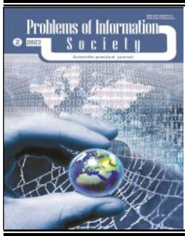

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Integrated approach to the development of the transport system in the urban agglomeration of Baku using digital technologies

Elchin R. Aliyev[1], Islam M. Ahmadov[2], Asgar Sh. Almasov[3], Emil A. Ahmadov[4]

[1,2,3]Institute of Control Systems, B. Vahabzade str., 9A, AZ1141 Baku, Azerbaijan

[4]Intelligent Transport Management Centre of the Ministry of Internal Affairs of the Republic of Azerbaijan, Baku, Azerbaijan

[1]elchin@sinam.net, [2]islam@sinam.net, [3]askar.almasov@sinam.net, [4]e.ahmadov@mia.gov.az

[1]*orcid.org/0000-0002-7987-2674*, [2]*orcid.org/0000-0001-6001-1519*, [3]*orcid.org/0000-0003-0453-9655*, [4]*orcid.org/0009-0000-7333-9687*

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ABSTRACT

Absolutely all megacities of the world are permanently suffering from traffic crowding, which negatively affects the business environment and the economy as a whole. One of the reasons for the formation of crowding is the lack of adequate transport infrastructure or when it works at the limit of its capabilities. However, in most cases, poor (ineffective) traffic management remains the main cause. Based on this premise, the importance and relevance of the tasks of strategic planning for the development of transport infrastructure and traffic management with the widespread use of digital technologies become obvious. The intelligent transport management center has been operating in Baku for a long time, but the city's transport system needs effective smart measures. The article analyzes the problem of practical modeling of traffic flows within the existing road infrastructure of the Baku urban agglomeration and, using the example of a pilot project of the IT-company SINAM, proposes an appropriate solution based on the integration platform of intelligent transport infrastructure.

1. Introduction

Over the past two decades, huge financial resources have been invested and continue to be invested in the development of the transport infrastructure of the urban agglomeration of Baku. On October 26, 2007, by the Decree of the President of the Republic of Azerbaijan Ilham Aliyev the Intelligent Transport Management Center (ITMC) was established in Baku, which was entrusted with the function of monitoring the transport system and managing traffic flows. Nevertheless, the actual functioning of the ITMC dates back to 2011, when a number of activities were carried out to provide information and technological support for its work, the most significant of which were the installation of special monitors at most bus stops, the creation of fiber optic infrastructure, and the equipment of road infrastructure with surveillance cameras and shuttle buses with GPS devices. The center has high-precision equipment and is equipped with the BARCO virtual reality system. In addition, ITMC has one of the largest monitors in the world, with a total area of 120 m^2.

However, in time it became obvious that the hopes assigned on ITMC did not justify themselves due to a number of objective reasons, the main of which is the uncertainty associated with the lack of proper powers of the Center for full-fledged joint work with specialized structures and city government institutions. Due to the lack of formal structural subordination, the ITMC remained indifferent, for example, to the operation of public transport and to the fixed offenses of drivers on the roads.

By the decree of the President of the Republic of Azerbaijan Ilham Aliyev dated February 7, 2022 (Decree of the President of the Republic of Azerbaijan on improving transport management in the administrative area of Baku city, 2023), ITMC was transferred to the subordination of the Ministry of Internal Affairs of the Republic of Azerbaijan, which made it possible to noticeably intensify the work of the Center to harmonize its activities with other structures of the urban economy. However, staffing problems still remain. Within the framework of the ITMC, it is necessary to form an information and analytical core, where the main actor should be a group of business analysts and programmers for the analysis, synthesis and planning of solutions in the areas of ensuring the sustainable development of transport infrastructure, improving transport accessibility, ensuring the speed and comfort of public transport, improving road safety and reduce the negative impact of transport on the environment. To achieve these goals, a systematic approach is needed to carry out technically and economically justified measures for the development of motor transport and roads. This approach should be based on the transport model of the entire urban agglomeration or models of individual districts integrated into the overall structure of the transport system (Elefteriadou, 2013; Knoop et al. 2016; Ni, 2015; van Wageningen-Kessels et al., 2015; Hoogendoorn et al., 2001). As a result, through interactive modeling it is possible to form a development strategy, optimize and streamline the urban transport environment in order to organize traffic without congestion. At the same time, traffic simulation is carried out on the basis of data obtained as a result of studying the traffic situation, analyzing the road network, traffic and pedestrian flows (Barceló, 2010; Daamen et al., 2014).

