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MODELLING OF ROAD TRAFFIC FOR TRAFFIC FLOW OPTIMIZATION OF MODERN REGIONAL CENTER AS AN EXAMPLE OF ODESSA

С.В. Мироненко, *Д. Гілліс*. **Моделювання дорожнього руху для оптимізації транспортних потоків сучасного регіонального центра на прикладі м. Одеси.** Сьогодні гостро стоїть проблема управління транспортними потоками, особливо в великих містах. Збільшення кількості транспортних засобів, як особистих, так і громадських, призвело до перевантаженості міських доріг, багатогодинних пробок, ускладнення руху пішоходів, збільшення кількості аварій і т.ін. ***Мета:*** Метою дослідження є оцінка можливості застосування імітаційних моделей для розв'язання проблем аналізу і оптимізації транспортних потоків. Для досягнення поставленої мети в середовищі імітаційного моделювання розроблено базу даних транспортної мережі. ***Матеріали і методи:*** Проблему аналізу і оптимізації транспортних потоків розглянуто на прикладі міста Одеси (Україна), проте отримані результати і рекомендації можуть бути легко адаптовані як для інших міст України, так і для міст більшості країн колишнього соціалістичного блоку. Особливості транспортних систем унеможливлюють побудову адекватної аналітичної моделі, яка б дозволила досліджувати варіанти управління цією системою і її характеристиками в різних умовах. У той же час імітаційне моделювання як метод дослідження подібних об'єктів є перспективним у розв'язанні цієї проблеми. Середовищем моделювання обрано пакет OmniTRANS як універсальний інструмент для моделювання дискретних, безперервних і гібридних систем. ***Результати:*** За допомогою програм OmniTRANS отримано модель дорожнього руху м. Одеси і інтенсивності руху транспортного потоку. У першому наближенні розглянуто і побудовано транспортну мережу центральної частини міста; без калібрування і імітації розроблено базу даних елементів транспортної мережі міста і показано, як вона може бути використана для розв'язання проблем аналізу й оптимізації транспортних потоків. Побудована з елементів створеної бази даних модель транспортної системи дозволяє змінювати ступінь детальності об'єктів і явищ, що моделюються, тим самим отримуючи моделі як макро-, так і мікрорівня.
Ключові слова: транспортні потоки, моделі транспортної мережі, пропускна здатність, вулично-дорожня мережа, транспортні засоби, організація дорожнього руху.

S.V. Myronenko, *D. Gillis*. **Modelling of road traffic for traffic flow optimization of modern regional center as an example of Odessa.** At present sharply there is a problem of traffic management especially in big cities. The increase in the number of vehicles, both personal and public, led to congestion of city roads, many hours of traffic jams, difficulty of movement of pedestrians, increase the number of accidents, etc. ***Aim:*** The aim of the study is to evaluate the possibility of using simulation models to solve problems of analysis and optimization of traffic flows. To achieve this goal in a simulation environment the data base of the transport network will be developed. ***Materials and Methods:*** The problem of analysis and optimization of traffic flow is considered by the example of the city of Odessa (Ukraine), the results and recommendations can be easily adapted for other cities of Ukraine, and for the cities of most countries of the former socialist bloc. Features of transport systems make it impossible to build an adequate analytical model to explore options for the management of the system and its characteristic in different conditions. At the same time simulation modelling as a method to study such objects is a promising for the solution to this problem. As a simulation environment an OmniTRANS package as a universal tool for modelling of discrete, continuous and hybrid systems. ***Results:*** With OmniTRANS programs the model of traffic in Odessa was derived and the intensity of the traffic flow. In the first approximation the transport network of the central district of the city was considered and built; without calibration and simulation it was developed a database of elements of the transport network and shown how it can be used to solve problems of analysis and optimization of traffic flows. Models constructed from elements of created database, allows you to change the level of detail of the simulated objects and phenomena, thereby obtaining models as macro and micro level.
Keywords: transport flows, the transport network models, capacity, street and road network, vehicles, traffic management.

