Archives of
Transport System
Telematics

Volume 11
Issue 2
May 2018

Improvement of Urban Taxi Services by Using a Mobile Application

A. PASHKEVICH[a], I. MAKAROVA[b], K. SHUBENKOVA[b]
[a] CRACOW UNIVERSITY OF TECHNOLOGY, Warszawska 24, 31-155 Krakow, Poland
[b] KAZAN FEDERAL UNIVERSITY, Av. Syuyumbike 10a, 423810 Naberezhnye Chelny, Russia
EMAIL: apashkevich@pk.edu.pl

ABSTRACT

Traditionally, besides personal vehicles, individual passenger transportation is carried out by taxi services. These services have both positive sides, such as, for example, door-to-door delivery and comfort, as well as negative sides, such as the high cost of the trip. On the one hand, the services, such as Uber and Gett, attract customers with the help of low prices, but, on the other hand, they have a number of disadvantages, the main of which is the problem concerning transportation security. In addition, it must be mentioned that the usage of individual transport is often associated with incomplete load of vehicles, which causes an additional negative impact on the environment as well as on the road network. This article presents a decision support system for taxi dispatch services based on the model of optimal route choice. Optimization is carried out with the help of multifactor analysis of transportation requirements and selection of the optimal route in accordance with given priorities. Such a system will reduce the cost of transportation through the selection of fellow travelers as well as a negative impact on the environment by using a mobile application.

KEYWORDS: taxi service, mobile application, optimal route choice

1. Introduction

Nowadays, the intellectualization is one of the main trends in the development of economy and society. The rational and smart management and development of all spheres of activities are connected with this concept. The modern human civilization entered the third millennium and, in the same time, faced an amount of global challenges, which solving is formulated in the goals of this third millennium. One of the reasons caused the most of the problems is urbanization.

Today, almost half of the world's population – around 3.6 billion – live in cities. And if 10 years ago the share of urban population was about 35%, then with such growth rate it will be 66% by 2050. Although the all cities occupy only 3% of the Earth's surface, they represent 60-80% of energy consumption and produce around 75% of carbon dioxide emissions. The twentieth century was a period of unprecedented growth of cities and settlement systems and revealed the need of people to develop as to implement new approaches, which shape the image for the city of the future. That is why in recent years in the field of architectural and urban science more and more attention has been paid to the concepts of "Smart Cities" and "Future Cities". In the same time, information technology is replaced by smart technology.

Smart City is an urban environment, which combines a variety of technologies to reduce the negative impact on the environment in general and, thereby, to provide a more comfortable living conditions. The main goal of the Smart City idea is to create a sustainable model of urban development and to preserve the quality of life for urban citizens. Considering the Smart Cities from the viewpoint of economic sectors, it is possible to single out such branches as smart energy, smart transport, smart construction, smart production, and so on. On the other hand, the Smart Cities are considered in the context of elements of various urban subsystems: smart infrastructure, smart buildings, smart cars, etc. And, finally, smart technologies are technologies, which improve people's lives: smart education, smart medicine, intelligent service. Any method to classify smart technologies gives the same output that it is impossible to organize the activities of any branch without transport. One of the main challenges to be solved for the successful operation of the urban ecosystem is the problem of citizens' mobility. At the same time, the transport system should cause minimal negative impact on the environment.

2. Mobility and Urban Transport Systems of the Future

For a long time the European Union (EU) makes a lot of efforts to develop such strategies for the development of urbanized areas, which allow them to become the Smart City in the future. This means that the transformation of the city into Smart City should be understood as a sequence of processes. The proposed changes should not only concern the visual appearance of cities, but they require also that enterprises, infrastructure managers, residents and scientists think and work together in the same direction. Sustainable urban development, improvement of the people's life quality and safety as well as introduction of energy efficient technologies are implemented in the following key areas: Smart Economy, Smart Mobility, Smart Governance, Smart Environment, Smart Living and Smart People.

The transport system is an integrative factor in the development of urban agglomerations. The level of its development and sustainability influences a lot on the life quality of the population, the performance of economic branches of cities and other settlements (if they are parts of agglomeration), the possibility to use the town-planning and socio-economic potential of the territory.