Thus, for the complex organization of traffic in the urban agglomeration of Baku, a software-module tool is needed that provides the solution to the problems of managing the dynamic development of the transport system based on traffic flow models.

2. SINAM solution for city traffic management

The application solution of SINAM relative to the management of the transport system in the urban agglomeration is based on the concept of "Intelligent Transport System" (ITS), which involves the use of various innovative developments for managing car flows in the form of simulation models that take into account huge arrays of accumulated data on traffic flows, and information technologies. European Commission Directive 2010/40/EU of July 7, 2010 defines ITS as a system that uses information and communication technologies in the field of motor transport. In a more comprehensive sense, ITS, covering the entire transport infrastructure, includes vehicles and other actors of the system, as well as elements of traffic regulation, such as traffic light network management systems, cargo transportation regulation, advanced driver information system, road markings, lighting, recognition of vehicle registration numbers and etc.

As a basis for the solution on transport mobility management of the Baku urban agglomeration SINAM Ltd chose the ITS integration platform of the Austrian company "SWARCO" (SWARCO: the better way, every day, 2023), which is characterized by:

- availability of modern monitoring, management and information technologies;
- automatic interaction of components integrated into the system;
- built-in system of effective management and informing scenarios.

The platform combines ITS components into a single integrated monitoring, control, management and information system, and also provides interaction with external information systems and sources. Based on the flexibility of the Swarco platform for the further development of ITS due to the possibility of additional integration of promising and modernization of existing components, SINAM Ltd adapted the SWARCO integration platform to the conditions of transport mobility of the Baku urban agglomeration in the form of a modular solution that implies the integration of existing systems and/or traffic control zones at intersections into a single environment for centralized management, monitoring and control of the state of the city's transport system (see Figure 1). The center integrates traffic control systems at intersections with highway system to develop coordinated flow control scenarios, both direct and indirect methods. There is an interaction between the system of linear dispatch control and adaptive traffic control at intersections for the formation and processing of "conditional" priority commands in automatic mode.

The centralized traffic management system collects traffic data offline and permanently, records and analyzes data, corrects and optimizes solutions for:

- improved overview of transport forks;

Fig 1. Centralized traffic management

- provision of information to various profile structures of the city;
- optimization of the capacity of the existing urban infrastructure;
- reducing waiting times on the road and relieving stress for road users;
- reducing the time of arrival to the destination;
- reduction of harmful emissions into the atmosphere;
- harmonization of public transport and parking.

In the list of tactical procedure, a special place is occupied by the implementation of traffic light object control scenarios under the control of various strategies based on adaptive-coordinated control algorithms (Aghabayket al., 2015; Bellomo et al., 2011; Flötteröd et al., 2011). According to (Treiber et al., 2013), one such scenario for full adaptive management of a traffic intersection with public transport priority (see Figure 2) involves: 1) choosing an action plan based on traffic; 2) choice of action plan taking into account time; 3) adaptive traffic control in a given segment of the transport system; 4) different management strategies for different transport areas; 5) different control strategies for different periods of time during the day and for different days of the week.

Fig 2. Adaptive junction management with public transport priority

The tool for modeling and calculating coordination plans for traffic light control systems built into the central traffic management system involves the creation, storage of a library of plans and their permanent updating by generating a roadmap and loading it back in a new configuration. Monitoring the status of all traffic lights in the control system includes real-time monitoring of the status and mode of intelligent cross-flow control, as well as the technical condition of the connected equipment by visualizing relevant information on the central monitors. Intelligent cross-flow control is shown in Figure 3.

