Development of Traffic Flows and Smart Parking System for Smart City

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Abstract. The relationship between the number and quality of transport infrastructure and the level of economic development is obvious. High density transport infrastructure and a wider network are usually associated with a high level of development. When transport systems are effective, they provide economic and social opportunities and benefits that lead to positive effects, such as improved market access, employment and additional investment. When transport systems are insufficient from the point of view of capacity and reliability, they can lead to economic costs, such as decrease or loss of quality of life. Transport has an important and quite significant social and environmental burden that can not be ignored. Modern society needs constant increase in the volume of transport, of its reliability, safety and quality. To do this, you need to increase the cost of improving the infrastructure of the transport network, of turning it into a flexible, highly managed logistics system. At the same time, the risk of investment increases significantly, if not take into account the patterns of development of the transport network, the distribution of the load of its parts, and ignoring these patterns leads to frequent formation of jam, overload or devastation of individual lines and nodes of the network, increasing the level of accidents and environmental pollution. In order to find effective strategies for managing the vehicles of a large city, the optimal decisions regarding the design of the street and road network and the organization of traffic should take into account a wide range of the traffic flow characteristics, patterns of the influence of external and internal factors on the dynamic characteristics of the mixed traffic flow. The research object is the traffic flows of a large city. The research subject is mathematical methods of managing traffic flows for various types of activities. The practical received results value is being able a method development for the formal representation of the tasks of managing traffic flows in the areas of support of the large city infrastructure; to develop a software product and instructions regarding its application for optimal solution of a certain class of difficult-to-solve tasks of managing traffic flows; to solve concrete practical

tasks of city transport management, which proved the adequacy of developed models and algorithms and shows the usefulness of their use.

Keywords. Traffic flow management, information system, information technologies, management system, transport network, vehicles, road quality, traffic congestion.

1 Introduction

In mathematics and construction traffic flows are the subject of studying the interaction between travellers (including pedestrians, cyclists, drivers and their vehicles) and infrastructures (including roads and traffic management devices) in order to understand and develop an optimal transport network with efficient traffic, as well as reducing problems with traffic overload [1-17]. However, even with the emergence of a significant computing power of computers today no satisfactory general theory has yet been created that can be consistently applied to real road traffic conditions [8-15]. Modern traffic models use a mixture of empirical and theoretical methods [16-21]. These models are subsequently redesigned in traffic forecasts, which take into account the proposed changes, either locally or in general [22-29]. Among them, increased use of vehicles, changes in the selection of transport or in land use (for example, people in a particular area give priority to a train instead of a bus or a car) and the definition of the area and density of the tributary, that is, the territory where the road network needs to be adjusted [30-37].

Road movement behaves quite difficult and moreover, in a non-linear way, depending on the interaction of the number of vehicles. The main parameters describing the traffic flow are also the direction, speed, intensity, density, as well as the individuality of the reactions of drivers in different situations. Let's consider properties of a transport stream in a bit more detail [2]. The spatial-temporal diagram graphically shows the flow of vehicles along the path over time. The time is displayed along the abscissa, and the distance is shown along the ordinate axis. The transport flow in the spatial-temporal diagram is represented by the trajectories of the lines of individual vehicles. Vehicles that follow other vehicles in a given lane will have parallel trajectories, and the trajectories will be crossed when one car overwhelms the other.

Speed is the distance passed within some time period. However, it is not possible to trace the speed of each vehicle; so, in practice, the average speed is measured by sampling vehicles in this area for a certain period of time. There are, therefore, two definitions of average speed: "time of average speed" and "space of average speed". "Time of average speed" is measured at the checkpoint on the carriageway over a period. "Average speed space" is measured throughout the carriageway segment. Sequential video sequences or video segments of the roadway trace the speed of individual vehicles, and then calculate the average speed [38-42].

