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Formation Of Transport Correspondence Dynamic Matrices At The Reconstruction Of Street Road Network

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Abstract- Due to the increase of motorization level and the growth of population and the territory population density there is a global problem of road congestion. They reduce the efficiency of road transport infrastructure, increasing the time of transportation, fuel consumption and environmental pollution. Currently different methods are used to address the traffic congestion. In this article the author's method of transport network load prediction is considered. This method is used to create a dynamic matrix of transport correspondences, which will allow to perform a prediction, and to develop different scenarios of control actions on traffic flows. The making of these transport correspondence matrices and city planning solutions for a street road network section and the study of individual object properties of a matrix will allow to explore the features of traffic flow and the patterns of congestion occurrence.
Keywords: Correspondence matrices, modeling, intensity prediction, the distribution of vehicles, urban systems, traffic, transit.

Introduction

Due to a constantly increasing burden on a street road network (SRN) the construction of new transport infrastructure objects and the change of work schedules for existing objects, as well as the consideration of different factors that have an impact on the load of SRN becomes necessary. These factors include climatic events, "event loads on SRN (for example, sports events, exhibitions, etc.), holiday and training periods of student and schoolchildren work, etc. At that at different sites MAC these phenomena are manifested in various degrees at different sites of SRN [1]. The combination of two or more factors in one area may increase the load on SRN greatly, so you need to take into account such features in the city-planning decisions, as well as at the development of general plans for agglomeration facilities.

It requires justified decision-making on the construction or reconstruction, which is not possible without the understanding of traffic flow characteristics at a particular period of time [2].

The analysis of modern literature sources on the modeling of transport processes, in particular the sources written by Erik Jenelius [3], Zhu S., Levinson D., Liu H., Watling D. [4], Berdica K. [5], Andjic Z. [6], Nicholson AJ [7] and a number of others, showed the presence of various models concerning the influence "of extreme factors on the load of the road network. At that these models are descriptive or evaluative ones. The solutions proposed by these authors and the models are focused on the existing transport infrastructure and the sustainable level of population motorization. These approaches do not allow to apply such models in Russia, in particular in the Belgorod region, because it does not involve an intensive street road network load increase within a relatively short periods of prediction. The effects of climate and event-oriented phenomena are used for the psychological profile of a European or an American driver that does not fully use the possibility of the proposed solutions in domestic conditions.

Methods

One may highlight the following shortcomings of existing approaches:

1. The inability to assess the dynamic changes of load on a street road network;

2. The inability to predict the effects on SRN loading and the development of recommendations on the construction of objects for the population attraction;

3. The inability to build an effective intellectual transport system of a locality or an agglomeration;

4. The inability to develop solutions in respect of managing impacts on various elements of urban infrastructure in order to equalize the load on SRN;

5. The large work content for data collection.

The methods and approaches for the determination of activity impact degree on the traffic flow are based on traffic correspondence matrix restoration, the details of which are formed on the basis of traffic intensity in the surrounding SRN areas or on sociological surveys. The prediction of traffic direction is also important, i.e., the development of transport correspondence matrix "source - target". At that it should be understood that this approach has the function of inversion, i.e. a goal becomes a source after a while. This approach is shown in a number of papers written by various authors [8, 9, 10]. Most of the works, including the works of the last year are dedicated to the creation of a correspondence matrix based on intensity study at the intersections of a street road network. However, this approach does not guarantee a full study of traffic flow characteristics. Based on this, the authors suggested the further development of the approach concerning the individual elements of the correspondence matrix. Any settlement consists of town districts or clusters [11, 12]. In general, a cluster is characterized by the presence of certain objects, for example the objects shown on Fig. 1.

Each of the cluster objects has its own characteristics of a traffic flow, for example, the intensity value. At that the total incoming and outgoing traffic in the area of cluster entry and exit will be the sum of its constituent objects characteristics described the time intensity function.

