Agent-based intersection modelling of traffic and pedestrian flows

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Abstract. The results of formal model design of a major intersection area essential for providing residents with transport accessibility and mobility are presented in the article. Simulation methods were applied to develop a model. The quantitative and qualitative characteristics crucial for the functioning of the model as its input parameters were determined. The importance of using a model when modelling different behavior scenarios of model objects based on typical situations of the real world is established.

1 Introduction

Modern methods of analysis and processing of statistical data in complex organizational and technical systems enables to establish patterns and, on the basis thereof, make control decisions, Malykhanov (2011). Simulation methods are used to reduce costs, increase the accuracy and quality of decision-making and process visualization. Such methods make it possible to create a corresponding formal model of the subject area which respond appropriately to experimental data, as it would happen in the real world, He et al. (2020), Zhikharev and Mamatov (2021).

Simulation modeling, among other things, allows solving the problem of traffic management. Any city has a number of problems associated with the organization of controlled pedestrian crossings, road markings, installation of traffic signs, improvement of the road network and the environmental situation, etc., Nikitina et al. (2017a), Nikitina et al. (2017b). Managing these requires a lot of resources. Therefore, a serious justification is required for carrying out any work related to the transport and road complex. The creation of a simulation model is helpful in solving these problems, Nikitina et al. (2017a).

Thus, the purpose of the study is to create a simulation model of the intersection to develop scenarios for optimizing traffic.

The theoretical significance of the study is due to the creation of a flexible model that reflects the quantitative and qualitative aspects of the subject area for conducting and analyzing the results of experiments on the organization of relevant processes.

The practical significance of the study is due to the possibility of changing the ecological situation of the area and the emotional mood of road users when introducing the positive results of the experiments.

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2 Methods

The object of the study is a regulated intersection in the center of the Yuzhnoye Medvedkovo District of Moscow (coordinates: 55.871003, 37.638337). The intersection is formed by Polyarnaya Street and Dezhnev Passage (Figure 1).

Fig. 1. Image of the intersection of Polyarnaya Street and Dezhnev Passage in the Yuzhnoye Medvedkovo District of Moscow (left – diagram, source https://goo.gl/maps/xitEXJqUX9SwP2q2A, right – satellite image, source https://yandex.ru/maps/-/ CCUZMKxr0C).

In the study, the following methods to obtain a formal model reflecting all aspects of the research object were applied:
1. A structuring method which allows to select all the key objects of the subject area, Malykhanov (2011).
2. Method of analysis, which implies that all properties significant in creating a formal model are distinguished in structured objects, Nikitina et al. (2017a), Nikitina et al. (2017b). Furthermore, it enables to establish the nature of the relationships between the objects of the selected area.
3. The synthesis method making it possible to establish the quantitative and qualitative characteristics of the selected objects and the relationships between them in order to develop the rules for the functioning of the model, Sreekumar and Mathew (2020), Jiang et al. (2020).
4. The method of agent-based modeling, due to which a low-level model of the subject area was with a display of the behavior of each participant in the movement developed, Malykhanov (2011), Zhu et al. (2020).

3 Results

All the qualitative and quantitative characteristics of the object were established with these methods.

The roads forming the intersection have a different number of lanes for traffic depending on the direction (Figure 2): on the Dezhnev Passage, the western part to the intersection has seven lanes, the eastern part has six lanes; along Polyarnaya Street from the southern part – five lanes, northern – seven and two lanes of an understudy. A special lane has been allocated for public transport: along Dezhnev Drive in both directions, along Polyarnaya Street – from the north to the intersection. There are no restrictions on the movement of vehicles. From north to east, the intersection is crossed by tram tracks in two directions.
Polyarnaya Street southern part:

Polar Street northern part:

Dezhnev Passage western part:

Dezhnev Passage western part:

Tram crossing:

Polar Street doubler:

Fig. 2. Panoramas of the intersection of Dezhnev Street and Polyarnaya Street in Moscow (source: Yandex-panoramas https://yandex.ru/maps/-/CCUZMCCLSC).

The intersection has a high traffic of public transport (the scheme of traffic directions is shown in Figure 3). It should be noted that buses of medium and extra-large capacity are used on the routes, trams – only extra-large capacity. All public transport routes provide the transportation of passengers of the region to two metro stations located on neighboring diametrical branches at a distance of about five kilometers.

Fig. 3. Scheme of public transport traffic along Dezhnev Passage and Polyarnaya Street (source of the base map: https://goo.gl/maps/xitEXJqUX9SwP2q2A).

The tram route is unique for Moscow, as it is separated from highways along its entire length. The interval of movement during peak loads is four minutes, the rest — 5-10 minutes (work schedule 04:20-01:36). In total, 11 daytime bus routes pass through the intersection with an average traffic interval of five minutes and one night bus route with an interval of 30 minutes (source: Department of Transport of the City of Moscow https://transport.mos.ru/transport/schedule).
Thus, the intersection has a high pedestrian traffic. This is due, among other things, to the location in the immediate vicinity of the shopping center and government organizations that receive the population. The intersection has regulated pedestrian crossings: in one place through Dezhnev passage and in two places through Polyarnaya Street.

All the phases of each of the traffic lights were established. Let us give as an example the phase of a traffic light for organizing the movement of a tram:

- the first phase lasts 25 seconds and allows movement from the east and west;
- the second phase lasts 15 seconds and allows movement from the north and south;
- the third phase lasts 40 seconds and allows the movement of trams;
- The last phase lasts 25 seconds and allows pedestrians to cross the intersection.

All of the listed parameters and relationships were used to create a formal model. AnyLogic is used as a simulation software environment. Figure 4 shows a fragment of the model of the movement of public and private vehicles.

![Figure 4. Model of the traffic process at the crossroads in AnyLogic.](image)

It should be noted that the model takes into account the occupancy of parking spaces near the shopping center, parking pockets, as well as the loading and unloading zones of the warehouse of the shopping center.

Figure 5 shows a simplified visualization of motion processes in the agent-based model. The process model includes all quantitative and qualitative characteristics of objects in the subject area, which can be configured to visualize certain motion scenarios.

### 4 Discussion

The developed model of the intersection has no restrictions in settings. The resulting model enables to select individual objects and study their behavior or interaction with each other. Thus, the model reflects the connections existing in the real world.

According to the researchers, the use of such a model, programming tools and statistical data will allow modeling various behaviors of road users, Malykhanov (2011), Nikitina et al. (2017b). All this will make it possible to estimate the duration of each phase of the traffic light and the time of idle time, make a decision on narrowing lanes or adding lanes for
cyclists, expanding pedestrian sidewalks, etc., Zhikharev and Mamatov (2021), Nikitina et al. (2017a), Sreekumar and Mathew (2020).

Fig. 5. Agent-based traffic model at the intersection of Dezhnev Street and Polyarnaya Street.

5 Conclusion

The research conducted made it possible to obtain an adequate model of the intersection of one of the residential areas of Moscow reflecting all aspects of the real world of the declared subject area. All the key objects in the subject area were identified. Links between the objects were established and the rules for organizing and implementing processes were formulated. Such rules served as the basis for the creation of an agent-based model.

The resulting model is reliable, accurate and consistent. This is due to the correct use of generally accepted research methods. The results can be used as part of the educational process to train specialists in organizing the movement of personal vehicles, in the department of public transport to draw up an appropriate schedule or organize pedestrian flows, environmental monitoring services to assess the impact of harmful or hazardous factors on the condition of residents from the current or potential traffic.

References

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