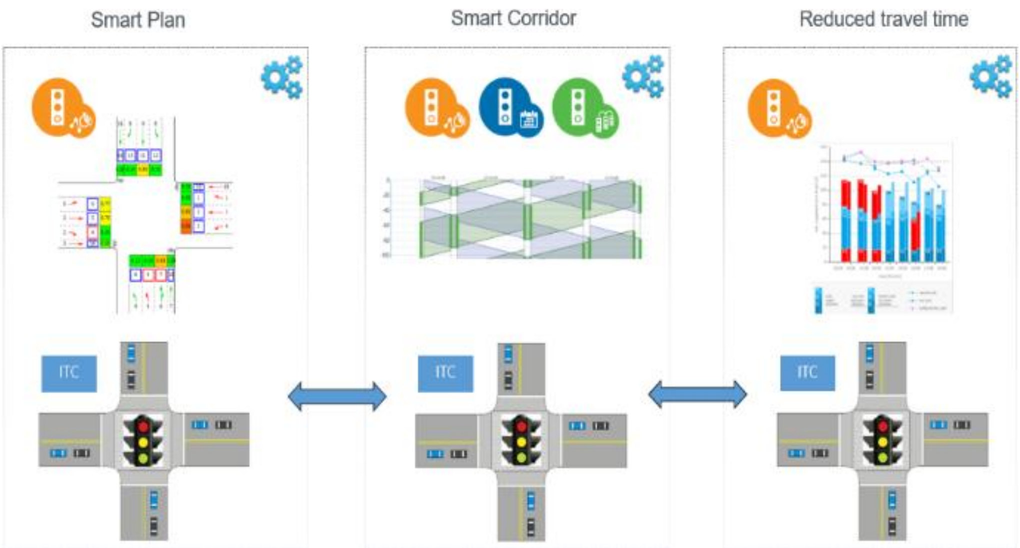

Fig 3. Intelligent cross-flow control

3. Highway management on the example of the pilot project "Tbilisi Avenue"

For the highway management within the framework of the ITS concept, the SINAM solution assumes the management of traffic flows based on a configured library of behavior scenarios. Creation and sending of commands to executive devices is carried out by the integrated subsystems "Control" and "Informing", respectively. At the same time, the presence of feedback allows editing scenarios and configuring scenario priorities in both automatic and manual modes.

As a pilot project for the implementation of the coordinated management of traffic lights and its optimization, SINAM was allocated a site on Tbilisi Avenue in Baku with a length of 1600 meters, which is characterized by heavy traffic for most of the day (Figure 4). The main task was to optimize the traffic schema along the avenue and regulate the operation of traffic lights to increase throughput during peak hours.

Fig 4. "Tbilisi Avenue" Pilot Project Deployment Area

As part of the implementation of the pilot project, the functionality of the integration platform offered by SINAM is based on incoming information about the conditions and parameters of traffic flow directly on the linear sections of Tbilisi Avenue, at interchanges and intersections, as well as taking into account the monitoring and analysis of the traffic situation on the adjacent road network for implementation of coordinated control scenarios. According to (Auberlet et al., 2014), the collection of the necessary information regarding traffic flows was carried out for one month: 1) on working days during rush hours (in the morning - from 8^{00} to 10^{00}, in the afternoon – from 12^{00} to 14^{00}, in the evening – from 17^{00} to 19^{00}); 2) on weekends during rush hours (from 12^{00} to 14^{00}).

Intersection planning activities were carried out using the Lisa+ software. The development of the existing and design transport simulation model was carried out in the PTV VISSIM software and, based on the observational data the possibility of obtaining preliminary results by simulating the transport interchanges was synthesized.

As one of the 5 traffic intersections along Tbilisi Avenue (Figure 4), a multi-level road junction on the January 20 Square was chosen (Figure 5, a).

