Intelligent Urban Management System by Minibus

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***Abstract*—The results of the analysis of the problems of passenger transportation by urban public transport are presented. More attention is paid to transportation using fixed-route taxis. To improve the efficiency of passenger transportation, an automated irregular transport management system developed at the Brest State Technical University is proposed. The article describes the structural components of the system and their functionality. The source of the development is the observation of the behavior of drivers, passengers and other road users. The exchange of information between the subjects of the movement is based on unified knowledge about the nature of the movement. This approach requires the use of semantic technologies in passenger transportation management systems. This publication describes the first stage of the project, designed to collect information and its semantic analysis**

***Keywords*—city minibus, passenger transportation management system, transportation on request, semantic model**

I. Introduction

Currently, public transport infrastructure is actively developing in cities around the world. This is due to population growth, as well as the fact that public transport is an ecological alternative to personal transport.

The main task of organizing the movement of urban transport is to ensure high quality passenger transportation at a minimum cost. The quality of passenger transportation is assessed by the following indicators: ensuring the regularity of movement, the size of the interval on the route, passenger occupancy, the total time spent by the passenger on the trip, the speed of communication and the comfort of transport services.

The system of scheduling public transport is not optimal. According to scientific research carried out at the company "Altimeta" [1] many management systems rely on relational databases, document-oriented information technologies, procedural algorithmic programming paradigms, and stack architecture. All these aspects reflect the features of the automation object and are determined by its features. The use of semantic models can bring productivity gains and other useful changes. A possible approach is to apply a semiotic approach to the creation of automation systems. An example of such an implementation is the Smart Stop mobile application [2]. The application of a semiotic approach to passenger transportation is aimed at integrating technical means and management methods in design solutions that meet the needs of all participants. This combination allows you to have a set level of satisfaction of both the needs of passengers and the optimization of the costs of carriers. In the proposed semiotic approach, passenger transport is analyzed in the context of the movement of material and information (symbolic, symbolic) resources. The urban passenger transport network in a semiotic context can be represented as a system of multilevel hypertext. At the same time, passenger traffic flows are expressed in the form of a system of symbolic communications. Such symbolic communications in automated systems can act not only as an accompaniment to traffic flows. An important feature of modern systems based on the semiotic approach is that it is the traffic flows that are motivated by symbolic communications. Such communications satisfy the informational, symbolic and symbolic needs of passengers. At the same time, it is the needs of passengers expressed by semiotic means that should be the primary source of urban passenger traffic flows. The implementation of the semiotic approach proposed by the authors [2] requires a different approach to the logistics system of passenger transportation. With this approach, significant connections are identified that determine the target functionality of the system as a whole. The main objectives of such links should be to provide each passenger with an appropriate quality service for transportation on request. The request must reflect the time of transportation, route and other properties. It should be noted that the level of service quality should also be determined by the cost of transportation with continuous adaptation to changing environmental conditions. In the proposed system, consideration of semiotic aspects is implemented by means of the user interface, personalization procedures. These tools can significantly improve two aspects that determine the basic needs of the passenger: the correspondence of the information received about possible transportation to the information requests of passengers (persistence of response to search queries), the degree of adequacy of the results of transportation to the expectations of the passenger (relevance of passenger transportation). In this paper, the main content is devoted to another author's research, which is a continuation of the above. The project of an intelligent management system for urban minibuses allows you to generate more meaningful information. Such information will be the basis for the implementation of an intelligent management system using semantic technologies [2].

Before describing the project, we will pay attention to the conceptual provisions that form the basis for building a semantic model of the city's passenger transport system. This order generally corresponds to the correlation of the concepts of semiotic and semantic modeling implemented by the authors in the studies of passenger traffic flows in the city of Brest.

It should be pointed out that the analysis of research on the application of neural network technologies for semantic analysis tasks has been carried out in the works of a fairly wide range of scientists.