In the spatial-temporal diagram, instantaneous velocity, the vehicle is evenly tilted along the trajectory of the vehicle. Its average speed is equal to the inclination of the line drawn between the endpoints of the trajectory, where the vehicle enters and goes out of the segment of the roadway [43-49[. The vertical section (distance) between the parallel trajectories is the interval between the first and the next vehicle. Similarly, the

horizontal section (time) represents the promotion of a vehicle. The spatial-temporal diagram is useful for the propagation ratio and the interval between vehicles to the actual traffic flow and density respectively. Density is defined as the number of vehicles per unit length of the roadway. In the transport stream, two of the most important densities are distinguished - this is the critical density and density of the blur [49-58].

Flow intensity is the number of vehicles passing through a certain point per unit time, usually vehicles per hour. The inverse of the intensity of the flow is the progress of the means. The flow passing through a fixed point during the interval is equal to the inverse of the mean translational motion of vehicles.

2 Review of several works in the field of transport flows theory

The book [3] addresses the design of motor roads and the organization of motion for optimal traffic flow of cars. The theories of transport flows and practical realization of these theories are described for estimation of capacity of highways, efficiency of the accepted design decision, and also application efficiency of separate means of movement organization. The results of studies of traffic flow patterns in real conditions are also given. On the basis of these observations, the levels of traffic comfort and the optimal loading capacity of a separate road are set.

The author pays special attention to the simulation of traffic flows on the computer and their use in designing roads and organizing the movement. In addition, already realized programs are described and they are recommended for estimating trails, road elements, all possible means of realization of traffic and, of course, bandwidth. Practical methods for calculating the throughput, speed and duration of vehicles with different road loads, which will be used for designing newly built roads, as well as improvement of the state of those already used transport routes, are outlined.

This publication [4] is an improvement to the monograph "Theory of Transport Streams", published in 1975. The work itself consists of 10 sections. The first 5 sections have the same name as the previous publication, but they are completely rewritten and include the latest research in their area. Section 2 depicts various models that characterize the relationship between traffic flow parameters that we discussed above. The author stresses the connection between theory and measurement capabilities, namely, how the development of the first depends on the other.

Section 3 is devoted to the human factor, namely man as a part of the relationship man-machine. This includes elements such as reaction time, human movement control, and distraction in different situations, response to an irritant, and so on. The most obvious application of human factors is the follow-up machines models development, which is described in section 4. These models study how individual vehicles (and their drivers) follow one another. The next paragraph of the monograph deals with continuous stream models, including their simple and complex-structured variants. Unlike the previous ones, the macroscopic flow models presented in Section 6 do not consider traffic from the standpoint of individual vehicles or their components, but perceive the macroscopic appearance of the network. All described models are supported by analytical, calculation methods and empirical researches for their further introduction and use.

Section 7 addresses traffic patterns that affect issues such as traffic safety, fuel consumption, air quality, and more. Section 8 relates to an unsigned intersection theory, according to which the driver himself performs his actions without the help of additional technologies, and section 9, on the contrary - the signalled theory of intersection, with estimates of delays and queues. The last section tells us about traffic simulation. Here are some details about traffic patterns embedded in simulation packages and procedures that are used for simulation experiments.

The main conclusions of this work [5] is to confirm and justify the role of modelling traffic flows in order to develop convenient and secure roads, solve the problems with traffic congestion and develop appropriate measures for traffic management. Also it was emphasized on the differences between the microscopic and macroscopic flow models of the traffic flow theory. Also interesting is the fact that the authors draw attention to the fundamental network diagram that is both simple and informative ratio because it shows the most important operations of network traffic.

In this edition [6] basic knowledge in the field of mathematical modelling of transport flows is collected, which allows to consider this edition as the basis of training of specialists of the highest qualification for many spheres of a municipal economy.