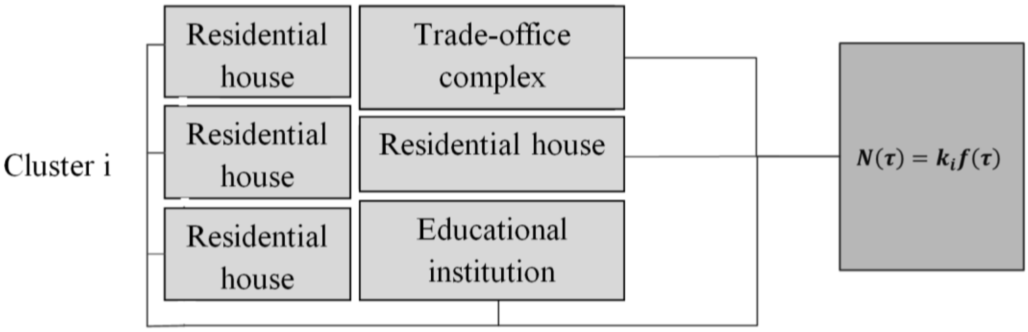

Fig. 1. A single cluster of a settlement district

The development of such a cluster model, or the characteristics of a single matrix element for transport correspondence is possible on the basis of vehicle entry and exit time record from the corresponding zone. At that the the methods of traffic flow characteristics determination developed by authors are based on the single matrix elements of transport correspondence provide the evaluation and give the ability to predict traffic flow characteristics only in a separate localized area of SRN, but they cannot describe the whole network. This makes the development of a uniform methodology for collection of information about the traffic flow characteristics on the basis of vehicle numbers state registration possible. This approach allows us to determine exactly when a car drove into a study area, when the car left it, what time was spent to overcome the area. The methods of vehicle state registration number record used previously on the basis of stationary cameras are quite complicated and have limited mobility, because they are more time-consuming for the connection, coordination, etc. [13, 14]. Therefore, the authors proposed the method of data collection on the basis of domestic video cameras and special video processing software use. This approach allows us not only to take full account of traffic flow characteristics at the time of stay in a particular section of SRN, but also allows you to develop a transport correspondence matrix. At that there is the need for a complete description of a roadway characteristics with a geodetic binding of a street road network. Based on previously conducted certification of the street road network of the city of Belgorod, the technique of a road network development based on the collected data with the obtaining of complete geometric characteristics of a certain SRN site (Fig. 2) [15, 16].

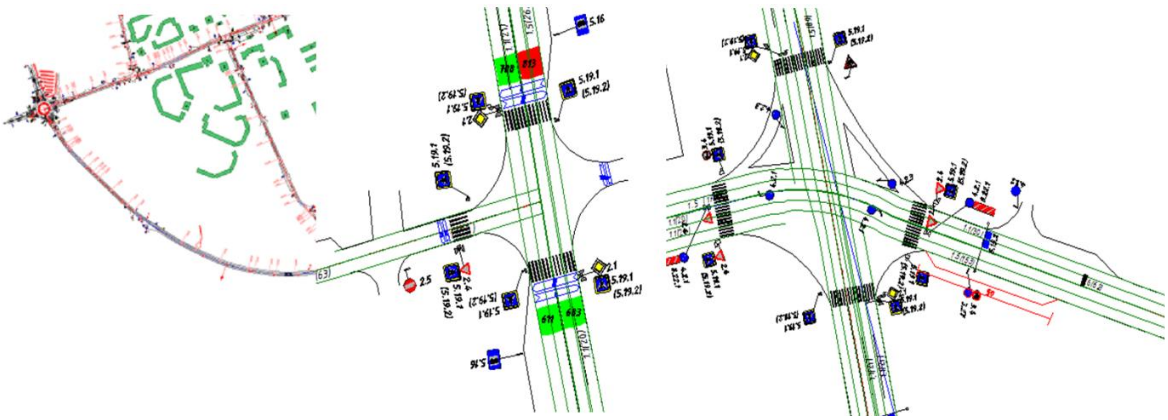

Fig. 2. Geometric parameters of the street road network

Thus, using the proposed methods of data collection, it is possible not only to determine the matrix of transport correspondence, but also the development of a simulation dynamic model for a test part of SRN.

Main part

Transport video detectors, the systems of vehicle numbers photo and video record, road weather stations may be involved for the implementation of such studies. On the basis of detector indications SRN load control was performed. These data are compared with the standard ones in the area. At that precipitation data, the data on the state of a road surface and temperature are analyzed additionally (Table 1). The obtained data showed that there are significant variations of traffic characteristics (the research were carried out within the same period of time, considering the lack of "event phenomena").

Table 1.Analysis of the traffic data depending on the road surface

Vehicle speed Intervals on a test site, km/h	The number of vehicles traveling along the roadbed:		
	dry	humid	snow
20-25	33	31	46
25-30	62	58	92
30-35	118	108	199
35-40	144	281	265
40-45	299	290	228
45-50	392	231	125
50-55	234	115	75
55-60	158	92	35
60-65	51	24	12

Along with the climatic events other factors affecting the traffic flow may occur, for example, the vacation and training period for students. As the research of the 6 main entrances to the city of Belgorod showed, this factor also leads to significant fluctuations on SRN (Fig. 3).