Introduction. At the present time there is acute problem of traffic management, especially in big cities. The increase in the number of vehicles, both personal and public, led to congestion of city roads, many hours of traffic jams, difficulty of movement of pedestrians, increase the number of accidents, etc.

The object of management in the traffic management system is a traffic flow consisting of machinery. At the same time, car drivers on a road act and respond to different events in different ways, not always predictable, which greatly complicates the analysis of the system.

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Thus, traffic is a techno-social system that determines its specificity as object of management. Even considering only technical aspects of traffic management, it should be borne in mind that the object is very peculiar and difficult in terms of management of its properties.

In the construction of an adequate analytical model of urban traffic flows should consider the following characteristics of the object:

1. Stochastic. Prediction of the traffic flow is carried out with a certain probability. Traffic flow moves through the transport network, which also has certain characteristics which admit more or less rigorous description and which are non-stationary;

2. Nonstationarity. Oscillation of characteristics of traffic flows occur in at least three cycles: daily, weekly and seasonal;

3. An incomplete manageability, the essence of which lies in the fact that even with full information about the flows and the possibility of informing drivers about the necessary actions, these requirements are advisory in nature. Consequently, the achievement of the global extremum of any control criterion becomes highly problematic;

4. The plurality of quality criteria, such as delay in the way, average speed, the predicted number of accidents, the amount of harmful emissions into the atmosphere, etc. Most of characteristics are interrelated, and to single out any one is not possible;

5. The complexity of an object management and the impossibility of measuring the basic characteristics of transport flows that determine the quality of management. Thus, the estimate of traffic volume requires either a presence sensor of traffic flows in all directions of movement, or the use of aerial photography or carrying out the labour intensive manual inspection;

6. The absence of the possibility of large-scale natural experiments in the field of traffic management, which should, in turn, provide:

– traffic safety;
– material and labour costs;
– changes in the complex scheme of traffic organization.

Features of transport systems make it impossible to build an adequate analytical model to explore options for the management of the system and its characteristic in different conditions. At the same time simulation modelling as a method to study such objects is a promising for the solution to this problem. Simulation modelling allows you to quickly and with good accuracy to predict the characteristics of complex systems of real objects and optimize the essential parameters.

The main methods of modelling transport flows are considered in the works of M. Treiber and A. Kesting [1], N.H. Gartner and G. Improta [2], M.A. Chowdhury and Adel Wadid Sadek [3], and Daiheng Ni [4]. From domestic research should be mentioned Yu. Zakharov and E. Karnaukh [5], L. Abramova and N. Chernobaev [6], who proposed a solution to the problem of coordination of traffic lights devices when leveling speed of movement of vehicles on the main streets of the city, as well as M. Grigorov, addresses the problem of modelling and traffic control in large cities [7].

The aim of the study is to evaluate the possibility of using of simulation models to solve problems of analysis and optimization of traffic flows. To achieve this goal, the data base of the transport network will be developed in a simulation environment.

Hereinafter, the problem of analysis and optimization of traffic flows is considered by the example of the city of Odessa (Ukraine), the results and recommendations can be easily adapted for other cities of Ukraine, and for the cities of most countries of the former socialist bloc.

Materials and Methods. Today, there are many special systems for the simulation of traffic flows (TRANSIMS, PARAMICS, EMME/2, SATURN, Vissim, etc.).

Existing approaches to modelling can be classified according to the level of detail of the simulated process – the model of macro- and micro-level.

Models of the macro-level (Fig. 1) describe the traffic flow as a whole, the collection of all vehicles. A significant parameter is the traffic density. The main area of application of models of this type – the analysis of the transport system of a large amount, i.e., networks of highways and interregional road network.

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Models of the micro-level (Fig. 2) are characterized by a description of certain vehicles and the interactions between them. Models of this class show the behaviour of individual road users that obey the rules of conduct and interaction between vehicles. The rules of conduct contain additional strategies to control the speed and acceleration. Currently, these models are used for traffic modelling at individual intersections and their collections.