To realize the concept of E-mobility, an integrated approach is required that can be implemented through a combination of the following directions:

- systematic transit to sustainable modes of transport (public and non-motorized modes of transport, electric transport) including renewable energy sources and alternative fuels for vehicles;
- minimization of the amount of people's trips (Internet of Things, Internet of Services - Internet of Everything, remote work);
- modification of the mobility model to reduce the amount of trips done by private transport, which requires to create an effective infrastructure.

The most effective way to reduce the total number of trips is the development of new communication technologies. In such situation, the purpose of the trip can be achieved without realization of this trip, for example: shopping on the Internet, remote work or participation in a conference in teleconference mode.

Almost all existing actual problems in cities are connected in somehow or other with the road and transport complex. Therefore, the key element to create a city, which is comfortable for life, is to ensure sustainable mobility of the population. The transport system is one of the main intellectual systems in the Smart City. To ensure its stability and security, the work is carried out in three directions: smart infrastructure, smart vehicles, smart users. To solve the mobility problem, it requires to change a paradigm in the field of urban planning; especially, it concerns the promotion of compact cities as a way to increase accessibility and to reduce the need for transport in general.

Thus, city residents should be able to meet their needs using the minimum possible number of trips. In addition, the current global bias towards private vehicles should change in favor of more sustainable mobility concepts.

The report of the Deloitte agency indicates that there are two opposite points of view on the future of mobility [2]. Their principal differences are foremost related to the question, whether the current model of traditional private car ownership controlled by human will remain relatively unchanged or people will sooner or later transit to autonomous vehicles predominantly of joint use. There are also fundamentally different viewpoints regarding the way how the situation will be exactly developed.

Supporters of the natural evolution idea believe that the development of the business ecosystem in the automotive industry will be consistent and straightforward, and its current assets and fundamental structure will essentially remain unchanged. Adherents of the opposite viewpoint – jerky development – predict the onset of a turning point, which promises very interesting economic prospects and benefits for society [2].

Taking into account the competition of market forces, which form the new structure of the automobile industry, four different scenarios of its development have been singled out, which will appear as an impact of two key factors:

- way of driving (driving with human participation or autonomous driving);
- forms of vehicle ownership (private or joint).

According to the analysis results, innovations will be distributed unevenly in the countries, whose population has different demands for different modes of transport. It means that all four possible forms of transport ecosystems of the future will likely exist at one time.

3. Literature Review

The increase of the motorization level is often associated with the convenience to deliver goods and passengers "from-door-to-door". Owners of private cars appreciate such advantages as the comfort of trip, the possibility of increasing mobility at any time, the lack of need for transfer to other modes of transport. However, the growing number of cars on the city streets has led to the appearance of strategies, which main goal is to increase the popularity of public transport. Considering the large and crowded cities, public transport is sometimes only one way to reduce traffic jams, especially, during the peak hours. That is why there are an amount of research work devoted to the demand for public transport. J. Ke et al. [6] present in their paper the short-term passenger demand forecasting for the on-demand ride service platform. The main aim was to improve the rate of car utilization and level of passengers' satisfaction. The proposed solution concerns the implementation of accurate real-time passenger demand forecasting to prepare suggestions for the platform how to change the balance of the spatial distribution for cruising cars and, in such way, to meet demand of passengers in each region.

There are papers of Nassereddine and Eskandari [9] and K. Kim [8] presenting the case studies of Tehran and Seoul, respectively. Both research works show that, if it is necessary to put public transport systems in big cities today in the decreasing order of importance, the sequence are following: subway, taxi, bus rapid transit, and bus. The taxi is on the second place, because it is close to travel by private car, especially, in terms of comfort. Also taxi can be used as an addition to other modes of public transport.

A lot of scientists investigated the usage of environmental friendly cars by taxi companies. The future of taxi transportation is connected with electric vehicles, autonomous vehicles, and systems of car-sharing. In addition, various electronic services are considered, which help to optimize the route, to choose the parking place as well as to calculate the travel time. There are also new services, which use a new business model: they aggregate information from different taxi companies and present it on the one platform in the Internet or in the form of mobile application. It is difficult for dispatch services to compete with such aggregators. According to various sources, up to 60% of passengers order a taxi through a mobile application. Taxi companies lost a part of the profits because of the forced cooperation with aggregators. In addition, many of them felt a loss of loyalty from the side of customers.