From the point of view of traffic control at low load of the road network (20-30% of bandwidth), the movement is actually free and control is reduced to the local traffic light control, which is introduced by the safety criteria. An interval of 20-70% of the load on the throughput of the street-road network is the sphere of traditional automated traffic control systems, when the task of increasing the throughput through the coordinated control of traffic signal signalling is being solved and solved. When loading 80% or more, the management task is fundamentally changing. Any overload of a highway over the bandwidth leads to fatal consequences. To do this, there are intelligent transport systems, since in an intensive motorization, it is impossible to balance transport without the introduction and maintenance of mechanisms for limiting traffic demand by informing traffic participants about the loading of the road network and possible routes of traffic, without the development of public transport, competent logistics, parking management space, redistribution of traffic flows, depending on complex conditions, etc. - up to the introduction of administrative prohibitions.

The book [7] addresses the issues of regulating the system of urban passenger transport in the context of conflict of interests of passengers, transport operators and municipal authorities. Here for the first time in the literature questions of optimization appear, in which the existence of Nash equilibrium in pure strategies has been proved.

3 Choosing and justifying solutions to the problem

At the beginning of the development of the information system of traffic flows of a large city, in addition to the aforementioned, the question arises of priority, relevance and modernity. Transport consists of several elements - infrastructure, vehicles and management. Vehicles are usually driven by drivers, that is, people. However, the world is developing day by day and technology is developing along with it. At the moment, there are autopilots driven machines.

Autopilot - a device or software and hardware complex that drives a vehicle for a specific given trajectory. Unmanned (autonomous, automated) car is a vehicle that is capable of feeling its surroundings and navigating without the participation of a person [11]. Unmanned cars use different techniques to recognize their environment, such as GPS, laser light, radar, odometer, and computer vision. Independent cars have control systems that can analyze sensor data to distinguish between different machines on the road, which is very useful when planning the path to the desired destination. All it takes to control an unmanned car is to tell it where to go. The car will find out the best route, will be guided on city streets (even without marking), will move through complex crossings with traffic lights, and will recognize the signs of stop. When it arrives at the destination, it enters the search mode for parking and automatically park itself. All the already mentioned advantages and disadvantages of designing unmanned cars can be added and the fact that with the growth of traffic flows will increase the number of such cars. Under these circumstances, more and more traffic jams on the roads of the city will start. The main task for each vehicle is to get from point A to the designated point B with minimal time. Unmanned cars, when calculating the optimal route, choose the fastest. However, taking into account obstacles such as traffic jams (which are usually formed at intersections), travel in such a way may take much longer than expected. Therefore, in order to minimize the time spent, the vehicle must calculate how quickly to reach the destination: either wait for its turn at the crossroads, or plan a detour. This will be the main task for the implementation of the program.

4 Technical characteristics of the selected software development tools

The C # programming language was chosen to implement the software, since it has several benefits as described below. Database. Microsoft Office Access is a database management system, a program that is part of the Office suite of office programs. Has a wide range of functions, including linked queries, sorting by different fields, communication with external tables and databases. With the built-in VBA, Access itself can write subroutines that work with older versions of Microsoft Office Access.

Graphical user interface. The best option for displaying roads and moving cars on them is the use of the Unity graphical interface. Unity is a cross-platform game engine developed by Unity Technologies, which is mainly used to develop video games and simulations for PCs, consoles, mobile devices and websites.

5 Description of the created software

Let's launch the program and select the required characteristics. We select the number of cars and press the start button. Let's see how cars ride without starting a congestion drive algorithm (Fig. 1). Next, we will switch to the mode of using the required algorithm (Fig. 2). We see that the paths of some cars differ considerably in these modes, and in the mode with the algorithm traffic is not formed. Now let's consider and compare the timelines of unmanned vehicle fares with initial data and algorithm.