The combined effect of various factors leads to significant fluctuations of traffic intensity on the same parts of the street road network. To determine the degree of influence and possible solutions it is proposed to create a uniform methodology of factor accounting influencing the characteristics of the traffic flow. At that, this technique should be developed on the basis of situation development prediction according to the regulatory indicators, and on the basis of an actual situation. So, based on the development of suburban construction, the growth of motorization and sociological surveys 3 scenarios of motorization level changes were obtained, therefore, and "a driver on different parts of the city of Belgorod SRN, which may be illustrated by the following graph (Fig. 4).

Thus, identifying the factors that influence the traffic performance and using various scenarios of a case development, you can develop a single simulation model for SRN study area (for different combinations of factors), which will allow to identify the opportunities equalizing the load on a street road network due to urban planning decisions.

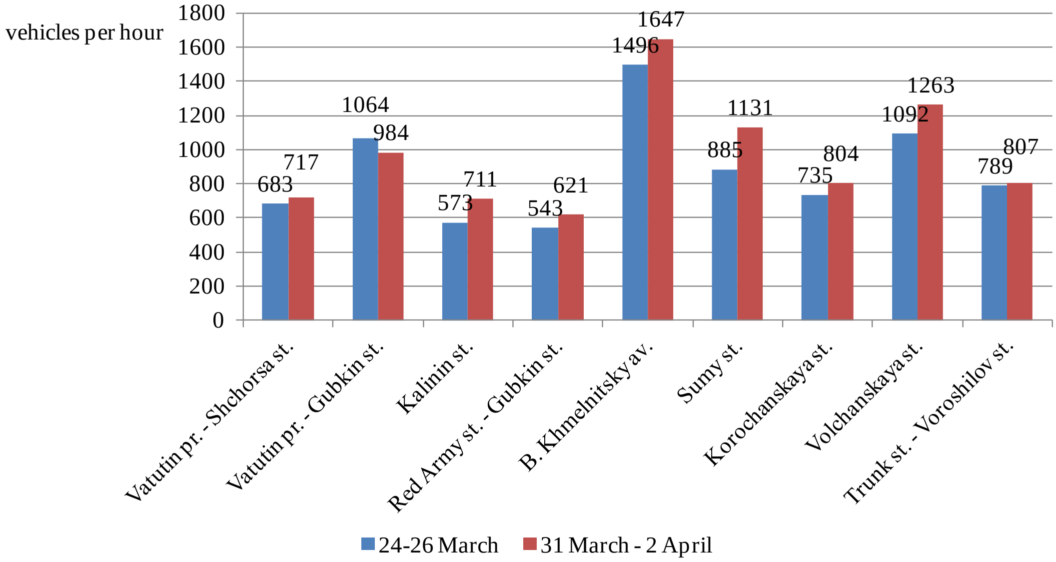

Fig. 3. Change of traffic flow characteristics during the holiday and training period of students