The appearance of new business models on the market of transport services is accompanied by problems of legal regulation. Flores et al. [3] in their paper show that appearance of new services can be considered from the viewpoint of San Francisco's experience. The ride-sourcing obtained there the status of mean, which supports local technology industry and its potential to create working places and to accelerate the growth of economy. Also it improves opportunities for people, because it is not required a large public investment.

The paper of Cetin and Deakin [1] considers the economic regulation for traditional markets of taxi services as well as an influence of fast developing services of ridesharing. This research work presents the advantages and disadvantages of existing taxicab regulation and explains the reason why ridesharing services have got a strong position in many markets. S.W. Kim et al. [7] suggest to use autonomous cars as taxis to minimize the presence of private cars on campuses of universities. This article considers the shared mobility systems as an alternative to private automobiles based on the example of the Seoul National University.

Hong et al. [5] suggest that the approach of clustering vehicle trajectories is an effective tool to identify potential routes for users of carpooling services. The proposed method is to create a potential solution for carpooling services by using the dataset of available and reliable trajectories. Authors assume that this study can be extended to the system of real-time ride-sharing based on the ride-matching method with dynamic routing and actual settings of customized preference.

According to Tong et al. [11], with the help of easy-to-access websites and smartphone applications, organizer of ridesharing service could quickly collect and use the detailed information of transport demand from potential users. By combining similar travel requests, for example, based on origin-destination data and departure/arrival times, special bus services can get more important role in the context of economically sensible solutions. Taking into account their increasing penetration rates in the market, this type of public transport service could offer better mobility and accessibility for residents, particularly, in case of a largely overloaded roads during the rush hours. Tong et al. [11] have developed an optimization model based on multi-commodity network flow. The aim of this model is to formulate a problem of customized bus service network design in such way to optimize the usage of the vehicle capacity as well as to satisfy individual demand requests, which are determined through space-time windows. Research of the Weng et al. [13] is devoted to how users appreciate the utility of mobile applications for ordering a taxi. Authors state that, when passengers find out the usefulness of the Mobile Taxi Booking (MTB) Apps, they would like to continue the usage of this application to order taxis. The MTB App has an opportunity to transform the ways, how passengers find and take taxis, into a more convenient one. Also article describes an approach how such service providers should develop their applications.

4. Taxi Service as a Way to Ensure the Sustainable Mobility

In order to combine the possibilities to use a private transport with the concept of the public transport development, several ways to develop taxi services have been proposed. To reduce the share of private car usage and in the same time to increase the effectiveness and environmental friendliness of passenger transportation, municipalities of some cities today are implementing such traffic polices, as a ban to drive private cars with less than three passengers on the main streets in the overloaded city centers. In the case of taxi transportation, the task to raise the occupancy of taxicabs could be solved by the implementation of the system to transport passengers by route taxi upon request. This system is considered as an addition one to support existing urban passenger transport. Such form of the transportation organization has developed mostly in the cities of the USA, Canada, Great Britain, France, Germany, Sweden. At the same time, these systems allow to avoid the main disadvantage of taxis – the high price, as they combine maximally the comfort of travel by car with the reduction of travel expenses. In this regard, the route taxi upon requests can be called the "social taxi".

The most widely used type of these systems is a dial-a-ride service, which provide the service of passengers in accordance with the orders submitted by phone. Also, there are such systems with the reception of orders from special calling devices. They are divided into two types: with fixed routes and with flexible routes. For the fixed routes, which are organized in accordance with the preliminary orders of passengers, the points of passenger getting on/off are determined in advance. Vehicles operated on the fixed routes make stops according to the request of passengers. Such systems are used to transport passengers, who cannot use the public transport for various reasons. For such kind of transportation, radio-equipped minibuses are mainly used, which have special design and colors to make them well-notable in the mass of traffic flow. Such minibuses work on requests and carry passengers "from-door-to-door", which means to take the passenger from any place specified by him/her and deliver it to any other place within the served territory. Transportation of passengers is done according to orders received from inhabitants of the serviced territory to the dispatch center. The organization of passenger transport for the specified system includes the reception of orders from customers and their processing as well as the creation of optimum routes by using special software to guarantee minimum expenses of time. Single orders are accepted by phone, and season tickets are sold for regular trips. Regular customers are those, who make daily trips for a week at the same time with established places for getting no/off. In the trip orders the following elements are indicated: the starting and ending points, the required pick-up time and the number of seats. The filling of orders is provided normally at the appointed time or with a deviation, which is not more than 5 minutes. The procedure to pay for trip in fixed-route taxis, which work on request, is similar to the scheme used to pay a traditional taxi. Payment for transport services from regular passengers is charged in advance and often at a discount [12].

