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IMPROVING THE EFFICIENCY OF TRAFFIC MANAGEMENT IN A METROPOLIS BASED ON COMPUTER SIMULATION

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This article considers an algorithm for traffic management. The process of simulation modeling of traffic flow at a road intersection in a metropolis is described. The optimization of the obtained simulation model is performed in the software system of simulation maintenance Anylogic. The application of the developed model is shown on the real example of a megalopolis road intersection. We considered the classification of highways, and analyzed the built model on the basis of the existing megalopolis crossroads, which allowed us to obtain the data comparable with the existing system. We considered and adopted methods to solve the high traffic problem by re-organizing the intersection using simulation modeling. The final system showed a 27 % throughput growth in the whole system and a 40 % growth in the main direction without traffic jams. The analysis shows the prospects of using the proposed simulation model to study real-world traffic flow management processes in order to study their behavior.

Keywords: megalopolis, control, simulation modeling, algorithm, model, transport stream, car roads.

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ УПРАВЛЕНИЯ ТРАНСПОРТНЫМИ ПОТОКАМИ МЕГАПОЛИСА НА ОСНОВЕ ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

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Рассмотрен алгоритм управления транспортными потоками. Описан процесс имитационного моделирования транспортного движения на перекрестке дорог в мегаполисе. Оптимизация полученной имитационной модели выполнена в программной системе имитационного обслуживания Anylogic. Применение разработанной модели показано на реальном примере автодорожного перекрестка мегаполиса. Рассмотрена классификация автомобильных дорог, на основании которой проведен анализ модели, построенной по существующему перекрестку мегаполиса, из которого были получены данные, сопоставимые с данными существующей системы. Изучены и приняты методы решения проблемы высокого трафика путём реорганизации перекрестка при помощи имитационного моделирования. Итоговая система показала прирост пропускной способности на 27 % во всей системе и 40 % прироста по основному направлению без образования заторов. Выполненный анализ обосновал перспективность использования предложенной имитационной модели для исследования реальных процессов управления транспортными потоками с целью изучения их поведения.

Ключевые слова: мегаполис, управление, имитационное моделирование, алгоритм, модель, транспортный поток, автомобильные дороги.

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Introduction

At present, the problem of organizing transport networks in megacities is the most urgent, since in all large cities traffic is developing at a much faster pace than the public road network. The capacity of most existing roads can only adequately support average traffic levels, but during “peak” hours, such as in the morning and evening, when the number of vehicles increases significantly, the problem of “traffic jams” arises. To solve this problem, effective management methods are needed to restructure traffic flows at the busiest locations, especially at complex interchanges [1, 2].

Obviously, it is difficult or impossible to conduct a full-scale experiment on traffic flow management in a megacity, so simulation modelling becomes the only tool for effective decision- making in this area. The advantage of this method is that, unlike the analytical method, simulation modelling of traffic flows allows an unlimited number of times to reproduce the system under study and determine its optimal state [3–5].

Study materials and methods

Initially an analysis of public roads should be carried out to identify the most problematic sections based on predetermined criteria, using appropriate road classification attributes and accumulated statistical data.

In general, these classification characteristics may include the presence and number of traffic lights, the number of pedestrians and vehicles, the presence of road markings, the number of traffic lanes, and their narrowing and widening [6, 7].

The main classification attributes of roads are shown in Table 1.

Obviously, the megacity traffic flow has features such as stochasticity, non-stationarity, incomplete controllability, and multiplicity of criteria for assessing its quality. These features affect the modeling process and make it impossible to build an adequate analytical model that allows studying this system and its characteristics under various operating conditions. The level of detail of the modelled process can be chosen depending on the respective approach, either macro- or micro-level models are used [8–11].

Macro-level models consider vehicles in groups without considering their condition individually. This makes it possible to estimate traffic characteristics at a particular point in time, which makes this approach preferable for simulations of complex roadway elements such as intersections.

At the micro-level models, it is possible to consider the individual characteristics of each vehicle and the interactions between them. This approach is preferable for modelling individual events at direct traffic points.