For example, in the source [3] provides a list of research areas that use neural network technologies to solve semantic analysis problems. Among these areas are listed:

- tasks of text classification;
- brain activity in pattern recognition based on signals processed by different areas of the cortex;
- building models of language learning based on sentence processing without prior knowledge of word semantics and others.

Quite interesting results are presented based on the results of the development of the OSTIS Project [4] These include:

- development of semantically compatible computer knowledge management systems for distributed solution of complex problems and their applications;
- practice-oriented training of students and undergraduates based on OSTIS technologies;
- clarification of the main provisions defining the interaction of science, education, engineering and business in the market of knowledge-driven computer systems.

Among other examples, the works of V. can be given. Golovko, A. Kroshchanka and others [5] D. Shunkevich and others [6], [7], I. Davydenko [8], I. Koronchik [9], [10] and many other studies.

It should be noted that the works listed above are devoted to fundamental areas of research in the field of semantic technologies. The main applications of research are their theoretical aspects. However, the practice of using semantic technologies for applied research cannot be ignored. As a possible application, we have selected projects based on knowledge processing, used to solve applied problems in the field of passenger transportation. An example of such a task is a semantic approach for designing automated urban passenger transportation management systems.

The most acute problem of traffic management is for a minibus. The route taxi schedule is more based on the set departure time from the final stopping points of the route. There is no timetable for intermediate points along the route. Minibus drivers receive information about the number of passengers waiting at stops and the density of passenger traffic by exchanging voice messages among themselves.

The information provided by the driver of the minibus in front affects the speed of movement along the route, allows you to adjust the time of departure from the final stops. However, this does not solve the general problems of the transport system's capacity.

The frequency of traffic does not change during the day. This indicator does not correspond to possible changes in the intensity of passenger traffic. Passenger traffic, in turn, depends on various indicators (weather conditions, working hours of passengers during the day and days of the week, etc.). The lack of funds to regulate the route taxi schedule leads to collisions. Collisions in the movement of a minibus taxi should be considered the occurrence of situations in which there is a sharp contradiction between the interests of the carrier and the passenger. So, in case of an increase in passenger traffic, situations arise in which public transport is loaded to the maximum, but there are passengers at the stops who are denied transportation. A decrease in passenger traffic leads to the movement of "half-empty" passenger vehicles. The so-called automatic transport gives special hopes for improving the situation, while still in the initial stage of development [**?**].

The problem of resolving collisions in passenger transportation can be solved by optimizing the operation of a minibus. On the one hand, such optimization should be carried out in the direction of increasing the carrier's profit. On the other hand, it is necessary to improve the comfort of the transport network for passengers. Currently, automated systems are not used in Belarus to solve the problems of improving the efficiency of transportation by minibus. However, there are similar solutions for another type of taxi. An example of a solution is the "Yandex Taxi" application.

II. Functioning Of The Transport System According To The "Transport On Demand Model"

The authors propose an optimized model of urban transport based on the "Transport on demand" model. This utility model is described in the patent "System for calling a minibus taxi, management and control of passenger transportation", obtained by the authors [11].

The model is developed based on the analysis of existing systems.

A. Features of well-known systems used to control passenger transportation

A device is known for indicating empty seats in fixed-route taxis (patent for utility model BY 4186 u 2008.02.28), including sensors for detecting the presence of a passenger, by installing contact devices under each seat of a minibus, a data generation and processing unit, an indication unit. The task of the utility model is to create a device for indicating empty seats in fixed-route taxis, which makes it easier for both its driver and passengers inside the cabin and at the bus stop to receive information about the availability of free seats in vehicles.

The disadvantage of this device is the low functionality, which consists in the fact that the minibus is relatively small (15-25 seats) and the driver is in the mirror condition of the cabin. He can visually determine the availability of seats. Also, passengers waiting for transport at the bus stop do not need external information about available seats in the cabin. The taxi has stopped, which means there are places, and passengers enter the vehicle. If there are no available seats, the minibus does not stop at the stop at the passenger's request. Thus, the information content of this device does not justify the cost of its implementation.