The realization of interaction with clients according to the traditional scheme (Fig. 1) is not always convenient, because it is difficult to predict the occupancy level of a taxi company. Also it is necessary to find taxi by phone, there is an uncertainty whether a taxi will arrive and in what time, client does not oriented in the city, etc. Automatic taxi services has become more and more developed. In such services the dispatcher is completely excluded from the process of car ordering. For example, an order can be made due to one of the following 2 ways: to send a SMS to a short phone number using a mobile application or fill in an order form on the taxi website. The SMS should include at least location and pick-up time. As a rule, an order together with an automatically calculated fixed price is transferred to all free drivers, and the first responded one receives this order for realization. However, automatic taxi services have their shortcomings: a long waiting time for the result from the operational call-center, overload of these call-centers, necessity to search for cars by mobile applications in numerous taxi companies.

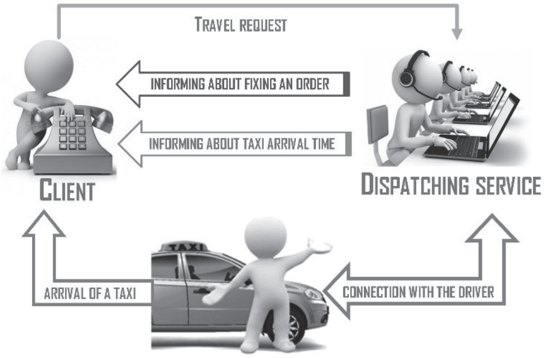

Fig. 1. The scheme of the traditional business model for taxi service [own study]

The above-mentioned problems, the need to improve the environmental situation in the residential area of the cities as well as the necessity to reduce passenger flows in places with intensive road traffic requires to change the concept of the further urban transport development. This issue requires an integrated approach, which includes the simultaneous solution of several tasks. Such tasks can be following:

- to create of a taxi service to ensure joint trips;
- to improve the tariff policy;
- to monitor the route network operation and its optimization;
- to reduce the harmful impact of transport on the environment.

5. Development of the Intelligent System for the Joint Trips' Regulation

5.1. Operational principles the proposed system

The proposed system will allow you to establish a direct connection between clients and drivers without participation of the dispatch service. Fig. 2 shows the interaction within such scheme. Customers send an order for a trip to indicate the possible options. The order contains information about the customer (name, contact phone), date and pick-up time, points of departure and arrival, the number of required seats, class of vehicle (standard, comfort, business), additional options (for example, availability of a child seat, air conditioning, baggage) and the desired number of passengers to take part in this joint trip. Then a group of passengers is formed according to criteria such as date, pick-up time and point of arrival (gravitation object of vehicle). According to the information about passengers, which is placed on the interactive city map, the service determines the optimal route to the final destination and calculates the trip cost for each customer on the route taking into account the above parameters. Then this route is displayed on the city map together with criteria description. The gravitation objects in this case are shopping malls, educational institutions, kindergartens, city hospitals and polyclinics, enterprises of the city, etc.

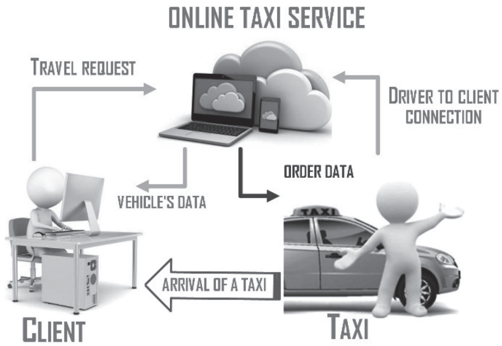

Fig. 2. Scheme of interaction between clients and drivers [own study]

5.2. Architecture of the Proposed System

The optimal variant of the system architecture in the context of scalability is the client-server with the dedicated server for centralized database and the server for mathematical calculations.

A visual representation of this architecture is shown in the Fig. 3. The client application software of the information-analytical system includes *the following functional modules*:

1. Formation of conditionally constant information about the traffic situation and routes in the city at different times.
2. Registration and accounting of planned and actual data for all objects in the information system.
3. Calculation of optimal route maps for each transport unit of the social taxi.