Consider an algorithm for controlling vehicle flows at an intersection of a metropolitan motorway, taking into account such factors as the functioning of traffic lights, the possibility of widening the road, and the possibility of using a new branch line [12–14].

To investigate the algorithm and conduct simulations, a transport scheme linking Ring Road 1 with High Speed Tollway 2, and the urban road network around Highways 3 and 4 was selected (Fig. 1).

The main problem with this scheme is the merging of three roads into one, with a final narrowing of 4 lanes. The traffic flows further to the junction with a pedestrian crossing, traffic lights and the ability to continue straight ahead, turn right, left and make a U-turn. Due to this large number of directions and the huge flow of vehicles, traffic congestion is a constant problem. In order to find a solution to this problem, a simulation model of the intersection was implemented, with the possibility of upgrading it and reorganizing the corresponding traffic. As a new solution to the traffic flow management problem, we proposed a reorganization of the intersection based on a roundabout.

The development of the new solution included:

1. Construction of an initial simulation model of an intersection.
2. Computer experiment with the original model.
3. Development of recommendations for the reorganization of traffic flows.
4. Formation of a simulation model of an intersection taking into account the recommendations.

To implement this approach, we chose AnyLogic software system, which allows the use of road library data to build the required models. The main objective was to find possible solutions to the problem of the road layout in question using different simulation model variants.

Table 1

Technical classification of public roads

Class of road	Category of road	Total number of lanes	Width of lane, m	Central dividing strip	Intersections with roads, bicycle and pedestrian paths	Crossings with railways and tram tracks	Access to the road from a single level abutment
Motorway	IA	4 or more	3.75	Obligatory	At different levels		Not allowed
High-speed road	IB	4 or more	3.75				Allowed without crossing straight ahead
The road of the ordinary like	IB	4 or more	3.75	Obligatory	Allow single level crossings with traffic light control	At different levels	
	II	4 or 3	3.75 / 3,5	The absence of			Allowed
	III	2	3.5	Not required	Crossings at the same level are allowed		
	IV	2	3.0			Allow for intersections on the same level	
	V	1	4.5 or more				

To develop the simulation model of the transport scheme under study, we used the blocks of AnyLogic road library, such as: Source – responsible for generating cars on the selected section of the transport network; carMoveTo – allowing to determine the next road and direction for cars; carDispose – block; selectOutput – allows you to select the direction for cars, based on probabilistic estimates; roadNetworkDescriptor – makes it possible to show the degree of congestion of sections using a color scheme; trafficLight – sets the time interval of traffic lights operation. The considered traffic network has 29 routes and is shown in Fig. 2 and 3.

The computer experiment performed on the original simulation model showed the same results as the real traffic process, namely, a large congestion formed, which is shown in Fig. 3.

After analyzing the existing situation, the model was adjusted based on the decision made to reorganize the traffic flow by creating a roundabout, i.e. to exclude the intersection and the corresponding traffic