The GeoBus automated system is known (GeoBus program for Android OS, State registration of programs No. RU2021660693) for booking and ordering tickets (seats) in public transport by passengers; managing free and occupied places in public transport by route drivers; dispatching control by public transport route drivers; geolocation of drivers and passengers; tracking public transport routes in real time; providing information about public transport routes; calculation of the approximate time of arrival of public transport at the stop.

The disadvantage of such a system is the need for dispatching transport management and the inability to view the number of boarding requests for the entire route. A route is understood as a pair: the route number and the direction of travel (the starting and ending stopping points of the route).

Analogues and prototypes for fixed-route taxis have not been identified anymore. But there is a large class of devices and systems for taxis that are close in functionality to the proposed utility model for calling a minibus, managing and controlling passenger transportation.

So there is a known method and system for managing taxi orders using automated dispatch control systems for taxi operation (patent for invention No. RU 2297042, G07C 5/00, 2007.04.10) in which the system contains at least one external terminal for accepting orders, a server of a single database of orders and one terminal in each taxi company. In this case, the order placed by the customer via telephone lines and/or from an external terminal is entered by the operator into a single database of orders. In this case, the order criteria are specified. An order entered into a single database is processed by a system that sends a specific order to a taxi company selected by rating, after which the taxi company operator processes the order and determines whether it can be fulfilled, while there is a possibility of canceling the order. In this case, the order is sent back to the unified system, which is sent by the program to the next taxi company for processing and execution.

The disadvantage of this system is the complexity of order fulfillment and inefficient operation of the order acceptance and processing system.

There are known systems for collecting and transmitting messages about vehicles containing a navigation signal receiver installed on a vehicle, a control unit, memory blocks with information about the vehicle, a message transmission and reception device for transmitting and receiving information from a control room. At the control room, known systems contain a message transmission and reception device, a message allocation unit, a database and a display tool (RU 2113013 C1, G08G 1/01, 06/10/1998; RU 2143745 C1, G08C 19/12, 11/27/1999 and RU 2173885 C1, G07C 5/00, 09/20/2001).

The disadvantage of these systems is the use of dispatchers exclusively, when the quality of service provision directly depends on the human factor.

A system is also known (patent for invention No. RU 2173885 C1, G07C 5/00, 09/20/2001) for controlling and monitoring the operation of vehicles, containing on each vehicle a device including a message generator, to which a GPS receiver, a current time counter, a status code generator are connected, the output of the message generator via a transceiver is connected to the transceiver of the control room device, on which the transceiver is located, connected via the parameter selection block to the data memory, designed to store current data on the parameters of all operating vehicles. The well-known system provides an audio communication unit between the dispatcher and the drivers.

The disadvantages of this solution include the use of expensive GPS equipment in the system, which requires the modernization of the technical service park of each taxi, while the quality of voice communication involved in the system is limited by the bandwidth of voice communication channels, which leads to errors when receiving information by system participants.

An automated system for ordering taxi services and monitoring the operation of a taxi is also known according to utility model patent No. RU 103952, G07C 5/00, 08/23/2010, containing at least one web server of the system connected via communication channels to the control system of remote dispatching taxi services and a user communication device. At the same time, all means of communication and the central computer are designed to function in the environment of a pre-installed program that provides online connection of all these elements of the device to each other, support for the functions of the control panel and display necessary for viewing and editing information contained in memory using each of the elements of the software module installed in the operating system, as well as the formation and transmission of data and the conduct of information exchange of data.

Among the disadvantages of this system is the need to install specialized software on the means of communication, which ensures the operability of the system, while all operations, including accounting for trips, settlement operations and other operations for the control of transportation are carried out in this program. This requirement may not be applicable for small taxi companies and/or individual drivers who keep records under simplified programs. Besides. The installation of this software requires the retrofitting of remote control rooms and driver workstations with communication devices compatible with this software.

The closest in terms of its operational characteristics to the claimed technical solution is a taxi calling system, management and control of passenger transportation according to utility model patent No. RU 126493, G07C 5/00, 06/9/2012, including at least one web server connected via communication channels to the control system of remote dispatching taxi services and user communication devices.