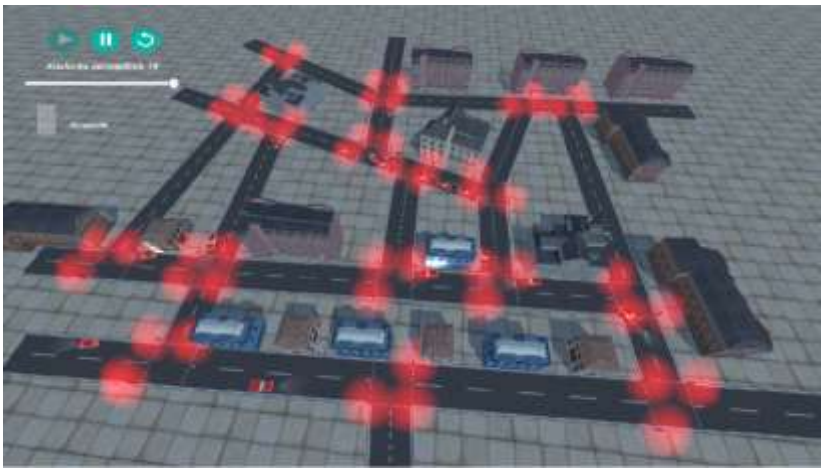

Fig. 1. The movement of cars with the initial data

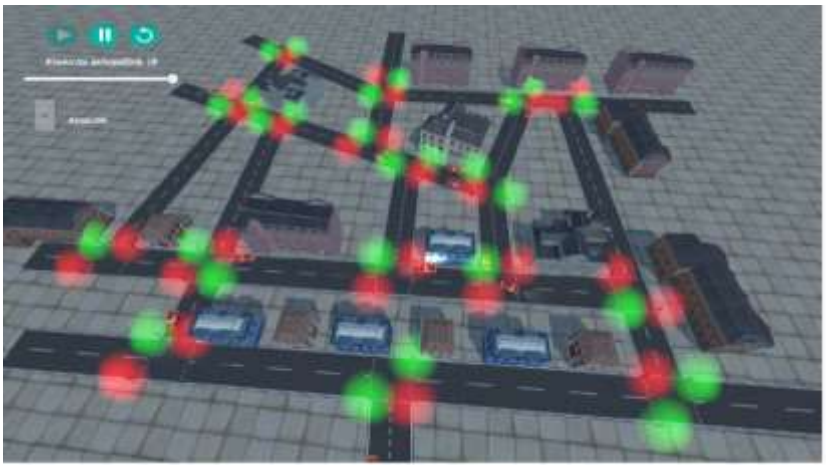

Fig. 2. Movement of cars according to the algorithm

6 The project Smart parking implementation

Walking through the central part of Lviv, you can see that there are no free places in the parking lots. And on specially designated areas for this, and just so - in the middle of the road or on the sidewalks. And despite the fact that travelling through the historic part of Lviv for six years as a forbidden. However, this prohibition does not prevent drivers customized to fit their cars near the Dominican and Armenian churches, narrow streets between stone buildings Lviv, run down on a flower bed next to the cathedral. Philosophy is simple: not mine - it is not needed.

By the way, the experts say that the situation on the Ukrainian roads is perhaps not the easiest. Indeed, in its current state of automobile crisis - gasoline is expensive and

does not give credit on cars. "However, the crisis will end sooner or later, and the parking problems will become even more hot," Bass accentuates.

At least two underground parking lots are planned to be built in the center of Lviv: in front of Ivan Franko University and Petrushevych Square. The idea of constructing underground parking near the main railway station is also considered. It can unload the central streets, where there is a chronic shortage of parking spaces.

Ideally, the infrastructure should be arranged so that people can leave the car at the entrances to the center, then go on foot or go public transport. Many large cities in Europe use the Park & Ride ("Park the car and go"). "In Strasbourg, for example, paying for parking space, seven passengers by car get you to ride public transport for free during the day" - says Olexandyr Shutyuk. According to Pavlo Syrvartko, many drivers from outside of Lviv have already become accustomed to leave cars at free parking lots near shopping and entertainment centers and continue to go public transport. There are no publicly available paid parking lots in Lviv yet (Fig. 3-4).