Fig.1 Macro-level model

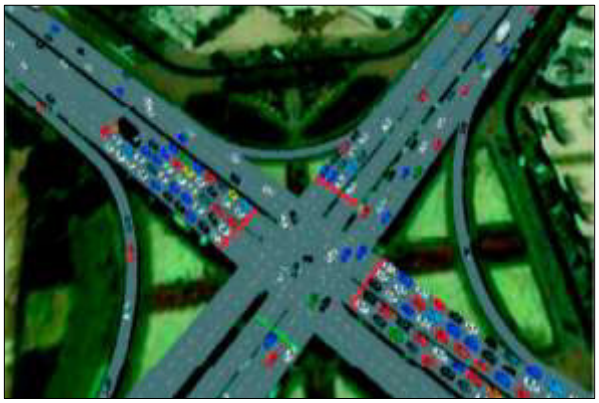

Fig.2 Micro-level model

Analysis of the current state of the problem under investigation has shown that most of the existing simulation systems designed for the construction and study of micro-level models.

The main objective of this work, as mentioned above, is to develop a database of the transport network of Odessa in a simulation system. As a simulation environment is chosen OmniTRANS package [8] as a universal tool for modelling of discrete, continuous and hybrid systems. The universality of the package, its ability to work with both continuous and discrete models, its simplicity of use will allow to build a database of elements of the transport network, which will be useful for a wide range of various problems in the field of transport in Odessa.

Speaking about the creation of the transport network database, you need to decide what kind of baseline data will be needed. Necessary input data the authors divided arbitrarily into four groups:

– the first group – the data received from the executive authorities and municipal services; information from socio-economic statistics (the number of places in schools, children gardens, universities, the number of jobs in the factories, business centers, etc.), passports of traffic lights; database of buildings and structures; accident data$

– the second group – the data obtained during the field surveys: characteristics of traffic lights (cycles, phases of the junction, and so on); information on the number of lanes, markings, signs traffic management.

– the third group – the data obtained by automatic sensors;

– the fourth group – the data received from private organizations.

Data of road traffic intensity required at the stage of the calibration model.

These elements were sufficient to build most areas of the city's transport network. Each of the database elements has customizable parameters that determine the important properties of the objects. A block diagram of the modelling of the transport network is shown in Fig. 3.

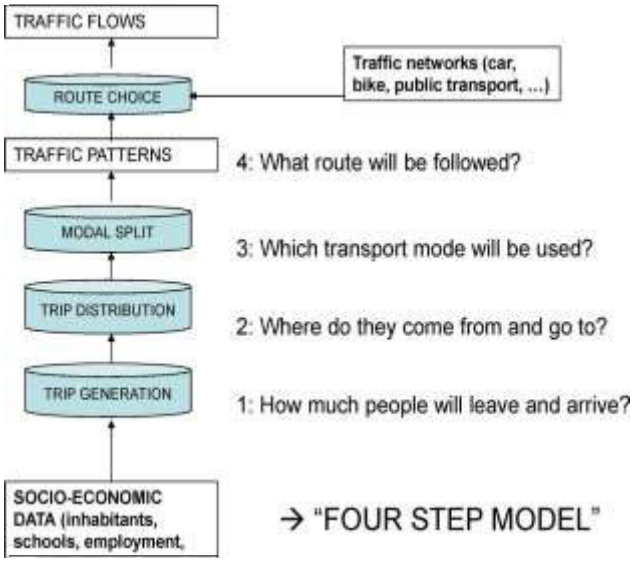

Fig. 3 Block diagram of the transport network modeling

With topographical maps and provided baseline data on transport network, with OmniTRANS package of tools was created the scheme of transport highways of Odessa (Fig. 4).

For a more detailed study and modelling, taking into account the preliminary data of the transport network congestion the town the scheme is divided into three sections (Fig. 5).