The Web server of the system contains interconnected, by means of system interface trunks and multiplex channels of information exchange, control and data processing units with a memory block containing at least one, implemented in a software and hardware manner, a consolidated database of stored order processing procedures, data on vehicles registered in the system, data about the user and the remote dispatch services registered in the system, and is connected to the dispatching services system and user communication devices by means of a hardware-software control module of the API system via an Internet gateway with feedback, with the ability to accept and process order data from user communication devices, select the order parameters of the vehicle registered in the system and transfer order information to the remote control system in the control room, with subsequent control of the order execution via the feedback line and the API module.

The disadvantage of this system (prototype) and all other above-mentioned systems is the presence of a dispatch service, which makes the system automated, not automatic.

The second disadvantage of this system is the presence of many unnecessary functions that are needed for a taxi, but are absolutely not required for a minibus that operates on a given, fixed route of the city. The second feature of a minibus taxi is the large number of passengers transported compared to a taxi. These two differences require different control algorithms while maintaining many matching hardware.

Thus, the complexity, high hardware costs, the lack of direct interaction between the driver of the vehicle and the passenger, as well as the lack of functions that are needed for optimal transportation management, namely by minibus, are the disadvantages of the prototype device.

The objective of this utility model is to create an automatic system for calling a minibus taxi, managing and controlling passenger transportation, free from the above disadvantages of systems of this type.

B. Description of the utility model

At the moment, there is no such thing as ”calling a minibus” in route transportation. The passenger, having approached the stop, patiently waits for the vehicle. In this system, he reads the QR code of the stop at the bus stop with his smartphone. From that moment on, it is initialized in the system, the request for its service was received in it, as in a taxi. There is an individual order in the taxi. In this system, this is a collective order. As soon as a sufficient number of passengers accumulate, the process of servicing them begins immediately.

The passenger is the first participant (subject) of the system. The second participant is a minibus driver. If the passenger’s goal is to minimize the waiting time, then the driver’s goal is to maximize the loading of the vehicle interior. At the moment, when leaving the initial (final) point of the route, the driver does not know how many passengers are on the route and whether there are any at all. Therefore, the moment of departure on the route is important for him. Hence the dilemma: I left early, then I drove empty; I left late, then I couldn’t take passengers at some stops because of the overcrowding of the cabin.

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any at all. Therefore, the moment of departure on the route is important for him. These situations are examples of collisions in which the interests of the driver and passenger collide. So, if the driver left earlier than the required number of applications was received, then the cabin will not be filled efficiently on the route. In case of late departure, the number of requests for transportation will exceed the cabin capacity. Passengers will receive a denial of service.

The proposed technical solution makes it possible to exclude both of these ”bad cases”, since the driver at any given time sees from his smartphone how many passengers are waiting for him on the route, as well as at each stop separately. Moreover, from the experience (statistics) of previous trips and the time of day, the system itself offers the driver the optimal time to set off on the route.

The technical result of the claimed utility model is to simplify the process of interaction between users of the system (passenger, driver) among themselves, improve the quality of service for minibus passengers due to the minimum delivery time of a minibus to the client, optimize passenger transportation by creating a single database of orders and optimal time for departure on the route.

The main features of the proposed minibus calling system are:

- the inclusion of a server for query management, a database and a system for managing this data in the system;
- the inclusion of a passenger client and a driver client in the system, made for the Android operating system;
- the presence of a server in the system, which is connected using the Internet;
- using client-server technology for system development;
- connecting users to the system through their existing smartphones;
- inclusion of QR codes of route stops in the system.

When developing the system, the authors took into account some of the features of the systems proposed earlier. These include: a method for determining the degree of occupancy of the cabin, the presence of a dispatching transport control to determine the number of requests from passengers for service, the presence of geolocation systems to determine the location of public transport, calculating the time of arrival of public transport at a stop, and others. So, in some cases, to determine the number of available seats, it is proposed to use special devices – sensors for indicating empty seats. External terminals are used to manage orders using automated systems. In such terminals, as a rule, registration of a service request is used using a telephone or a dispatcher accepting the request. There are also known vehicle control systems using devices for generating messages using GPS navigators, current time counters and other expensive equipment. Such equipment includes a sound communication unit between the dispatcher and the drivers.