Fig. 1. Interchange with junction

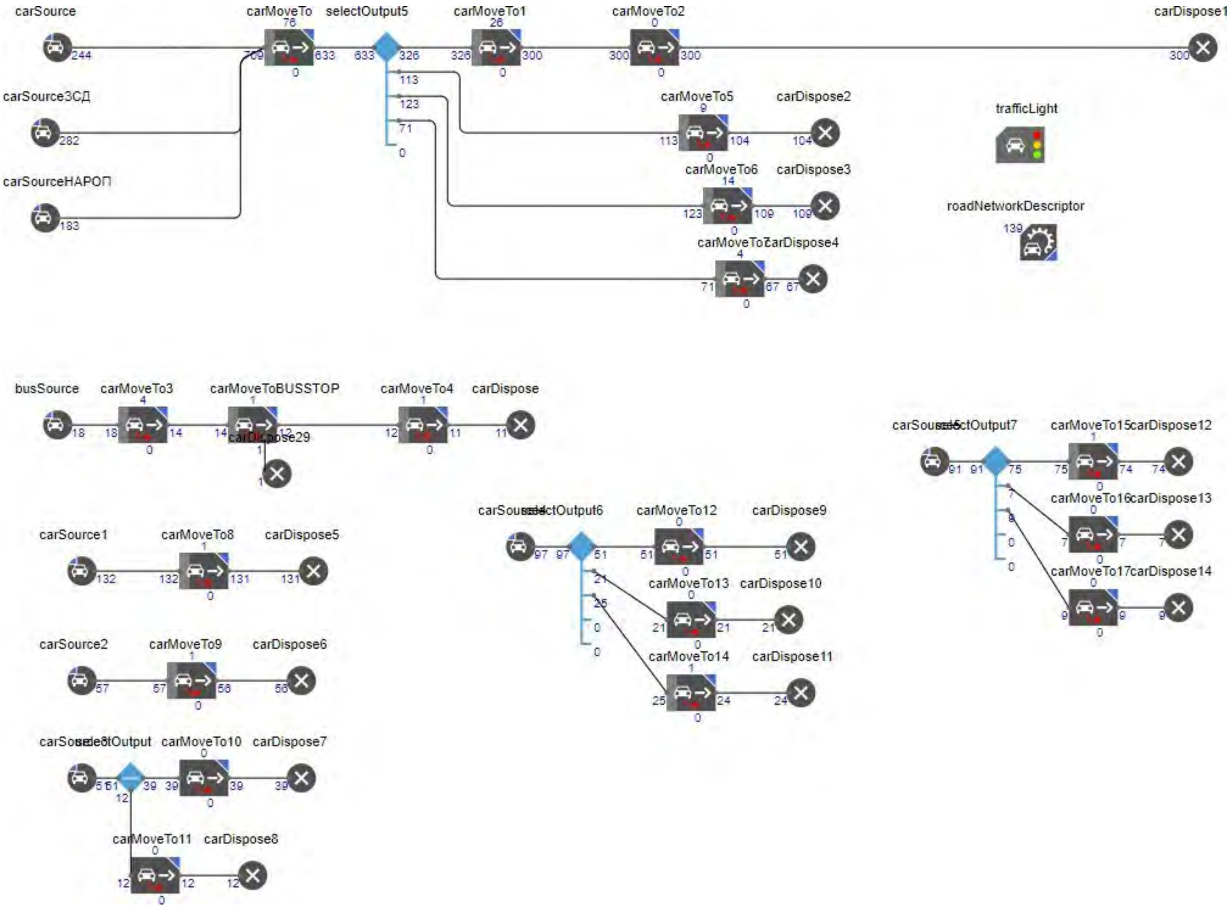

Fig. 2. Transport network before the change

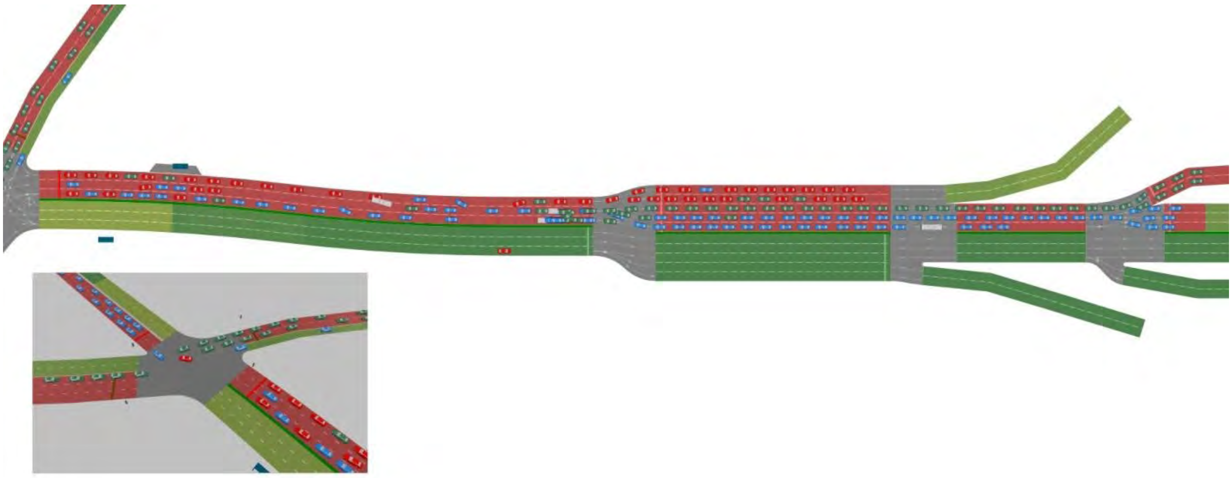

