Simulation Model for Traffic Flow of Projected Recreational Area by River Desna in the City of Bryansk

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Abstract. The paper presents the results of simulation modelling of a transport hub connecting Bezhitsky and Sovetsky districts of Bryansk (Russia). A project for sustainable development of the territory has been designed for the area formed at the intersection of Bezhitskaya, Flotskaya and Ulyanova streets, aimed at creation of a comfortable environment. This project envisages the creation of a special “green” recreation zone that includes access to River Desna. To assess possible changes connected with the prospective commissioning of a new urban facility, evaluation of public accessibility within the given area is required. For this purpose, structuring and analysis of all qualitative and quantitative characteristics of the objects adjacent to the site was carried out with a view to create a traffic flow simulation model. The development of such a model will enable the profile experts to evaluate transport accessibility of the new facility by private and public transport and the expected traffic changes in the specified area.

1 Introduction

The increase in the number of urban residents significantly affects the diversity of public functions and extent of their use. An urban street in today’s reality is not only a transport artery, but also a centre of social life and a territory for business [1]. Achievement of high-quality urban environment requires a comprehensive change of adjacent streets cluster by improving the functional and planning organisation of public spaces. Numerous governmental programmes have been developed, intended to stimulate the formation of a modern comfortable environment (for instance, “My Street” in Moscow, “Development of Urban Environment” in Moscow region).

Comfortable conditions for city dwellers are created by achieving a high-quality environment in a large modern city. Such conditions should contribute to people’s productive labour activities [2]. As noted by the researchers, the development of a recreation area (renovation or reconstruction of some territory) should be based on the comprehensive analysis of quantitative and qualitative factors [3, 4]. It should be taken into

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account that when some area is modified people’s activity is displaced, transport hubs change because of the ensuing redistribution of traffic and pedestrian flows.

Predicting such changes is a complex process requiring identification of key aspects of the territory, population needs, transport accessibility and many other indicators [3, 5]. Creating an area simulation model allows to solve this problem. Simulation modelling tools help to estimate the traffic flow change, the expected congestion of streets and people’s travel time depending on different traffic situations, etc.

Thus, the aim of the study is the creation of a simulation model that can be used to form a comprehensive estimation of accessibility of projected recreation areas.

The theoretical significance of the research lies in obtaining the results necessary for substantiation of decisions on the organisation of area planning and design stages, on the development of the improvement plan and operational decision-making in respect of managerial operation of the recreation area and the entire infrastructure, securing its safe, comfortable and permanent use.

The practical relevance of the obtained results lies in their practical use for public organisations or private investors engaged in territorial development.

2 Objects and Methods

The object of the research is represented by private car and public transport flows in the River Desna area of Bryansk (Figure 1). This area is bounded by Liteynaya and Flotskaya streets and Delegatsky lane.

![Satellite image of the projected recreation area by River Desna in the city of Bryansk](https://goo.gl/maps/NqHnQfkQDHoADWG16)

Fig. 1. Satellite image of the projected recreation area by River Desna in the city of Bryansk (source: https://goo.gl/maps/NqHnQfkQDHoADWG16)

A simulation model was to be developed in order to estimate the road network load in the area of the projected recreation area. The following research methods were used to realise this task:
1. **Structuring method.** This method made it possible to identify all proper objects of the subject area. The used input data included administrative territorial division maps, public transport schemes, road maps, road traffic density data, population density data. As noted by Krasnikov [6], Altunina [3] and Arata [7], the derived objects, after applying the structuring method, can serve as input parameters for the simulation model.

2. **Method of analysis.** This method allowed the authors to establish interdependencies and patterns of the subject area objects established in the course of structuring. Such dependencies make it possible to establish the rules to inter-handle the objects in the simulation model [2, 8, 9].

3. **Lax-Friedrichs method.** This differential method makes it possible to reach a numerical solution for transport-related model situations. In using the method, it was assumed that the number of transport vehicles that would enter a particular road section should be the same as the number of vehicles that would leave that section over the same period of time. Jelinek notes in his work that “if the vehicles’ speed on a monitored road section varies depending on road conditions, for instance, in case of a traffic accident or due to a speed limit prescription, or is a consequence of some reaction to warning lights, then the flow function is not linear and will depend on other parameters (maximum speed, maximum traffic warning lights density)” [10]. Thus, the following function was used in the study:

\[
Q_{j+1}^{n+1} = \frac{1}{2} \left( Q_{j+1}^{n} + Q_{j+1}^{n} \right) - \frac{\Delta t}{2\Delta x} \left\{ v_{\text{max}} \left[ Q_{j+1}^{n} \left( 1 - \frac{Q_{j+1}^{n}}{q_{\text{max}}} \right) - Q_{j-1}^{n} \left( 1 - \frac{Q_{j-1}^{n}}{q_{\text{max}}} \right) \right] \right\},
\]

where $j+1$ is the interval division point;
$\Delta x$ is the distance between the adjacent intervals;
$Q_{j}^{n}$ is the approximation of the exact solution at point $x_j$ and at the moment $t_n$;
$q_{\text{max}}$ is the density at which the jam occurs;
$v_{\text{max}}$ is the maximum speed set on the road section.

4. **Simulation modelling method.** Based on the structured data, established rules, mathematical models, this method made it possible to create a simulation model demonstrating the behaviour of all objects within the given time intervals and under changing external and internal conditions. As noted by Silin [2] and Chernova [9], this model makes it possible to visualise the changes resulting from the realisation of area transport load scenarios upon addition of a new object.