The closest in terms of its operational characteristics to the solution proposed by the authors is the taxi calling, passenger transportation management and control system, which includes web servers that connect remote taxi dispatching services and user communication devices. Web servers of such systems, as a rule, contain a database with information about incoming orders, data on registered passenger vehicles on routes, data on users of the system and dispatching services.

Among the disadvantages of the existing systems, we have identified the following:

- the complexity of registration and execution of orders;
- low efficiency of the registration and order processing systems;
- the need to install additional equipment on vehicles (receivers of navigation signals, control units, memory blocks with information about the vehicle, information exchange devices with a dispatch point, and others);
- the presence of functions in the system that complicate its operation and use by users.

One of the main disadvantages of the existing passenger transportation management systems is the lack of direct communication between the passenger and the driver.

All these factors served as the basis for setting the task of creating a useful model of a minibus taxi calling system. For a more detailed acquaintance with the utility model, you should refer to the content of the authors' patent [11].

Based on the utility model, an automated system is being developed to optimize the operation of a minibus taxi, which has the following functionality:

- creating an application for a passenger waiting at a bus stop;
- informing the driver about the busy route;
- informing the driver about the number of passengers who enter and exit the taxi cabin at each subsequent stop.

Passenger traffic data is stored and transmitted in the form of requests to the server. Each request is a set of data defining the route, starting and ending stops. The route, in turn, is determined by an ordered sequence of stops.

The diagram of the interaction of the components of the automated system is shown in Figure 1.

The interaction of the system components takes place according to the REST (Representative state transfer) architecture.

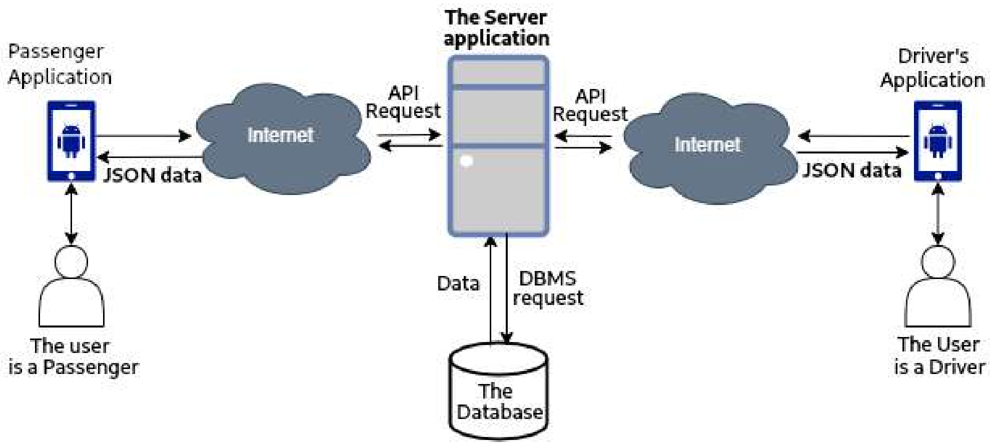

Figure 1. Flowchart of the passenger client application.

According to the information received by the server, the driver will receive an activation signal that indicates the departure time from the current stop point. Departure takes place at the time corresponding to the estimated time of maximum passenger occupancy at one of the stops on the route.

The components of the client-server system are applications for the two main participants of minibus transportation – the passenger and the driver, as well as the software implementation of the server. The user part of the system is represented by two separate client-server applications. Both applications are primarily focused on use on mobile devices.