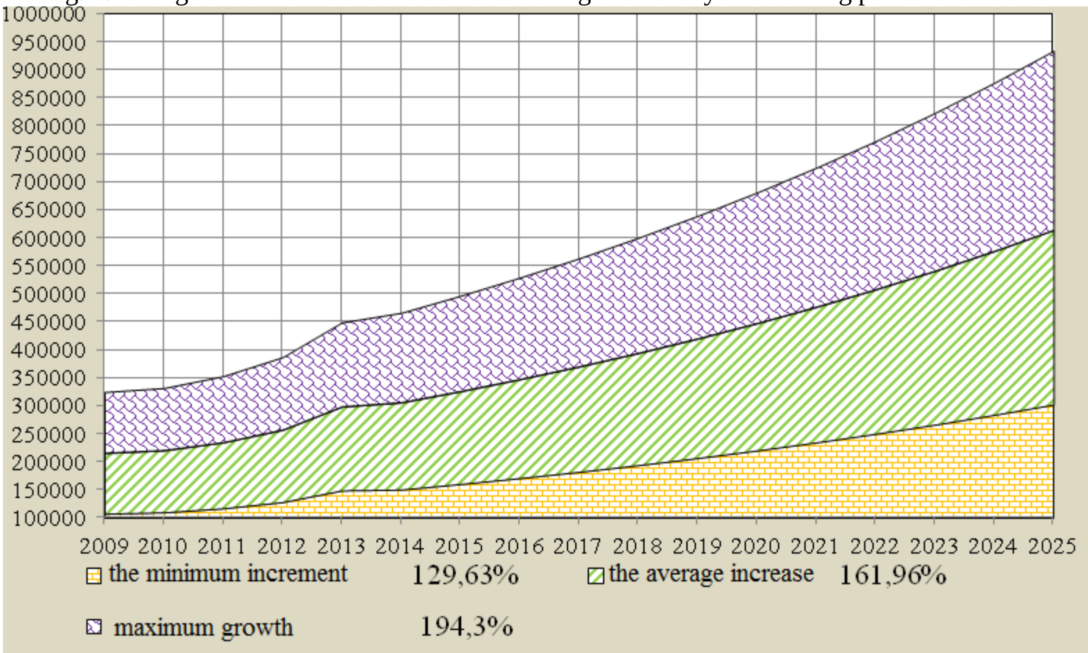

Fig. 4.Motorization development scenarios

This approach was tested on the example of a new sports complex construction in the city of Belgorod. For this purpose, the analysis of traffic flow characteristics belonging to the object-analog from different directions was performed (Fig. 5).

Fig. 5. Traffic characteristic control zones on a prototype object

To implement this approach the requirements should be developed for the specialized software that have to implement the functions of object diagnosis, the single elements of transport correspondence matrices and accuracy control based on transport detector values and the selection of "radiation" and "absorption" functions for the individual elements of a matrix. In this case, traffic detectors act as a control element, providing the estimate of the original data accuracy. Thus, for the given area of Belgorod city SRN the transport correspondence matrix is built on the basis of transit transport state registration number data. The incoming flows from clusters to the main highway were described by the functions of transport correspondence matrix individual elements.

Software, assessing the performance of the transit flow and making a unified matrix of transport correspondence, provides the final result in the following table.

Table 2.The resulting correspondence matrix

Cameras	1	2	3	4
1	0	a_{12}	a_{13}	a_{14}
2	a_{21}	0	a_{23}	a_{24}
3	a_{31}	a_{32}	0	a_{34}
4	a_{41}	a_{42}	a_{43}	0

The following designations are accepted in table 2:

1, 2, 3, 4 - places on the map for the vehicles equipped with video surveillance cameras;

a12 - the number of vehicles, arrived in point 2 from point 1;

a13 - the number of vehicles, arrived in point 3 from point 1, etc.

Each camera shall be described by the following characteristics, which are placed in an appropriate database.

Each point of observation / camera shall be provided with:

1. The exact date and time of observation. Time and date shall be the same for all cameras involved in the monitoring (if it is possible to connect to the Internet, the time and date in the cameras must be synchronized with the exact time of the Internet).

2. The entry of a week day for the convenience of working with information in the future - this will give the opportunity to specify a day of a week, such as Friday, and see how the correspondences changed during this day for a month.

3. The input of geodetic coordinates, the place of shooting, the name of a nearest building (street, house number).

4. The selection of traffic direction, which will be recorded by a camera (forward or reverse one).

5 Shooting location photo in .jpg; SRN area drawing, which is "adjacent" a shooting site in .dwg.

6. General drawing of studied SRN sites displaying the location of a selected camera.

7. The storage of each camera video records.

Each camera will record the following data:

1. The registration number of a vehicle;

2. A vehicle travel time through the section of a road, which is equipped with a camera;

3. Vehicle travel date.

When you run the program you must enter the number of observation points.

At the entrance of a car at any of the observation points the listed data are recorded, and the following table is developed for each camera (e.g. for camera 1).

Table 3.All camera data (shall be kept separately for each camera)

Vehicle number	Travel date	Travel time
n_{11}	$dd.mm.yyyy_{11}$	$hh.mm.ss_{11}$
n_{12}	$dd.mm.yyyy_{12}$	$hh.mm.ss_{12}$

At the entrance to the second observation point a similar table is developed. The data of the first and the second table are compared by vehicle registration numbers. If a number is recorded by the first and the second camera, then the table 4 is generated for these numbers.

If a number is recorded by the first camera and the second camera did not record it, then there is the table named "Former numbers" for such numbers, similar to the table 3. If a number is not recorded by the first camera and was recorded by the second one, then, the table "Arrived numbers" is drawn up similar to Table 3.