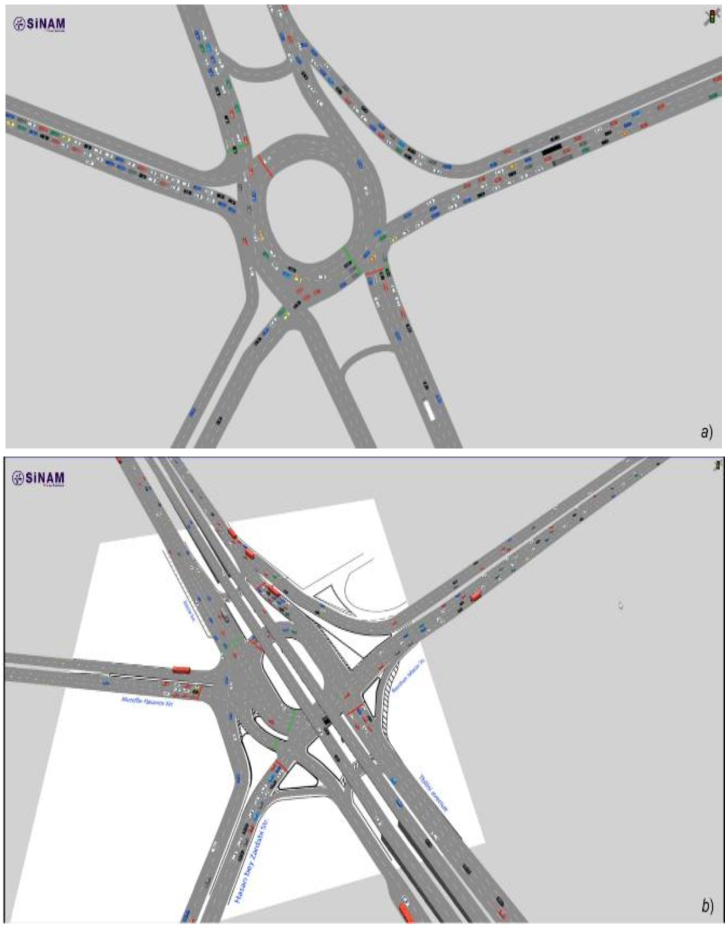

Fig 5. "January 20" logistics hub: a) Configuration before; b) expected configuration after the implementation of proposals

As a result of a preliminary analysis of this logistics hub, the number of transport problems were identified, the main markers of which are the following:

- excessively large traffic flow in the direction of the left turn on R. Jafarov street from the northern direction of Tbilisi Avenue;
- lack of regulation of the transport hub by traffic lights, in particular, lack of regulation of traffic lights at the confluence of transit traffic from Tbilisi Avenue and R. Jafarov street in the north direction;
- lack of organization of canalized traffic using dedicated security islands;
- placement of the public transport stops at the roundabout.

As a result of software simulation of traffic flows in the logistics hub for various scenarios (Figure 5, b), solutions were obtained that explain the following recommendations (Some of the proposals within the framework of the pilot project are taken into account by the relevant structures and brought to execution):

- to organize traffic light regulation in all directions at the roundabout;
- to locally expand the carriageways in certain sections when approaching the roundabout;
- to impose restrictions on stopping and parking of all types of transport vehicles;
- to cancel public transport stops directly at the roundabout;
- to organize canalized traffic by creating dividing islands;

- to impose "waffle" markings within the boundaries of the roundabout on intersecting conflict directions.

Similar studies with the application of simulation of traffic flows were carried out for all logistics hubs along Tbilisi Avenue as indicated in Figure 4, and the expected results (Figure 6) were formed relative to the average delay of transport vehicles as a result of the implementation of the corresponding recommendations (Lesort et al., 2003; Sun et al., 2017). According to the plan, 5 intersections were allocated:

1. Tbilisi Ave. – Rovshan Jafarov str.
2. Tbilisi Ave. – Hasan Aliyev str. – Shafayat Mehdiyev str.
3. Tbilisi Ave. – Azer Aliyev str.
4. Tbilisi Ave. – Izmir Street str.
5. Tbilisi Ave. – Hanifa Alasgarov str.

As a result of the measurements, we found it appropriate to add the 6th junction.

6. Tbilisi Ave. – A. Salamzade str. Pedestrian crosswalk. This node is a pedestrian crosswalk moved under bridge to provide the shortest evacuation time for pedestrians.

