https://doi.org/10.31891/csit-2022-2-13
UDC 004.3

Yelyzaveta HNATCHUK, Anita BOIKO, Alina HNATCHUK
Khmelnytskyi National University

RESEARCH OF METHODS OF SEAT DISTRIBUTION IN PUBLIC TRANSPORT

In large cities, especially during a pandemic, the problem of allocating seats in transport and building the most successful route is an urgent task. The study of four methods of distribution of seats in public transport. Their advantages and disadvantages are investigated. According to the results of the research, it became clear that the existing methods alone do not allow to effectively solve the problem of distribution of seats in transport, so it is necessary to either improve existing methods or develop new methods. Improving existing methods is possible by either combining several methods into one or adding certain elements that eliminate existing shortcomings or minimize their impact on the effectiveness of the method. According to the results of the research, the method of electronic seat selection has been improved in terms of adding seat weight sensors, which makes it possible to record the number of occupied seats and helps to provide information to passengers using a mobile application for free seats. The method was also further developed with the help of a mobile application that allows you to pave a route and helps you choose a convenient place to travel to your destination.

Keywords: distribution of seats in transport, infrared sensors, touch sensors, mobile application

Єлизавета ГНАТЧУК, Аніта БОЙКО, Аліна ГНАТЧУК
Хмельницький національний університет

ДОСЛІДЖЕННЯ МЕТОДІВ РОЗПОДІЛУ МІСЦЬ В ГРОМАДСЬКОМУ ТРАНСПОРТІ

У великих містах, особливо під час пандемії, проблема розподілу сидячих місць в транспорті та складання найбільш вдалого маршруту є актуальною задачею. В роботі проведено дослідження чотирьох методів розподілу місць в громадському транспорті. Досліджено їх переваги та недоліки. За результатами проведених досліджень виявилось, що існуючі методи окремо не дозволяють ефективно вирішити задачу розподілу місць в транспорті, тому необхідно або удосконалювати існуючі методи або розробляти нові методи. Удосконалення існуючих методів можливе за рахунок або об'єднання декількох методів в одному або додавання певних елементів, що дозволяють усунути наявні недоліки або звести їх вплив на ефективність методу до мінімуму. За результатами проведених досліджень удосконалено метод електронного вибору місця в частині додавання вагових датчиків сидіння, що дає можливість фіксувати кількість зайнятих місць та допомагає надавати інформацію пасажирам за допомогою мобільного додатку про вільні місця. Також набув подальшого розвитку метод за допомогою мобільного додатку, що дозволяє прокласти маршрут та допомагає обрати зручне місце для поїздки в пункт призначення.

Ключові слова: розподіл місць в транспорті, інфрачервоні датчики, сенсорні датчики, мобільний додаток

Introduction

The main task of the organization of urban public transport is to ensure the quality of traffic, which is assessed mainly by the average waiting time of passengers at the stop or by the average interval of traffic on the route. The quality of passenger traffic is determined, in addition, by the actual duration of the trip, the cost of travel, the speed of arrival and the fullness of the vehicle [1, 2]. It is these indicators that determine the attractiveness of using a particular type of public transport. Uneven distribution of passenger traffic by periods of the day significantly affects the organization of traffic and this, in turn, affects the level of efficiency of public transport.

The efficiency of passenger traffic has been studied by many scientists [1]. The vast majority of studies concerned the analysis of passenger traffic in the city, the probability of passenger traffic in transport interchanges, but the issue of determining the availability of vacancies in transport was paid almost no attention. Therefore, the study of existing methods of allocation of seats in transport and the choice of an effective method of allocation of seats for convenient use of transport and ensuring the arrival of citizens in time to the destination is an urgent task, which this study is devoted to.