### 3 Results

The structuring method made it possible to establish that the studied section of the transport network represents an intersection of three motor roads having a different number of lanes and involving circular traffic. The number of lanes in terms of vehicular access is as follows:

- north – 5;
- east – 6;
- southwest – 4;
- northwest – 4.

There are no restrictions on traffic movement in the given area. The traffic density is distributed over days of the week and time of the day. The results of this distribution are given in Figure 2. Analysing the road situation, the authors’ team concludes that the traffic
density increases significantly during the peak hours and is connected with the pendulum-like migration of the working population (traffic congestion is marked in orange). The road connects the bedroom community located on one side of the river with the city centre and major objects of social, work-related and recreational infrastructure.

**Monday to Friday 07:30-10:00, 17:30-20:00**

**Monday to Friday 10:00-17:30**

**Saturday morning and afternoon**

**Sunday morning, afternoon and evening**

**Fig. 2.** Traffic flow density in Bryansk near Pervomaisky bridge (*source* Yandex.Traffic Jams: [https://yandex.ru/maps/191/bryansk/?ll=34.306688%2C53.289908&z=16](https://yandex.ru/maps/191/bryansk/?ll=34.306688%2C53.289908&z=16))

When designing the recreation area and making an appropriate simulation model, the availability of parking space should be taken into account. This influences the distribution of transport flows and, therefore, their density. Fig. 3 shows the layout and density of parking spaces.
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Using the differential methods and simulation modelling results, the authors developed a traffic flow model with regard for the traffic chart and the presence of controlled and uncontrolled pedestrian crossings (Figure 4).

Fig. 3. Layout and number of parking spaces

Fig. 4. Transport flow chart for the simulation model of the investigated object
In addition to private vehicles, the traffic flow covered by the research includes the public transport flow. It was found, using the structuring method, the traffic patterns and the public transport timetable, that the density of this flow was high (Figure 5).

**Fig. 5. Public transport density**

It should be noted that 20 public transport routes are operated on the explored site with a traffic interval depending on the time of the day. The rolling stock can be classified as follows:

- trolleybuses (5 routes) with intervals of 7–40 minutes;
- municipal buses (11 routes) with intervals of 5–60 minutes;
- privately-owned shuttle minibuses (12 routes) with intervals of 5–30 minutes.

Figure 6 gives a public transport flow chart for the simulation model of the object under study.
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Fig. 6. Public transport flow chart for the simulation model of the investigated object

It should be noted that, when creating the public transport flow chart, all standard external influence factors were taken into account (delays at controlled and uncontrolled pedestrian crossings, delays caused by boarding and discharge of passengers at transport stops, etc.).

The graphic visualisation of the simulation model based on traffic flow charts is shown in Figure 7.

Fig. 7. Graphic realisation of the simulation model for the investigated object

It should be noted that the simulation model takes into account the traffic rules for each mode of transport, as visualised by traffic striping and road signs located on respective road sections.

4 Discussion

The current urban development situation in many cities is characterised by uneven distribution of people’s housing, workplaces, public centres of socio-cultural, commercial and consumer services [11]. This assumption was confirmed by the present study.

The task of any urban planning process is to form a single and coherent, spatial and functional urban environment [12]. The well-developed transport infrastructure should integrate one or more urban systems of different level, forming a comfortable environment for living. The construction of public recreation areas in modern urban development should, first of all, meet the requirements of accessibility for as many people as possible. This increases the load on the urban transport network [7, 10]. In order to assess all the factors making it possible to form a proposal for the organisation of road traffic and public transport schedule, the development of due simulation models is required. The present study made it possible to identify the key objects involved in the formation of traffic flows, to be involved in the development of relevant recreational areas. The obtained results are in accord with the modern works by the national and foreign scholars [5, 7, 8].

5 Conclusion

Simulation modelling is used for problem solution when conducting experiments or realisation of some scenario is not possible for a really existing facility or a system, or is
impractical. This is primarily connected with high costs or excessive length of time involved. The possibility to recreate real-world processes using computer modelling tools makes it possible to analyse all possible outcomes and solve the assigned problem – or take a decision on corrective action. The development of urban areas as well as minimisation of its negative impact on surrounding objects or processes can be assessed only by using simulation models. Using them, it is possible to apply and analyse all possible scenarios safely.

Traffic flows in today's urban environment represent a complex system; its operation affects many indicators connected with convenience, comfort, safety and environmental friendliness of any territory. When creating any improvement concept, it is necessary to take into account the changes that will take place in traffic flows in the immediate vicinity to the developed object, and on a wider scale. The density of pedestrian flows in this case is determined by transport accessibility (both private and public transport). Maintaining the attendance density of a leisure facility is conditioned by public transport schedule, availability of parking space, ability to get to the site quickly, safely and comfortably by transport – all this should be considered when designing public space infrastructure facilities. Estimating the changes in flows direction and density as well as the load on the transport network is possible only after structuring and analysing the existing facilities. All of this was implemented as part of the research with the purpose to create due rules and input parameters for the simulation model. The use of the general scientific methods makes it possible to state that the results obtained in the course of the present research are adequate to the given subject area and can be suitable for use in simulation modelling in terms of evaluating the decisions connected with sustainable territorial development.

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