The *first module* is designed to display the following information:

- Information about the city districts. This information is needed to detail points of passenger getting in/off on the taxi route maps. Besides that, it is necessary to cluster the city in order to reduce the dimension of mathematical model.
- Information about the city micro-districts. This information is indicated on the taxi route maps and determines the location of the getting-in/off objects.
- Information about gravitation objects. This information is needed to establish the points of passenger getting off. Also it is grouped by the types of these objects depending on their social significance level.
- Information about the routes. This set of data allows to establish the routes of taxis between the getting in/off points. Routes are determined depending on the day of the week, time of day and objects themselves. In addition, alternative routes for a taxi at each step are presented.

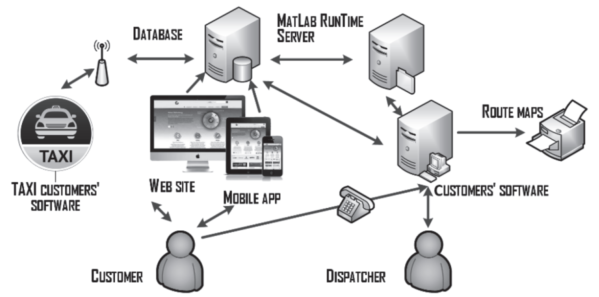

Fig. 3. Client-server application to form joint trips [own study]

In the second module, the directories are filled with data, which is necessary for the information system operation. These data are initial data for the developed mathematical model. Registration of planned data is carried out in the corresponding screen forms:

- Categories of passengers. The directory of passengers' categories consists of only one field, in which categories of the passengers with limited mobility are entered, if it is necessary.
- Orders. To fill in information in orders for the usage of social taxi services, it is necessary to specify the actual origin address of passengers together with indication of the city micro-district, the planned pick-up time, the date of order. Also, it should be noted, whether the getting-in operation is a priority for the passenger (concerning the people with restricted motility). Besides that, to form an order, it is necessary to identify the number of passengers for each category, which require to get in a taxi within the framework of this order. Also, it should be indicated the places of passenger getting off: the city micro-district, the planned getting off time and the number of passengers of each category for each getting off.
- Vehicles. To create this directory, the information should include the make of the car, its state registration number, the total available number of seats as well as the number of seats, which passengers of each category can occupy. In addition, it is necessary to fill in the information about the initial location of the car at the beginning of its working period.
- General parameters. General parameters of the model are formed for a certain date and take values, which determine the operation of the information system.

The accounting of actual data is carried out by entering in the database the calculated values, which are determined during the process of the optimization task solution in the *module number 3*. The accounting of actual data is done in the context of the following data:

- Distribution of orders between cars. This dataset is formed for a certain date and allows to determine the taxi, which performs an order.
- Time moments, when orders are fulfilled. It characterizes the time during the working period, in which the car must perform an operation within the scope of filling of an order.

Both these information arrays are displayed in the final document of the information system – route maps of taxi cars. To build rational routes as well as to improve the quality of planning, it is necessary to study the demand for taxi services and factors, which affect it, such as, for example, distribution of traffic, parameters of the transport system, etc. To forecast and to plan the demand, different models are applied [10, 4, 14, 15]. The operation process of the third module is based on the following mathematical model, which objective function minimizes the number of empty seats in all taxis during the working period:

$$\sum_{i=1}^{IC}\sum_{s=2}^{SC}\left[IV \times \sum_{g=1}^{JC^2\times ZC\times TFC} X_g^{i,c} + \sum_{a=1}^{s-1}\sum_{k=1}^{KC}\left(\sum_{g=1}^{GC}\left(GV_g - GP_g\right)\times GK_{k,g}\times X_g^{i,s}\right)\right] + \sum_{i=1}^{IC}\left[IV_i \times \sum_{g=1}^{JC^2\times ZC\times TFC} X_g^{i,1}\right] \to \min \qquad \mathbf{(1)}$$

Where:

KC – number of passengers' categories, *k*–its counter: $k = 1...KC$;

JC – number of objects participating in the creation of taxi routes, *j* – its counter: $j = 1...JC$;

TFC – number of time moments;

SC – maximum amount of objects, which can be visited by vehicle during the working periods;

IC – number of taxicabs on routes, *i* – its counter: $i = 1...IC$;

IV_i – total number of seats in taxicab *i*;

ZC – amount of orders during working period, *z* – its counter: $z = 1...ZC$;

$ZP_{z,j}=\{0;1\}$ – matrix, which determines the getting-in operation for passenger of order *z* on the object *j*.