Analysis of the peculiarities of passenger traffic in public transport

As an example of public transport, consider bus transport. On weekdays, business trips predominate, so the peak passenger flows fall on the period from 07.30-09.00 and 17.00-19.00. The inter-peak period is characterized by a decrease in the efficiency of vehicle use due to the increase in the intervals of their movement [3]. This increases the waiting time at stops. The flow of people through urban infrastructure has a major impact on several areas, such as tourism and transport. In particular, the ability to accurately count the number of passengers is one of the most important components of the transit service, as it provides a key indicator of the efficiency of public transport companies and is key to effective transit network planning, both long-term and short-term. Indeed, long-term route planning and related schedules make it possible, through the analysis of departure-destination matrices, to obtain information about travel during peak hours [2, 3]. Moreover, such matrices provide guidance on congested travel time and appropriate routes, which affects short-term planning strategies. Thus, long- and short-term planning promotes efficient use of resources and ensures that buses run on the right routes.

To obtain information on the number of passengers, transport campaigns usually use traditional mechanisms, ranging from non-automatic visual counting performed by a person to automatic counting of passengers. Automatic methods based on various data collection technologies (eg matte sensors, infrared sensors, video cameras. These systems need to be installed on vehicles and they are usually quite expensive.

Consider in more detail the following methods: method of electronic location selection, infrared technologies of distribution of places in transport, method of allocating seats in transport using a mobile application and method is based on the detection of the maximum intensity of passenger traffic.

Method of electronic location selection

The essence of this method is that when entering public transport, the passenger must pay with an electronic ticket, select a place on the screen and then go to the selected place [3]. The distribution of seats in public transport through electronic seat selection will help to record the number of occupied seats and warn subsequent passengers about free seats in the vehicle. The method is effective provided moderate passenger traffic. For rush hour, you should improve this method: add weight sensors to the seat. The strain gauges are connected to the information board by means of a strain gauge cable and an analog-to-digital converter to illuminate up-to-date information. To pay for travel on the back of the seat, attach an NFC-sensor (Fig. 1), which will be programmed for non-cash payment, which will be an advantage for passengers.

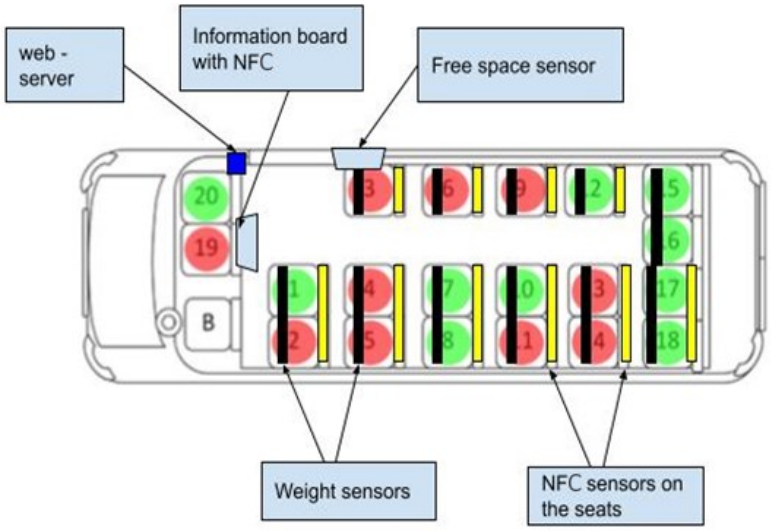

Fig 1. Diagram of a vehicle using the electronic seat selection method with a weight sensor on each seat and an NFC sensor on the back of each seat

Infrared technologies of distribution of places in transport

Cameras with infrared sensors measure the number of passengers with light rays (Fig. 2). When the beam distance is reduced, the occupied position is registered. The sequence in which the rays are broken determines the direction of movement of the passenger. Infrared technology is most common in buses and widespread in retail chains. This method is effective, but during heavy passenger traffic there is a possibility of incorrect data. Therefore, the error of incorrect data is present here. Video imaging technology measures the number of passengers using appropriate cameras in the bus that recognize the passenger. They use several algorithms to:

a) motion detection;

b) assessment of its direction;

c) confirmation of the existence of a moving passenger.

The cameras send a signal through the router to the web-server, where the data on free seats in the vehicle are processed and displayed on an additional board for information to subsequent passengers.

In addition to the task of fixing free passenger seats, infrared sensors can serve as cameras that provide control in the vehicle during heavy passenger traffic [3, 4]. This helps drivers avoid dangers on the road and transport companies improve service.