The Passenger client application allows you to send a request for transportation along the route. The application guarantees the time interval during which the specified transport will arrive. Also, the passenger user has the opportunity to track the location of the called car. The passenger client application allows you to send a request to the server from a stop, which indicates: the location on the route, the selected route, the starting and ending points of passenger transportation. The server processes the received information and accumulates data. When a situation arises that is necessary and sufficient to send a transport along the route, the server sends an activation signal to the application for the driver client. The generation of an activation signal based on accumulated data on passenger requests can significantly reduce the number of collisions in passenger transportation or avoid them altogether. The absence of collisions leads to lower transportation costs and improved passenger service quality.

III. The Server Of The Automated Taxi Management System

The server acts as the central element of the system. Tasks solved by the server: providing data flow management, providing a service for processing data requests from client components, ensuring the storage of information in the database, interacting with the database management system (DBMS).
The JavaScript programming language was used to implement the server, in particular the “Node frameworks.js”, “Express.js” and “Mongoose”. Node.js is a software platform that transforms JavaScript from a highly specialized language into a general–purpose language. In the developed system, the web server is “Express.js” serves as the standard framework for “Node.js” and implements the mechanisms of the server component working with requests. Mongoose introduces a special ODM library for working with MongoDB. The ODM library allows you to map class objects and collection documents from a database.

The storage of information about passengers, drivers, stops, routes and other data is provided by the MongoDB database management system.

Tasks solved by the server component:

- registration of a request from a passenger client for transportation along the route between selected stops;
- sending information about passengers waiting at the stop;
- sending information about passengers leaving the vehicle at a stop;
- accounting for the dynamics of all incoming requests and requests from mobile and static customers;

- collecting statistical information and making recommendations to improve the efficiency of passenger transportation;
- maintaining a database of an automated route transport management system;
- registration of drivers in the system;
- providing a sequence of stops and routes on request.

IV. Passenger Client Application

The passenger and driver client applications were created in Java in the Android Studio environment for mobile devices running on the Android operating system. The JSON standard is used to exchange data with the server.

The passenger client application provides the user with the opportunity to generate requests in two modes: the mode of choosing the desired route or the mode of choosing stops. The flowchart of the passenger client application is shown in Figure 2.

In the case of the first mode, the user selects the route number, starting and ending stops. At the end of the selection, the passenger's request is generated and sent to the server.

Selecting the second mode allows the user to specify only the starting and ending stops. Based on the choice of route points, the application suggests a suitable route or reports the lack of direct communication between them.

Instead of specifying the point of departure, the passenger is asked to scan the QR code placed at the stop.

Tasks solved by the passenger-client component:

- identification of the stop where the user is located by means of a QR code;
- providing complete information on the routes passing through this stop;
- formation of requests for transportation and sending them to the system server.

V. Client Application For The Driver

The flowchart of the driver client application is shown in Figure 3.

To use the driver client application, the user must register and log in to the system.

The application for the driver client provides the user with information about the current route number, the nearest stop point, and the current number of passengers in the minibus. The number of passengers is recorded on the server by the client application. However, not every passenger uses it. For this reason, the user of the driver client has the opportunity to adjust the number of passengers.

The implementation of the driver client also allows you to keep statistics on the number of users of the application for the passenger client.

Tasks solved by the client-driver component:

- displaying information about the number of passengers in the vehicle with the possibility of its adjustment;
- display information about the number of passengers leaving the vehicle at the next stop;
- display information about the number of passengers waiting for the vehicle at the next stop;
- registration and authorization of a minibus driver in the system.

VI. Conclusion

The presented automated management system for irregular transport makes it possible to effectively solve the tasks set: improving the efficiency of transportation and the quality of passenger service, eliminating collisions of passenger flows. The system can also be used to optimize the interaction of traffic participants and improve the efficiency of the urban transport system as a whole. Currently, an automated management system for irregular transport is being implemented on individual routes. In case of positive results in the future, the system can be implemented for the entire transport network of the city. Using such a system will increase profits and improve the quality of passenger transportation.