For the analysis of the traffic scheme in the city the studied simulated central district of the city is divided into 24 zones (Fig. 6).

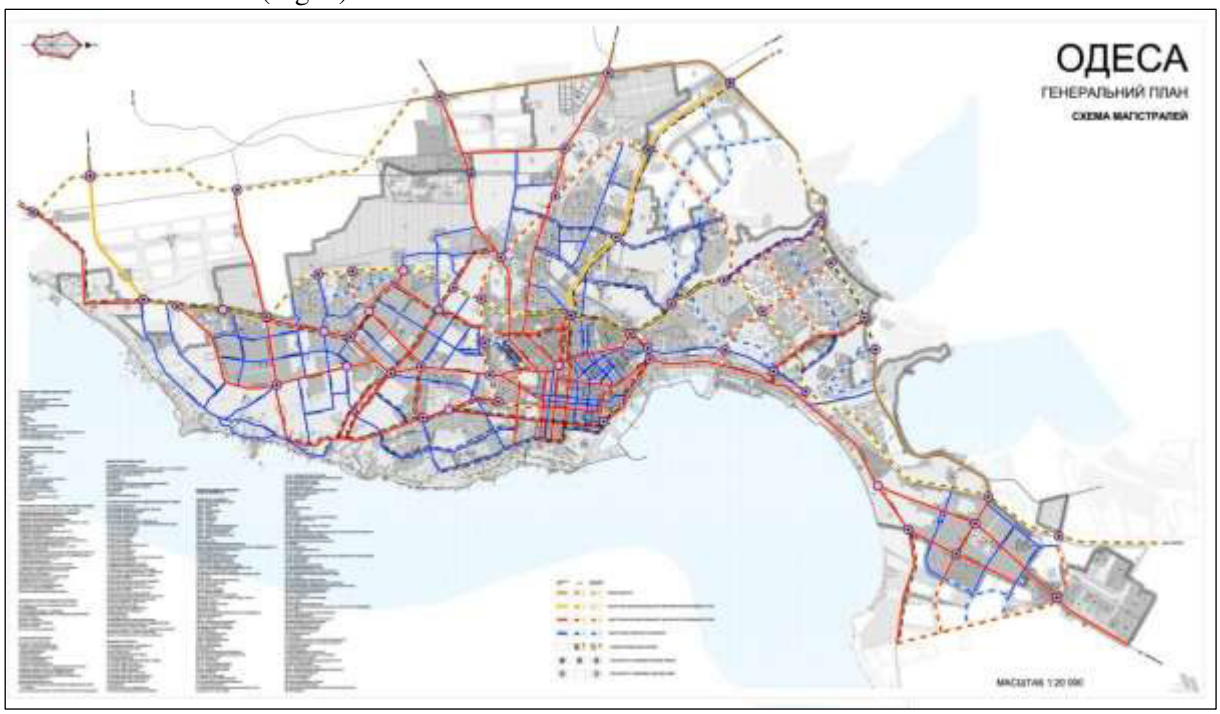

Fig. 4. Scheme of highways of Odessa

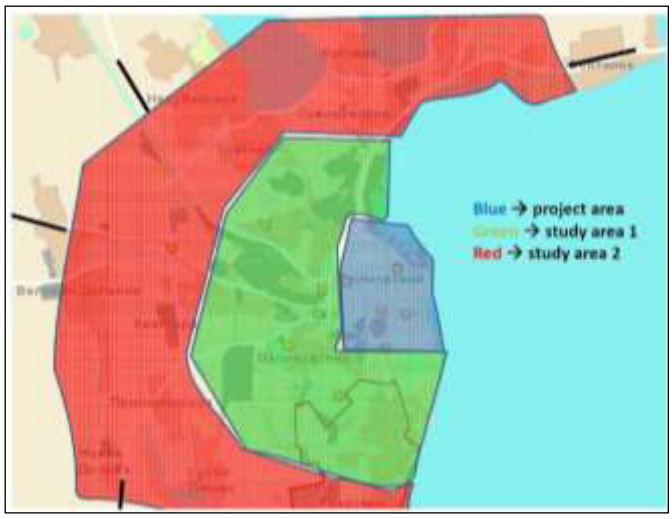

Fig. 5. Test area of urban transport system

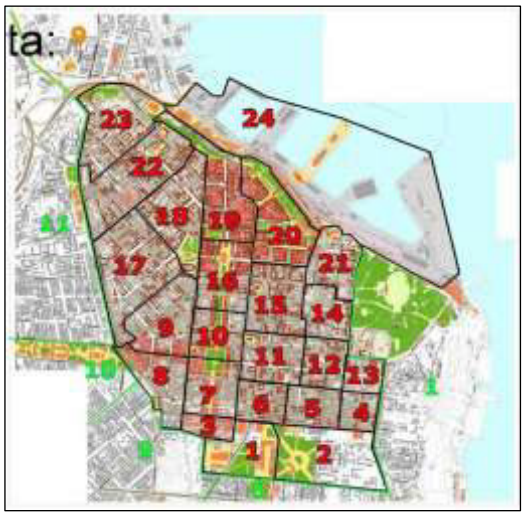

Fig. 6. Zoning of central district of the city