These data will be compared with the data obtained from the third camera as follows. First of all the data from table 3 are checked for coincidence for the third camera, with the Table 4 data, prepared according to the first and second camera data. If there are matched numbers another 3 columns are filled in the Table 4:

1) 3rd camera date of travel;

2) 3rd camera time of travel;

3) the movement time from the 2nd camera to the 3rd camera.

Then the numbers from the table 3 are checked for matching for the third chamber with the table "Arrived numbers" for the second chamber. At the coincidence of numbers a record is put in Table 3, like for n12 number. If, after the travel of a few observation points the number is eliminated, the record about it will be like for the number n11.

Then the numbers from the table 3 are checked for matching for the third camera with the table "Arrived numbers" for the second camera. At the coincidence of numbers in table 4 an entry is put down for both numbers n12. If, after the passage of a few observation points a number is eliminated, the record about it will be like for the number n11.

The mean time of driving through several observation points is calculated as the sum of the following cell values: "Vehicle traveling time from the camera #, to the camera #+1 and recorded in an additional column of the Table 4. The average time of vehicle movement from the camera #, to the camera #+1 is calculated as the average value in the column "Vehicle movement time from the camera #, to the camera #+1" and displayed in the last line of the table (for each similar column).

For the 3rd and all subsequent cameras the lists of "Former numbers" and "Arrived numbers" for vehicles were also developed like with previous cameras.

The drawing up of a correspondence matrix will be as follows: the point of entry and the point of exit is determined for each vehicle registration number. The vehicles, recorded at the entrance by the first camera, will be distributed along the first line of the Table 2. Point of departure: it is checked whether there are records in the table 4 about a vehicle travel with a certain registration number through the following observation points.

Table 4.Summary table of traffic duration along SRN site

Vehiclenumber	1 cameratraveldate	1 cameratraveltime	2cameratraveldate	2cameratraveltime	Vehicle travel time from 1st camera to 2nd camera	3cameratraveldate	3cameratraveltime	Vehicle travel time from 2nd camera to 3rd camera
n_{11}	dd.mm.yyyy$_{11}$	hh.mm.ss$_{11}$	dd.mm.yyyy$_{21}$	hh.mm.ss$_{21}$	hh.mm.ss$_{21-11}$	dd.mm.yyyy$_{31}$	hh.mm.ss$_{31}$	hh.mm.ss$_{31-21}$
n_{12}	dd.mm.yyyy$_{12}$	hh.mm.ss$_{12}$	dd.mm.yyyy$_{22}$	hh.mm.ss$_{22}$	hh.mm.ss$_{22-12}$	dd.mm.yyyy$_{32}$	hh.mm.ss$_{32}$	hh.mm.ss$_{32-22}$

The example is the vehicle movement with the registration number n11. A vehicle entered the first observation point. It is checked whether the vehicle entered the second observation point. If so, then it is checked whether the vehicle entered the third observation point, etc. If the vehicle with that number did not enter the 3rd observation point, the value of the cell "a12" of the table 2 is incremented by 1. Thus, the table 2 is filled in.

The obtaining of the following data is assumed as the result of the program work:

1) Table 3 - for each camera;

2) The table "former numbers" - for each camera, starting from the second one;

3) The table "Arrived numbers" - for each camera, starting from the second one;

4) Table 4 - a summary table for all cameras;

5) Table 2 - a summary matrix of correspondence for all cameras.

The output data must be presented in the form of tables (in Excel format). One should also consider the output data possibility in the form of graphs or diagrams.

Summary

Thus, the resulting dynamic matrix of transport correspondences was recorded in a simulation model built in the Aimsun system. The dynamic model of the SRN area is as follows (Fig. 6).

In this part of SRN part the measurements were performed using the detectors of transport in different periods of a year (autumn and winter period) and correlated with the change of the characteristics during the sports competitions. Thus, the most unfavorable ratio of factors with the corresponding matrix of transport correspondences was determined which was superimposed on an area, as the previously studied one in terms of characteristic changes of the transit traffic.

Imposing the matrix of transport correspondences with the prototype object under the most adverse conditions on a similar matrix at a newly erected object, it is possible to take into account the most unfavorable indicators, and on the basis of established development scenarios to calculate the load of the street road network and develop appropriate solutions. On the basis of the data obtained for the considered SRN site, where a sports complex is planned the reconstruction project is developed shown in Fig. 7.