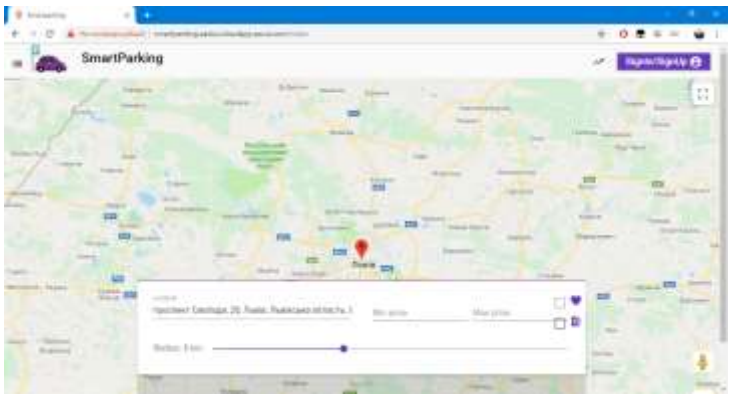

Fig. 3. Example of Smart parking implementation in Lviv area

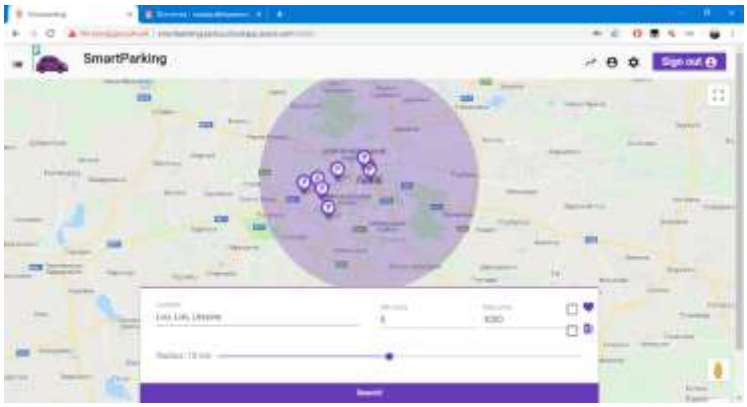

Fig. 4 Smart parking identification

It is the problems described above of our city and it is intended to reduce the system that we are designing. Aim: Develop a Smart Parking Web project and place it on one of the cloud-based services, Microsoft Azure.

Let's imagine that the driver, coming to the city center, can find out free places in advance, to know if he should go to this parking lot, or better to another, which is in the opposite direction! He sees the number of vacancies on each of them, and even the placement of parking spaces inside the parking lot (Fig. 5-6).

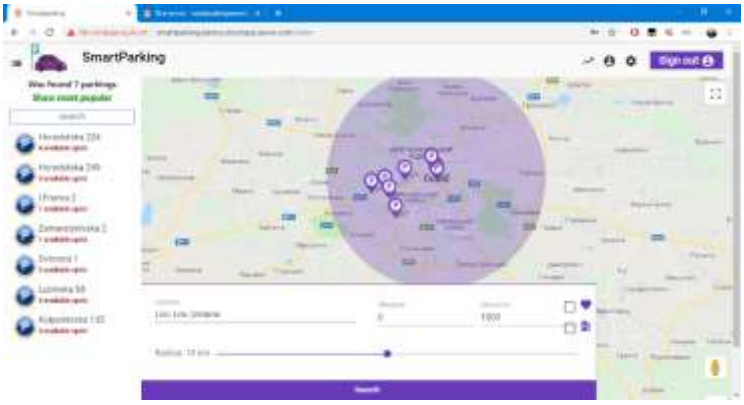

Fig. 5. Change parameters for Smart parking implementation in Lviv area

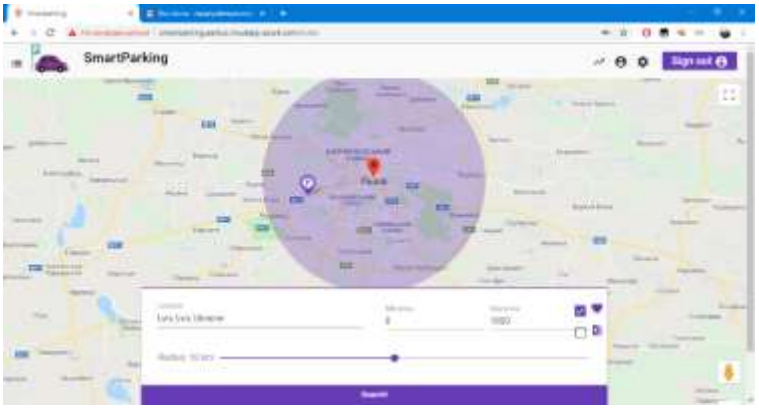

Fig. 6. Results of Smart parking implementation in Lviv based on new parameters

Well, this script sounds fantastic, but from a technical point of view it may well be implemented in the form of a convenient information system.

