Vahabzade street	A.Hagverdiyev street	A.Abbasov street
T_c	58	97	114	79	65

Results and discussion [23,24,25].

Coordinated control scheduling report

Table 14

Regulation report / Crossroads at Matbuat Avenue	T_c	T_{g+r}	T_m	a	t_g^*	t_r^*	T_c^*
	sec.				sec.		
A.Sultanova street	58	50	91	33	33	50	91
M.Rahim street	97	89	91	- 6	63	20	91
B.Vahabzade street	114	106	91	- 23	66	17	91
A.Hagverdiyev street	79	71	91	12	58	25	91
A.Abbasov street	65	57	91	26	52	31	91

Building a schedule of coordinated regulation (Figure 2). Recommended speed:

From the intersection of Matbuat Avenue with A. Sultanova Street to the intersection with A. Abbasov Street - 55 km / h,

In the opposite direction - 50 km / h.

Horizontal scale in 1 cm 10 sec., vertical scale in 1 cm 100 m.

The width of the timeline is 24 seconds.

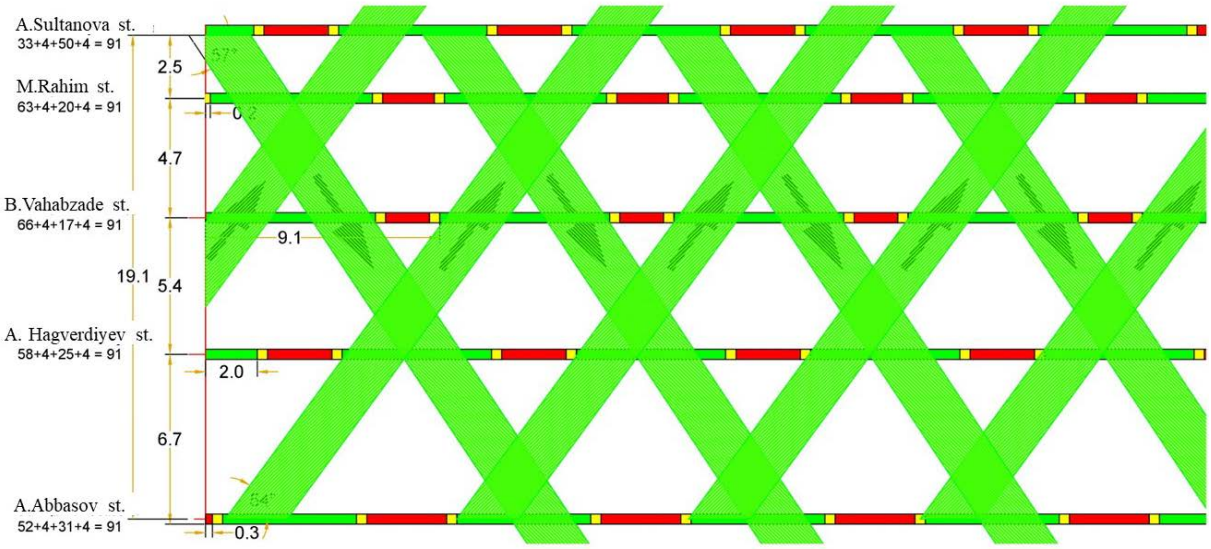


Fig. 2. The green wave graph established on Matbuat avenue of Baku city

Conclusion

Based on the foregoing, it can be concluded that with the use of these materials, a coordinated regulatory system on Matbuat Avenue can be prepared. Because all traffic lights on the avenues and streets of Baku function in a flexible setting system, they can work in different periods depending on "peak", and "off-peak" hours, weekends, holidays, and other time modes), and, accordingly, an agreed adjustment schedule should be established as shown in Figure 1, and eventually the green wave system should be applied in all directions. As a result of the application of the "green wave" system, delays on the roads are reduced, the negative impact on the psychophysiological indicators of drivers is reduced, the free flow of traffic is normalized, and the time of "traffic jams" is minimized (Figure 2).

Based on the foregoing, it can be concluded that with the use of these materials, a coordinated regulatory system on Matbuat Avenue can be prepared. Because all traffic lights on the avenues and streets of Baku operate in a flexible setting system, they can work in different periods depending on “peak”, and “off-peak” hours, weekends, holidays, and other time modes, and, accordingly, an agreed adjustment schedule should be established, as shown in Figure 1, and eventually, the green wave system should be applied in all directions. As a result of the application of the "green wave" system, delays on the roads are reduced, the negative impact on the psychophysiological indicators of drivers is reduced, the free flow of traffic is normalized, and the time of "traffic jams" is minimized.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Розробка узгодженого графіка регулювання для запобігання шкоди транспортним засобам навколишньому середовищу та покращення структури енергетичної системи: Докази з міста Баку (Азербайджан)

Анотація. Проблема. *Масштаби дорожнього руху постійно зростають у всьому світі, що є основою і неодмінною умовою сталого економічного зростання, з одного боку, і джерелом комплексу транспортних і екологічних проблем, з іншого. Однією з найактуальніших проблем є перевантаженість дорожньої мережі.* ***Мета.*** *Мета статті – як організувати створення ефективної системи контролю дорожнього руху в міській агломерації.* ***Методологія.*** *У цій статті проаналізовано випадок одного з головних проспектів Баку для розробки узгодженого графіка регулювання для зменшення шкоди, яку транспортні засоби завдають навколишньому середовищу через очікування на червоне світло, а також для вдосконалення структури енергетичної системи в країнах, що розвиваються, особливо в Україні, яка постраждала від війни.* ***Результати.*** *З цієї причини в статті була внесена пропозиція щодо підвищення ефективності організації дорожнього руху на головному перехресті проспекту Матбуат в Баку, вивчена кількість транспортних засобів, що рухаються по проспекту, і зроблено звіт про хронометраж світлофорів на всіх перехрестях, звіти були адаптовані до головної дороги та побудовано зелений хвилеподібний графік.* ***Оригінальність****. Удосконалено методологію оцінки еколого-економічного збитку від впливу автотранспорту на міську екосистему, включно з коефіцієнтом індексації. Обґрунтовано методичні основи розробки комплексу природоохоронних заходів щодо зниження впливу автотранспорту на навколишнє середовище м. Баку. У статті закладено основу для розробки комплексу природоохоронних заходів.* ***Практична цінність.*** *Розроблено комплекс заходів щодо зменшення забруднення від міського автотранспорту, які можуть бути використані в регіональних та муніципальних програмах.*

Ключові слова: місто Баку, перехрестя, «Зелена хвиля», «непікові» години, узгоджена система регулювання

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