The network topology (Fig. 7), for which the modelling is carried out, is created by entering to the reference plan (Fig. 6) of the source data elements of the transport network of central district of the city. This data includes the length of the road sections, the phase of traffic lights, traffic intensity, the direction and the probability of motion for directions.

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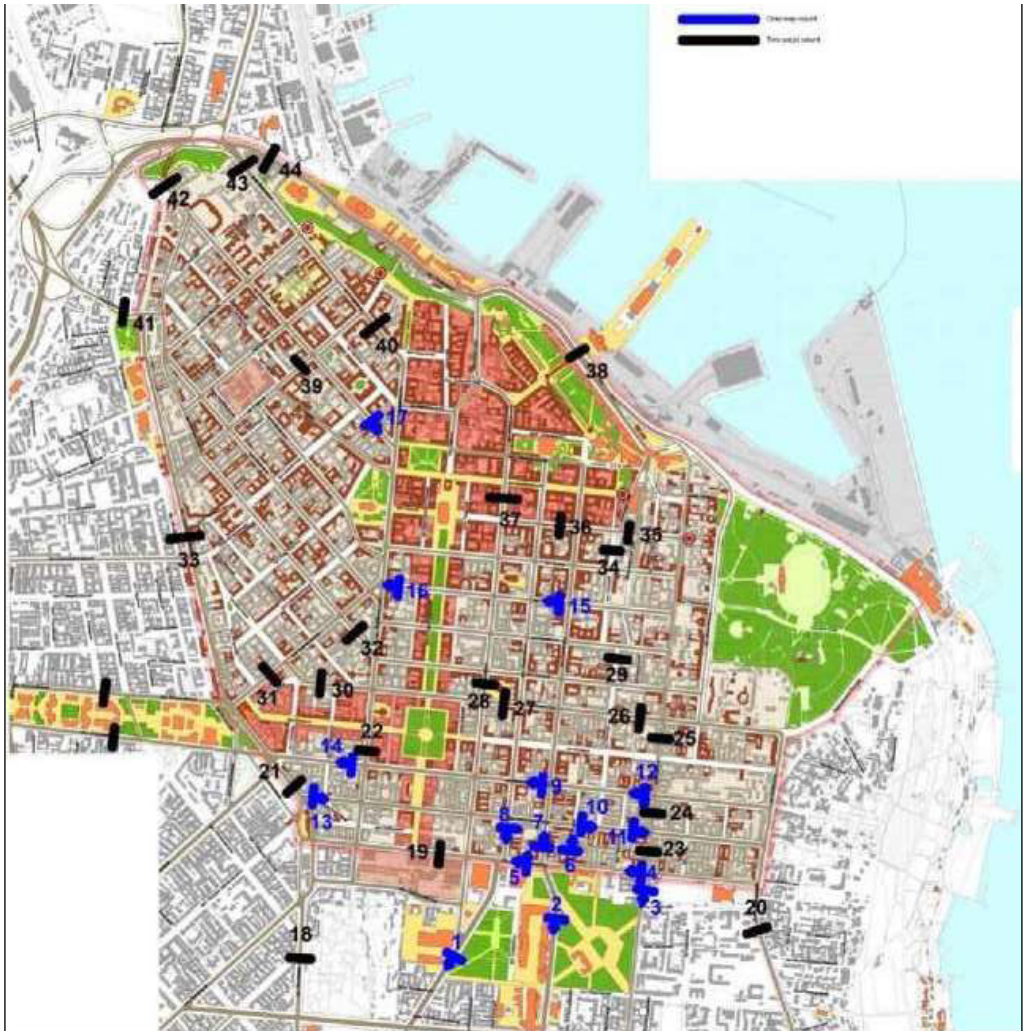