With the idea of development, we became acquainted, we will turn to the more technical aspects of its implementation. First of all, you should choose a platform for the development of the system. The most common platform is a kind of operating system running on a PC (personal computer). However, in this case it is not very suitable for us, because our target audience is car drivers, they have inherent mobility,

which is not at all a feature of the PC. Imagining a driver driving a car at his disposal is a maximum tablet, but rather even just a simple, modern smartphone.

So, the most correct choice will be the creation of a mobile-oriented product. Now the question arises: developing an application for the operating system of the phone is not the best solution, because there are a lot of jobs and needs to be spent to implement the applications for Android OS and iOS at the same time. Cross-platform - one of the most pressing needs in the development of information systems. A completely different thing is a mobile-oriented web product (Fig. 7-8).

Fig. 7. Example of Smart parking statistics

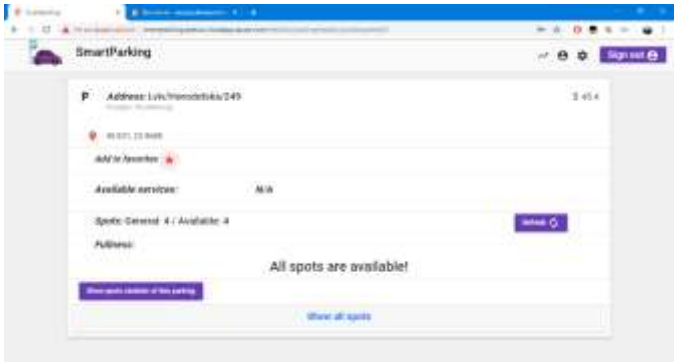

Fig. 8. Example of detailed information about Smart parking statistics

Though it needs some knowledge and skills in developing client-server architecture, it ultimately brings a finished product that is available at the same time on all platforms that can only have a browser, even a PC. So, we will implement our project as a web-based project from the mobile site design. The next problem facing developers is the choice of the programming language of the various architectural parts of the product, since the program is planned to be implemented as a web project, and here we can not do without client-server architecture. In our case, for the server part, it was decided to select the Java language, since it allows you to design stable servers, implements all the powerful principles of the OOP and has a very readable syntax. The client part will be written in the TypeScript language, which though interpreted in prototype-

oriented JavaScript, however, tries to adhere to a strict Java typing. Briefly describe also other technologies and software that were used in developing our system: LiquiBase, RabbitMQ, EventBus, Angular, TypeScript, HTML, CSS, Bootstrap, SQL, MySQL, Java, Hibernate, Spring, Spring Sequrity, Git, GitHub, Google Maps. Eventually, our site was hosted on the Microsoft Azure cloud service for free access to it via the Internet. In Fig 9-15 is an image of the main windows and the main snippet of the code of the designed Smart Parking system.