$ZV_{z,j}=\{0;1\}$ – matrix, which determines the getting-off operation for passenger of order *z* on the object *j*.

$ZV_{z,j,k}$ – number of passengers of the category *k* on the object *j* for order *z*, which includes there an operation of getting in or getting off.

GP_g – vector, which determines the getting-in operation for operation g. This array is filled by values from $ZP_{z,j}=\{0;1\}$.

GV_g – vector, which determines the getting-off operation for operation *g*. This array is filled by values from $ZV_{z,j}=\{0;1\}$.

GK_{kg} – vector of passengers of the category *k* on the object *j* for order *z*, which includes there an operation of getting in or getting off. This vector is filled by values from $ZV_{z,j,k}$.

GC – supportive array, which aim is to reduce the dimension of required parameter. This array is obtained by processing the initial data and is a specially ordered vector. Dimension of vector *GC* is calculated by the formula:

$$GC = JC^2 \times ZC \times TFC + JC \times TC \quad \textbf{(2)}$$

The formula (2) consists of two elements. The first component defines all possible combinations of getting-in/off objects, orders and time moments. The second component describes the "empty journeys" of a taxi: it is a state where a taxi does not move anywhere at a certain step and continues to be on the previous objects.

The solution to this optimization task is to achieve certain optimization criteria, which indicate the efficiency of work planning for a social taxi. The mathematical model of the system operation can be realized with the help of the following performance criteria or their combinations:

1. Minimization of waiting time for taxi passengers during getting-in operation.
2. Minimization of waiting time for taxi passengers during getting-off operations in case of its preschedule arrival to the "gravitation object".
3. Minimization of waiting time for taxi driver in case of his preschedule arrival to the getting-in object.
4. Minimization of passengers' delay time during the getting-off operation.
5. Minimization of the time, which a passenger spends in case of the necessity to realize a preschedule getting-in operation.
6. Minimization of the total unproductive waiting time, which passengers and taxi drivers spend in case of the deviation from the schedule of cars arrival on the objects.
7. Minimization of the total number of journeys done by taxis filled in by less than 3 passengers.

All the above-mentioned performance targets of the efficiency achieve their optimality criterion depending on one array, which represents the optimal distribution of orders between transport units of a social taxi during the working period.

$X^{t,i,s}_{jn,jk,z} = \{0;1\}$ is an array, which determines a journey of taxicab *i* in the step *s* for the time moment *t* between objects *jn* and *jk* to realize order *z*. Thus, this array is a parameter to calculate the above-mentioned performance indicator. This array could be re-written using supportive array GC. Then it takes the following shape: $X^{i,s}_{g} = \{0;1\}$ – array, which determines a journey of taxicab *i* in the step s for operation *g*.

As an alternative objective function, the composite function can be taken. It will consists of a function, which minimizes the amount of unproductive taxi idle times, waiting time for passengers in case of preschedule arrival of taxi in getting-in/off point as well as in case of delays of passengers. The constraint system contains restrictions on the required parameter, time limits, route restrictions, restrictions on the number of passengers, and restrictions on the completeness of order fulfillment. The number of passengers, who get in within the scope of one order, should be equal to the number of passengers, who get off from the taxi.

The third module is designed to form the initial datasets, which are transferred to the mathematical model described in the previous chapter of this article. Also in this module, functions are called, which perform the solution of the integer linear programming problem.

As a tool to develop the software information system were selected:

- MS SQL Server as a database server.
- CodeGear RAD Studio as a development environment.
- MATLAB application package as a development environment of mathematical support. This package includes such tools as Matlab Compiler, Optimization Toolbox as well as Database Toolbox. To realize the mathematical model, the function bintprog was used, which is a function to solve integer linear programming problems.