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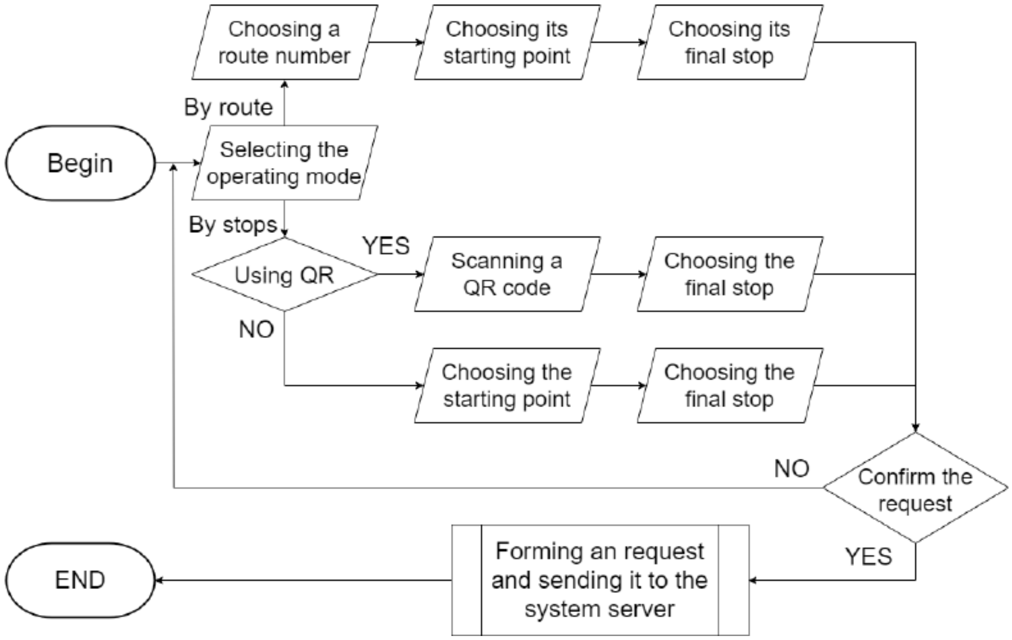

Figure 2. Flowchart of the passenger client application.

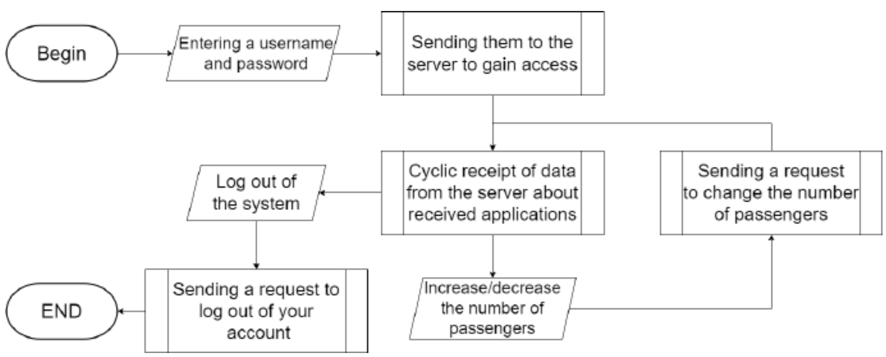

Figure 3. Flowchart of the client application for the driver.

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ИНТЕЛЛЕКТУАЛЬНАЯ СИСТЕМА УПРАВЛЕНИЯ ГОРОДСКИМИ МАРШРУТНЫМИ ТАКСИ

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Представлены результаты анализа проблем перевозки пассажиров городским общественным транспортом. Большее внимание уделено перевозкам с использованием маршрутных такси. Для повышения эффективности перевозки пассажиров предлагается автоматизированная система управления нерегулярным транспортом, разработанная в Брестском государственном техническом университете. В статье описаны структурные компоненты системы и их функционал. Источником разработки являются наблюдения за поведением водителей, пассажиров и других участников движения. Обмен информацией между субъектами движения опирается на унифицированные знания о характере движения. Такой подход требует использования семантических технологий в системах управления пассажирскими перевозками. Данная публикация описывает первый этап проекта, предназначенный для сбора информации и ее семантического анализа.

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