Fig. 7. The topology of network of the central district of Odessa (black marks – the survey area; blue marks – transport number)

Such indicators are important: the number of vehicles (traffic volume, the share of passenger cars and trucks), the period of congestion (peak periods). You cannot manage without information on the number of nodes (turns). The simulation also takes into account data on the number of public transport, the number of passengers and number of flights. The reference plan also included information about the full-scale surveys of road traffic, about the depending of the traffic intensity from time, about the survey of municipal services.

Results. After processing the initial input data of the transport network via OmniTRANS programs it was derived a model of road traffic of Odessa (Fig. 8) and the intensity of traffic flow (Fig. 9).

Investigation and analysis of the transport network using the developed model were made by inserting the different original data of the transport network elements in the corresponding object model toolkit – Odessa transport network (in this case its central district).

The model parameters can be set for each element separately. Time of creation of the transport network model and the degree of precision depends on the amount and accuracy of the source data.

It should be noted that the models that can be built from elements created database, cannot be entirely attributed only to the micro or macro level. They combine the properties of both categories. The constructed model of the transport system allows you to change the level of detail of the simulated objects and phenomena, thereby obtaining a model both macro- and micro-level.

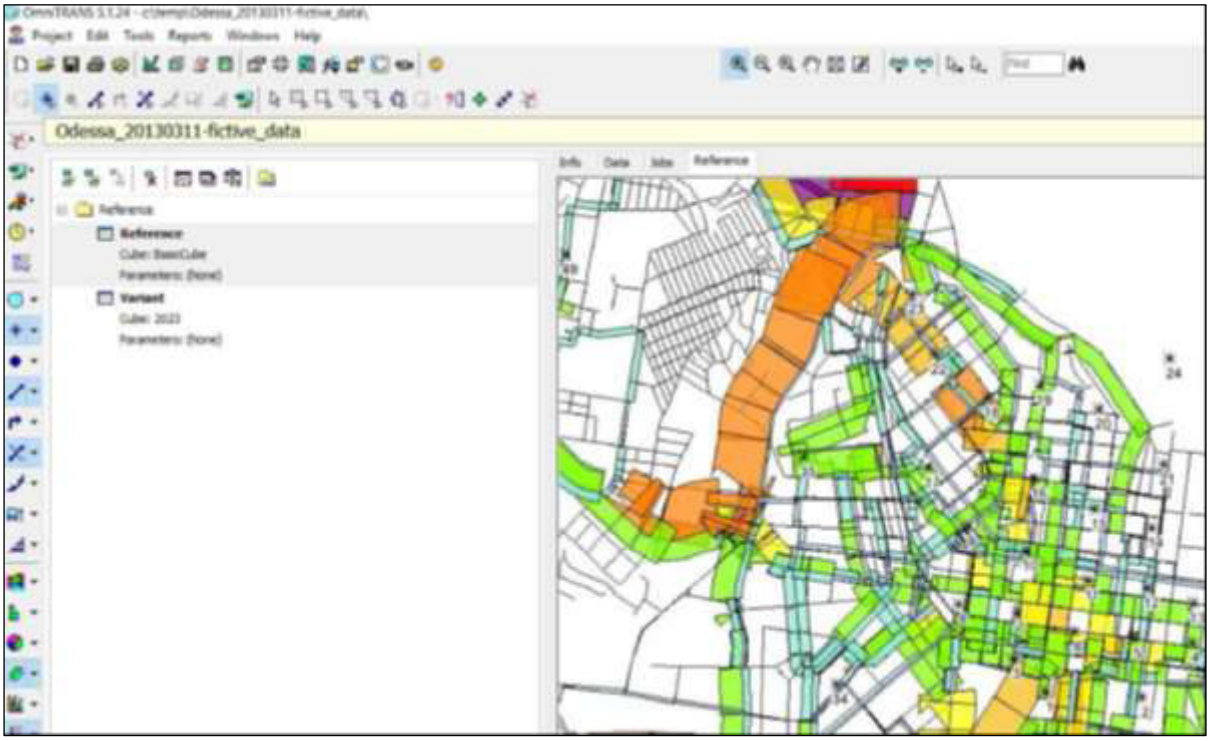

Fig. 8. Model of road traffic of Odessa city (the central district)

Fig. 9. The intensity of traffic flow (degree of congestion):
– free flow; – densely saturated flow; – an extremely rich flow

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Constructed network model allows us to explore the different characteristics of transport systems. Such a study may be carried out in several ways, namely:

– case studies. The real situation (accident, harvesting) is simulated, in which we analysis such system characteristics as an average speed of movement of the vehicle, waiting time (delayed on the way), etc;

– search for the optimal solution of traffic management tasks (switching time of traffic lights, the number of lanes, etc.) and the definition of the objective function (optimizable value). This function may be, for example an average speed on the analyzed portion of the transport network, the waiting time at crossroads, etc;

– prediction of the impact of changes in transport network topology (the construction of bypass roads, the introduction of the vehicle presence sensor at the crossroads, changing types of intersections, etc.) on the important characteristics of the traffic flow;