Fig. 3. Congestion on the model before the change

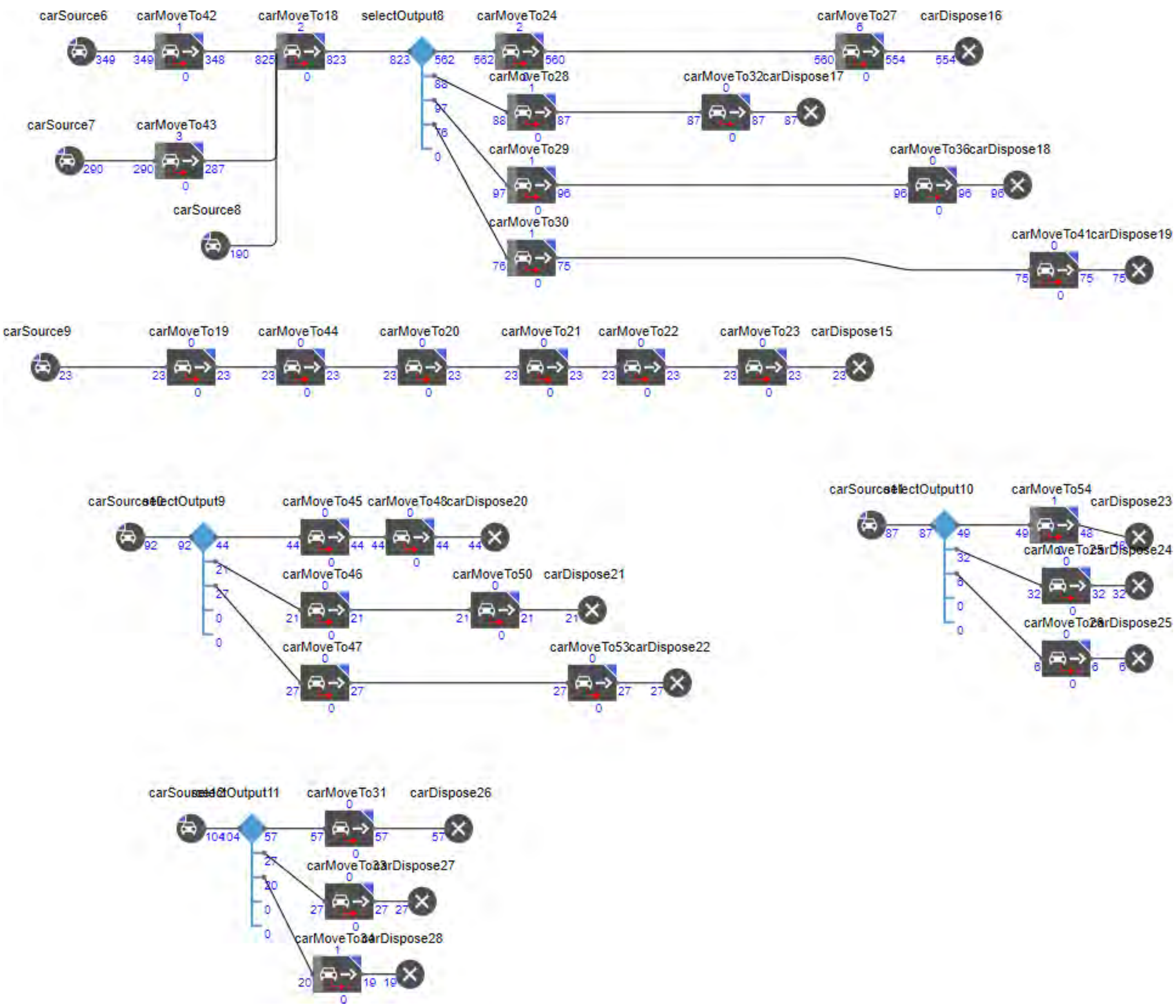

Fig. 4. Transport network after change (with roundabouts)