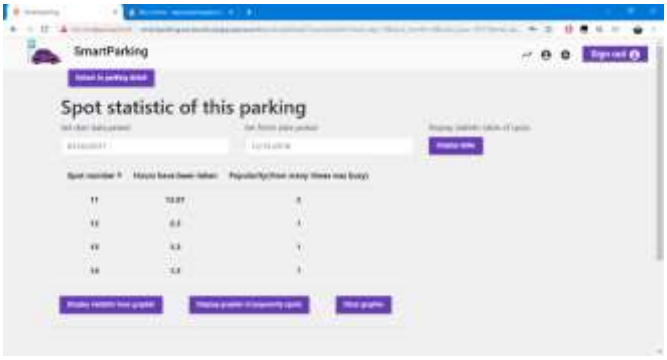

Fig. 9. Example of spot statistic of Smart parking

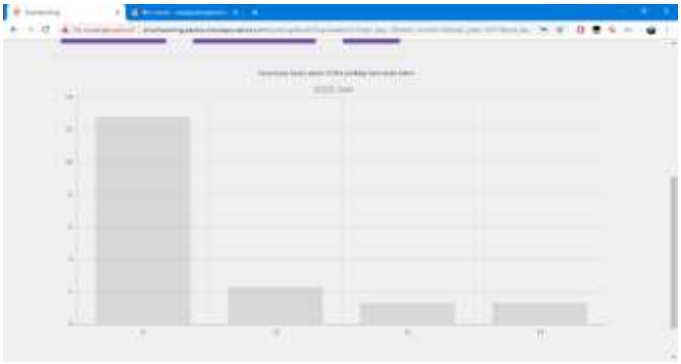

Fig. 10. Example of statistic diagram of Smart parking

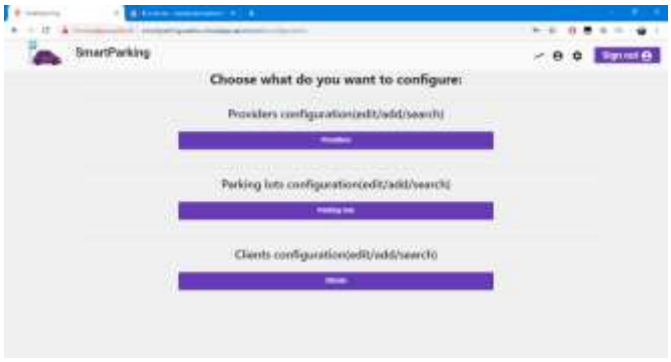

Fig. 11. Example of chose what user want to configure

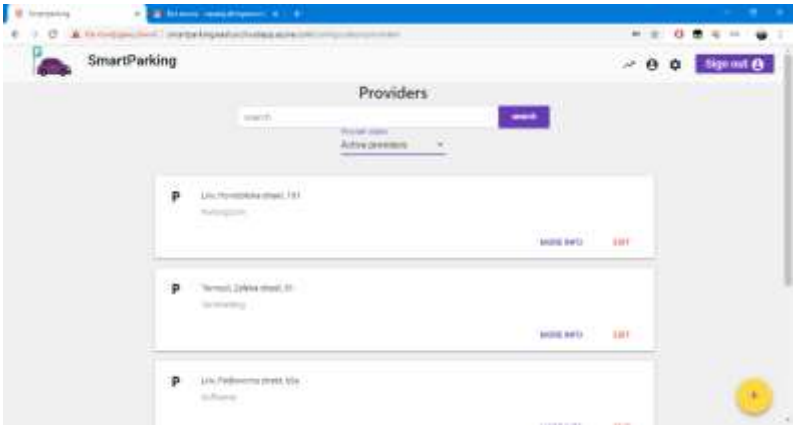

Fig. 12. Example of search results of providers

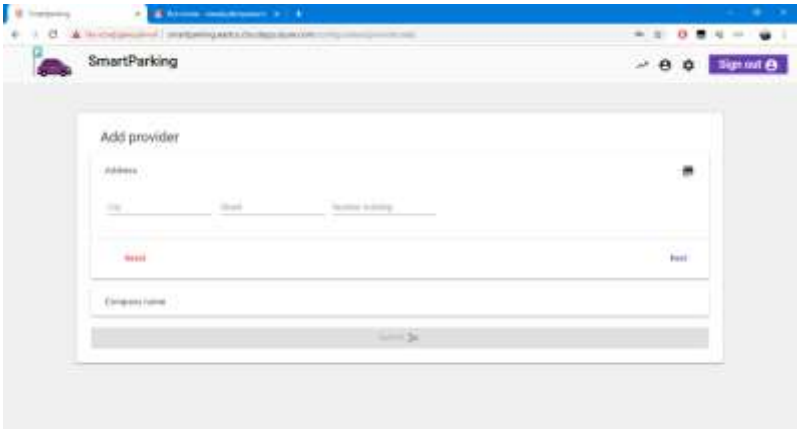

Fig. 13. Example of add provider

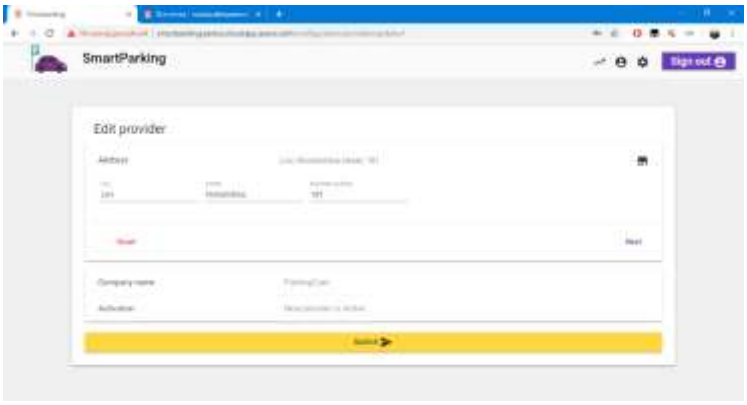

Fig. 14. Example of edit provider

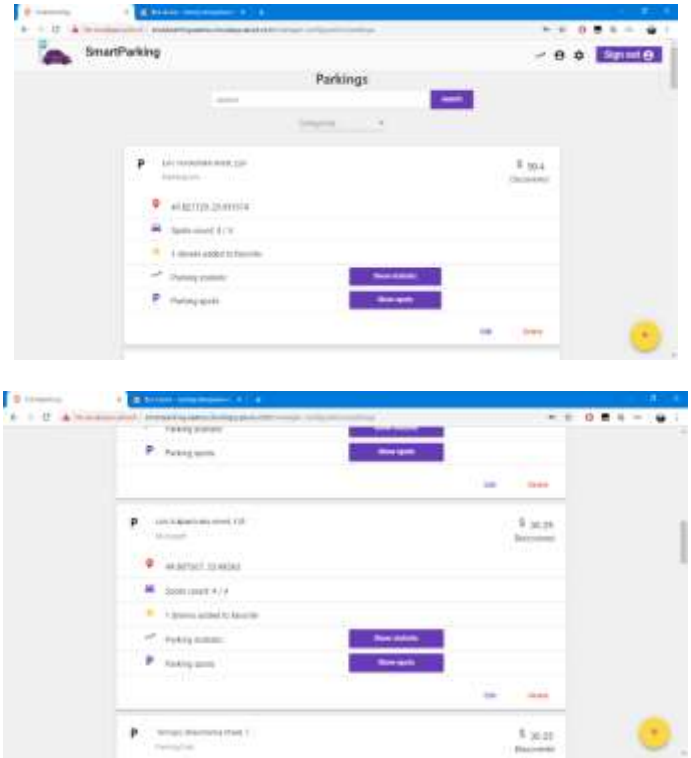

Fig. 15. Example of search results

7 Conclusion

During the work a critical analysis of the literary sources for identifying and developing the issue of the theory of transport flows was conducted. The main characteristics,

methods of problem solving, methods of presentation of knowledge, software, system and auxiliaries, which are used in work for construction of mechanisms of choice of the optimal route of a detour passage are given. The description and analysis of methods for solving the problem with congestion is presented, as well as for the implementation of the C # language and the Unity tool for developing a graphical interface for working with the map and unmanned cars. The composition, structure, content and functions of the developed software and the processes of their joint operation were described. The reference example confirms the working capacity of the development, and the results of the system's operation correspond to the task. As a result of this work an information system was developed, the main element of which is the traffic flows of a large city. The theoretical and methodological provisions and mathematical tools for performing various types of tasks for managing these flows and improving the transport network and supporting the state of roads were also researched and developed.

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