– the fight against traffic jams. This problem is solved by decreasing the intensity of motion in a predetermined direction, for example, redirecting of traffic flow onto adjacent road.

As part of the OmniTRANS package it is possible to perform the optimization of model, i.e. obtaining optimum values of any parameters of the model for given optimization criteria. In the transport system model in the optimization is possible to change parameters and/or the functionality of the objects of the transport system.

Also, we can easily solve other problems arising in the study of the city's transport network.

Conclusions. As a result of this work the methods of approach to modelling of traffic flows were analyzed. It is analyzed the features and functionality of the software package OmniTRANS. In a first approximation, it is considered and built transport network of central district of the city; without calibration and simulation developed database elements of transport network of Odessa, and it shows how it can be used to solve problems of analysis and optimization of traffic flows. The advantages of this approach to modelling and study of transport networks is simplicity and clarity of building a network, the possibility of expanding and improving the model by the user.

Time of creation of the transport network model depends on the amount and precision of the input data.

Using the established transport model for Odessa will contribute to the following changes.

1. Ordering of Information transport databases of the city and communication between the different organizations. This will create a single information center at the city administration, which will allow the city to develop its own long-term strategy of development of the transport network and to perform a qualitative analysis of the proposed options.

2. Obtaining of objective and verified baseline data for the design of the road network at any level.

3. Attraction of investors due to the fact that the city's development concept will become transparent and understandable.

4. The optimal solution to the most complicated transport problems of the city. Transport model is only tool that allows you to justified and comprehensively address the city's problems associated with transport.

5. The participation of the inhabitants of Odessa in the development of the concept of development of the city. One of the moments of creation the city transport model - it is an opportunity to demonstrate the results of its work to all citizens who wish to receive such information. In practice, it looks like a web site, where the information related to the results of the transport model is placed.

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