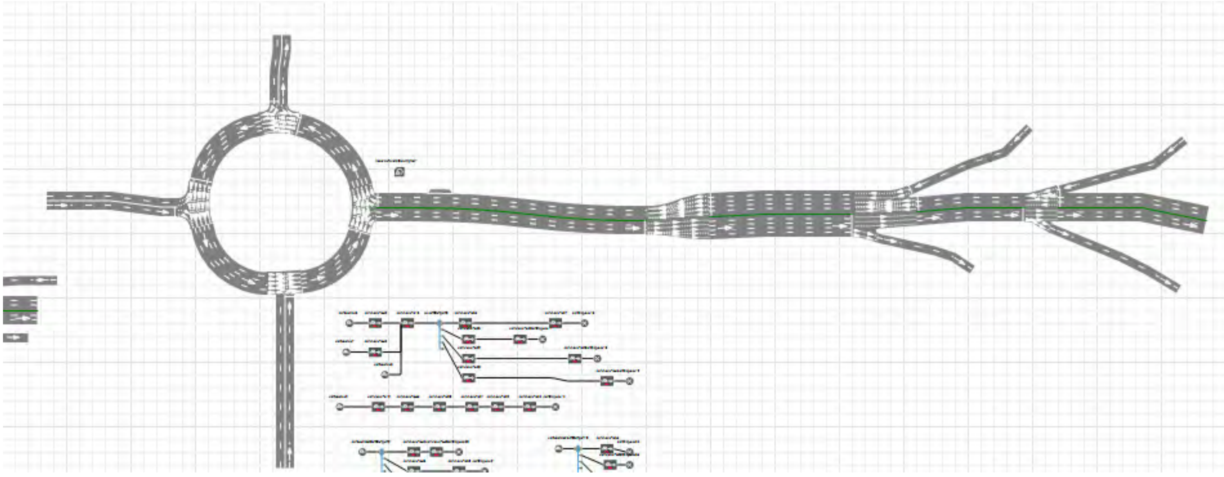

Fig. 5. Model after modification

lights from the traffic pattern. The implementation of the new version of the model is shown in Fig. 4 and 5.

Research results and discussion

The final comparative analysis of both models, with the same input data per unit time (1 hour), showed the following results, presented in Table 2.

Table 2

Final comparative analysis of models

Without circular traffic, pcs.		With circular traffic, pcs.	
Buses treated	11	Buses treated	23
From road No. 3	580	From road No. 3	812
Towards road No. 3	99	Towards road No. 3	103
To road No. 4	96	To road No. 4	92
From road No. 4	90	From road No. 4	86
TOTAL	865	TOTAL	1093

The results of the modelling show that the capacity of the motorway in the main direction has increased by 40 %, which allows a significant increase in traffic flow without the risk of congestion (Fig. 6). The final model has received an increase of 27 %. Accordingly, the roundabout-based scheme can handle around 1,500 vehicles per hour.

Thus, when performing a computer experiment on the model, it is possible to determine the degree of congestion of sections of the metropolitan route network in each period of time. In addition, the model allows varying the input parameters such as vehicle schedules, type and number of vehicles on the route, route structure, vehicle speed, etc., and analyzing changes in the situation to the benefit of effective decision-making [15, 16].