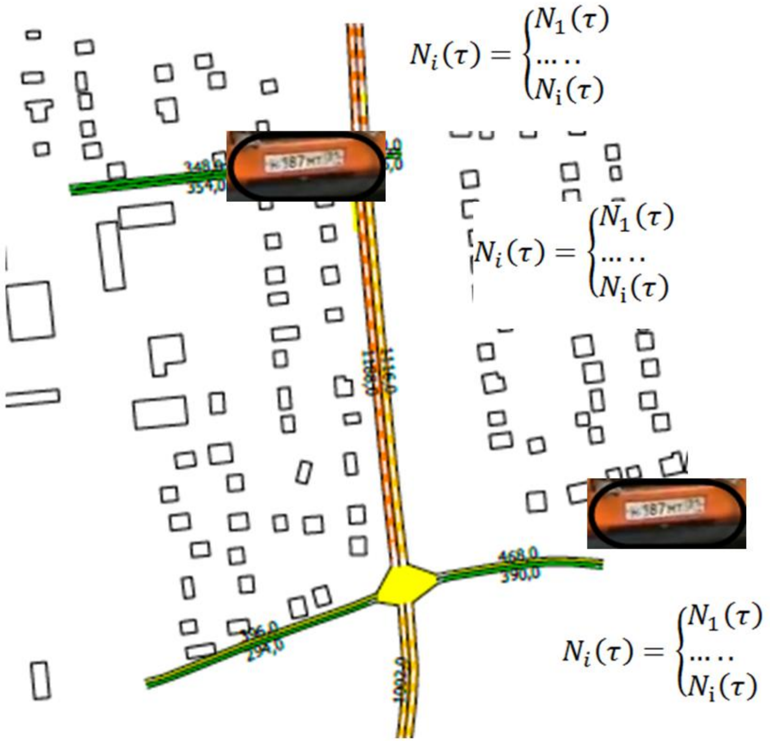

Fig. 6. The dynamic model of SRN area with the description of traffic intensity on the basis of single correspondence matrix elements and the record of transit transport numbers

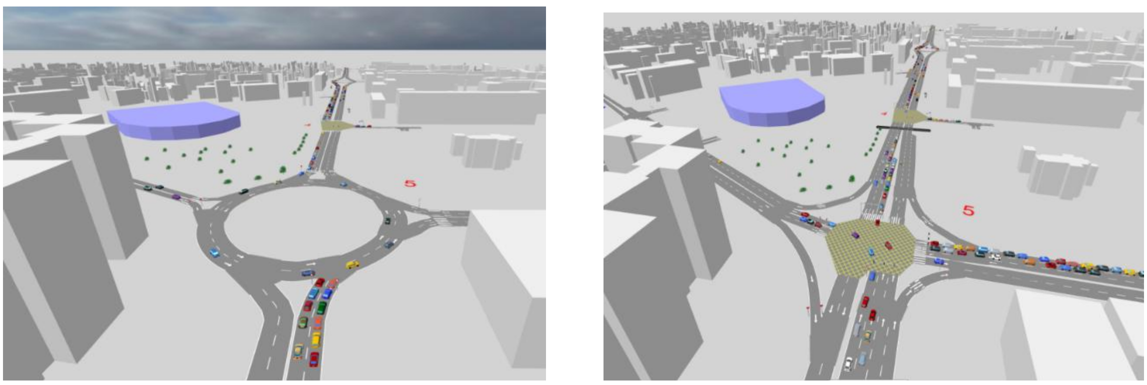

Fig. 7. The project on SRN reconstruction at a newly built sports complex

Conclusion

The obtained research results, the methods and algorithms allowed to perform a dynamic assessment of the "event-related" phenomena on a road network for the first time and therefore to decide on the temporal and spatial locations of certain event performance, to optimize the operating modes of automated traffic management systems in respective directions. The second important result is the ability to account for "wandering" traffic flows, i.e. the identification and quantification of agglomeration impact on the loading of a street road network in the area of population attraction. These results are based on a dynamic model development of transport correspondence matrix based on the algorithms and the methods of vehicle numbers registration.

The accuracy of the resulting model was estimated using the video detectors of INFOPRO transport. The estimation was performed according to the following parameters: speed within the SRN area, traffic density, intensity, a site time travel. Thus, the accuracy of the model made 85% - 92% for different parts of Vatutina prospect SRN in the city of Belgorod. These figures make it possible not only to assess the events on the reorganization or reconstruction of SRN, but also to recommend the placement of urban infrastructure objects in a particular area.

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