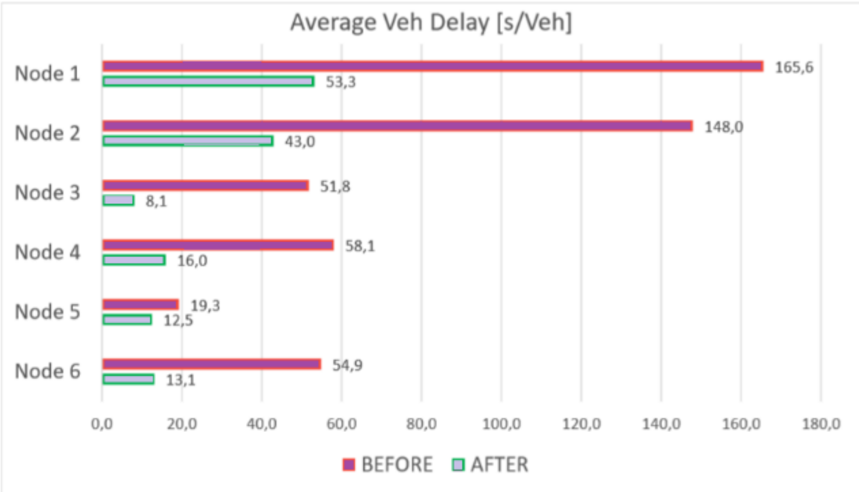

Fig 6. Average delays of vehicles at logistics hubs: actual and expected after the implementation

Tbilisi Avenue, as one of the important transport arteries of Baku, is characterized by constantly emerging traffic jams, which negatively affects the business environment and the economy of the city as a whole. One of the reasons for the formation of congestion here is the inefficient management of traffic flows, the lack of proper organization of traffic with the widespread use of digital technologies. To relieve traffic pressure on Tbilisi Avenue, within the framework of the pilot project SINAM company offers simulation models of traffic flows, which, as sources of useful information, can provide support for making operational decisions on managing traffic flows in real time. Short-term forecasts relative to the average travel time along the avenue are built on the basis of quantitative characteristics of the state of adjacent traffic flows (speed and intensity of traffic on each section of the transport network, travel time, traffic volumes from adjacent areas, etc.), which are generated by the corresponding mathematical models. The results regarding the average travel time along all routes between logistics hubs are shown in Figure 7.

As a result of the studies using simulation modeling based on data from objective observation of the movement of traffic flows at different times of the day and days of the week, the values of performance indicators (throughput) of logistics hubs along Tbilisi Avenue were established before and after the implementation of proposals as part of the pilot project by SINAM Ltd. The simulation results are shown in Figure 8.

No.	From	To	Distance [m]	Avg. Travel Time [s]	
				BEFORE	AFTER
1	Node 1a: NORTH	Node 5: SOUTH	2377,0	542,5	211,2
2	Node 5: SOUTH	Node 1: NORTH	2417,1	410,5	332,2
3	Node 5: SOUTH	Node 2a: Akim Abbasov Str	1150,2	307,4	176,8
4	Node 5: SOUTH	Node 3: H. Aliyev, passage 1	708,8	166,7	72,2
5	Node 2a: A. Abbasov Str	Node 5: SOUTH	1032,8	187,7	107,7
6	Node 2b: Azer Aliyev Str	Node 1: NORTH	1491,4	141,8	210,9

Fig 7. Average travel time between logistics nodes: actual and expected after the implementation

Node	CO Emission [grams]		Fuel Consumption [US gallon]	
	BEFORE	AFTER	BEFORE	AFTER
1	85927	45821	1229	656
2	46447	26619	664	381
3	11555	3518	165	50
4	13248	6804	190	97
5	11973	11299	171	162
6	16900	7439	242	106

Overall Network results

Situation	Avg. Delay [s/veh]	Avg. Stops per vehicle [-]	Avg. Speed [km/h]	* CO Emission [grams]	* Fuel Consumption [US gallon]
BEFORE	256,82	10,28	21,42	186051	2662
AFTER	59,88	1,46	39,38	94060	1345

Fig 8. Performance indicators of logistics hubs: actual and expected after the implementation

4. Conclusion

On the example of the implementation of the pilot project "Tbilisi Avenue" by the IT-company SINAM Ltd, carried out on the basis of the ITS integration platform of the company "SWARCO", it became obvious that it is necessary to create an integrated traffic management system in the urban agglomeration of Baku, which will allow the implementation of the following basic solutions:

- creation of the unified information space based on the continuous exchange of data of various types between the integrated components of the ITS;
- integration of existing traffic light control systems, regardless of the data exchange protocols adopted in them based on built-in software adapters;
- integration into a unified centralized system of control, monitoring and management of

city and main automated traffic control systems;

- creation and implementation of complex scenarios for managing and informing drivers, taking into account the current traffic situation, as well as ongoing planned activities and events.

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