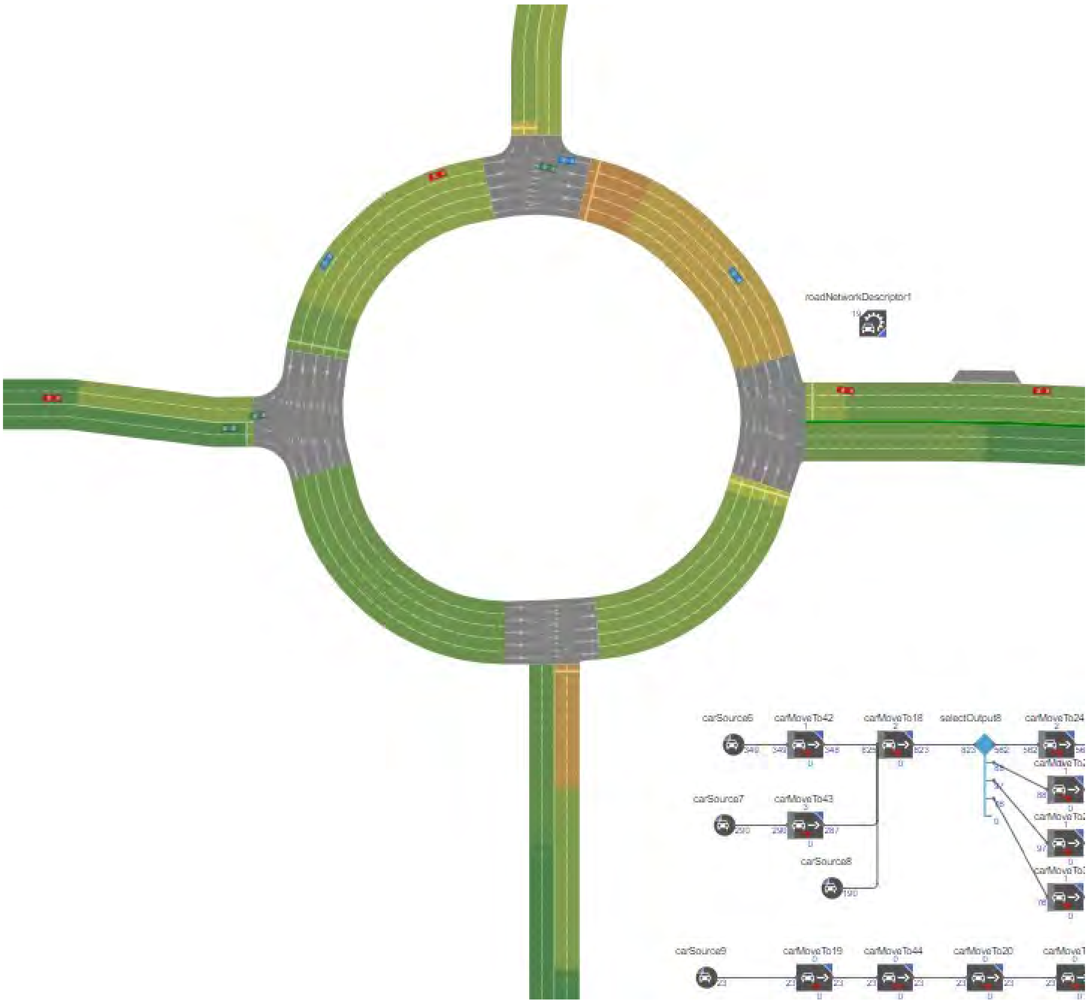

Fig. 6. Model after the computer experiment

Conclusion

The analysis shows the promise of using the proposed simulation model to study real traffic flow management processes in order to study their behavior. This model can be further improved by introducing more complex parameters and increasing the size of the transport network under study.

The model proposed in the article has the following advantages:

1. The model of the actual transport system is based on the object-oriented approach.
2. Visualization of the model allows identifying the busiest sections of the city's transport network that require redistribution of traffic flows.

The application of the developed model and the analysis of the data obtained from the experiment based on its use will improve the quality of transport services to the population, will contribute to the reduction of tension on the metropolitan motorways and reduce the number of road accidents.

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