The presented scheme for the architecture of client-server application should include such hardware elements as database server, mathematical calculation server, operational stations to work with a client application, a web server, peripheral hardware to print route maps

5.3. Operating procedure of proposed system

The algorithm of the information system based on the above-mentioned technical support elements is following:

1. The user of the system sends an order for social taxi services through a website, mobile application or phone call to a taxi service. In the last case, the dispatcher registers this order in the client application.
2. The order data is put in the database on the server and is displayed in the client application of the dispatcher.
3. Data are collected during a certain period of time. Then the dispatcher starts to calculate the optimal routes by using the client application. In the course of this step, parameters of orders, data about current location of taxis, data about possible routes are sent to the server of mathematical calculations. Thereafter, a calculation of taxi routes takes place immediately. Parameters of the calculated routes are written to the corresponding tables on the database server and are displayed in the client application for dispatcher.
4. Then dispatcher can print out route maps for taxi drivers.
5. The calculated route maps are also displayed in the client applications, which are installed directly in the taxi cars. When taxi driver finishes the next stage of work, he marks this fact in his client application, which is recorded in the database. Changes in the status of orders are made available to the dispatcher and are displayed in his client application.

6. Conclusion

The difficult situation in cities, especially in metropolitan city, which is caused by the fast development of transport and, consequently, by the negative environmental impact of the transport and road complex, requires to improve the quality of planning and management. This is possible with the new IT services, which allow to find a balance between demand and supply for transport services. The proposed version, how to manage joint trips by using taxies, allows to increase the quality of customer service and to reduce the negative load on investment funds. Currently, the developed system is tested in the city Naberezhnye Chelny.

Bibliography

[1] CETIN T., DEAKIN E.: Regulation of taxis and the rise of ridesharing. In: Transport Policy, 2017. URL: http://dx.doi.org/10.1016/j.tranpol.2017.09.002 [date of access: 17.01.2018]

[2] DELOITTE: Mobility of the future: How transport technology and social trends affect the development of a new business ecosystem, 2015. URL: https://www2.deloitte.com/content/dam/insights/us/articles/transportation-technology/DUP-1374_Future-of-mobility_vFINAL_4.15.16.pdf [date of access: 17.01.2018]

[3] FLORES O., et al.: How cities use regulation for innovation: the case of Uber, Lyft and Sidecar in San Francisco. In: Transportation Research Procedia, 25, 2017, p. 3756–3768

[4] HE F., et al.: Pricing and penalty/compensation strategies of a taxi-hailing platform. In: Transportation Research Part C, 86, 2018, p. 263–279

[5] HONG Z., et al.: Commuter ride-sharing using topology-based vehicle trajectory clustering: Methodology, application and impact evaluation. In: Transportation Research Part C, 85, 2017, p. 573–590

[6] KE J., et al.: Short-term forecasting of passenger demand under on-demand ride services: A spatio-temporal deep learning approach. In: Transportation Research Part C, 85, 2017, p. 591–608

[7] KIM K.: Exploring the difference between ridership patterns of subway and taxi: Case study in Seoul. In: Journal of Transport Geography, 66, 2018, p. 213–223

[8] KIM S.W., et al.: Autonomous Campus Mobility Services Using Driverless Taxi. In: IEEE Transactions on intelligent transportation systems, 18 (12), December 2017, p. 2213-2226

[9] NASSEREDDINE M., ESKANDARI H.: An integrated MCDM approach to evaluate public transportation systems in Tehran.: Transportation Research Part A, 106, 2017, p. 427–439

[10] TANG J., et al.: Taxi trips distribution modeling based on Entropy-Maximizing theory: A case study in Harbin city – China. In: Physica A, 493, 2018, p. 430–443

[11] TONG L.C., et al.: Customized bus service design for jointly optimizing passenger-to-vehicle assignment and vehicle routing. In: Transportation Research Part C, 85, 2017, p. 451–475

[12] Transport for London: London Dial-a-Ride, 2017. URL: https://tfl.gov.uk/corporate/about-tfl/what-we-do/dial-a-ride. [date of access: 17.01.2018]

[13] WENG G.S., et al.: Mobile taxi booking application service's continuance usage intention by users. In: Transportation Research Part D, 57, 2017, p. 207–216

[14] YANG ZH., et al.: Analysis of Washington, DC taxi demand using GPS and land-use data. In: Journal of Transport Geography, 66, 2018, p. 35–44

[15] ZHU G., et al.: Analysing journey-to-work data using complex networks. In: Journal of Transport Geography, 66, 2018, p. 65–79