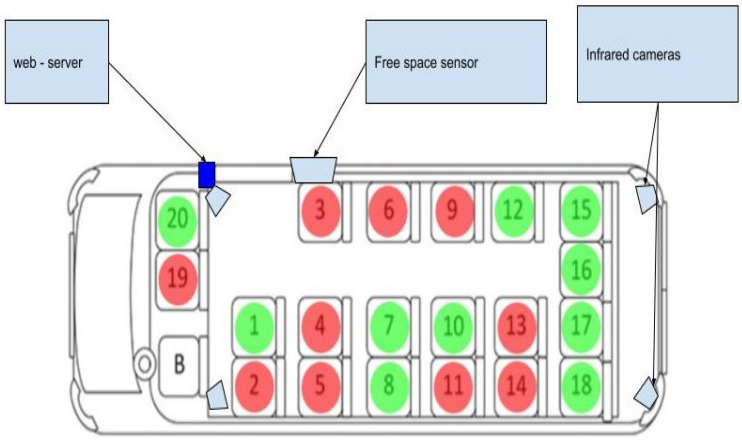

Fig 2. Diagram of a vehicle using the Infrared technologies of distribution of places

Method of allocating seats in transport using a mobile application

This method is based on the method of electronic seat selection and is advanced in terms of adding weight sensors to the seat, which allows you to record the number of occupied seats and helps to provide information to passengers through a mobile application for free seats. Thanks to the installed weight sensors in the bus, passengers can see the number of occupied seats and find out which route to take next. Thanks to the built-in artificial intelligence system, the information is quickly updated and provides only accurate data. When developing a computer system for automatic allocation of seats in transport, it is necessary to take into account that during peak hours there will be a large load on the server. In addition, a potential passenger will be warned that during rush hour seats are quickly occupied.

With the help of the developed application on the smartphone, the passenger can enter the start and end points of the route. A similar system can be seen in Google Maps, which selects the fastest route. In megacities, the function of viewing the employment of minibuses based on passenger feedback is available. But a small percentage of public transport users leave feedback, so Google Maps may not always be relevant. The block diagram of such an appendix is presented in Figure 3.

The application works on the following principle:

1. The passenger chooses a route by number or enters points A and B.
2. The system automatically searches for options for the appropriate route.
3. Check of free places in transport:

a. if there are more than or equal to 3 seats, then a message about the waiting time for the vehicle;

b. if there are less than 3 places, another route is laid and the set conditions are checked again;

c. we repeat cyclically until we find a suitable option.

4. After finding the desired route, the application informs in which part of the vehicle it is better to take a place and the approximate time of arrival at the station.

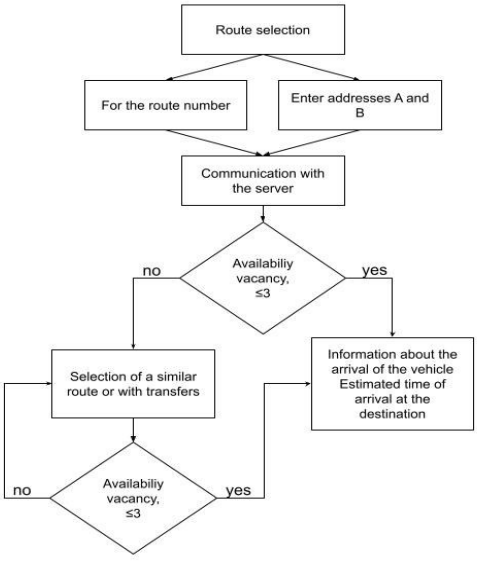

Fig 3. The logic of the application to find the appropriate route

Each bus carrying citizens of the city must have appropriate weight sensors that will record the number of occupied seats. They are placed under the seat. The sensor has measuring limits from 20 kg to 200 kg. A strain gauge is a device that translates mechanical effects into electrical signals and transmits them to a suitable connected device. They come in different types. This work uses a cantilever strain gauge Keli SQB-A 260kg, which when loaded creates resistance, gives the desired signal and fixes it on the screen. The information about the occupied places will be transferred to the server, which is synchronized with the mobile application to provide up-to-date information (Fig. 4).

The characteristics of such a load cell are as follows:

1. 10kg - 250kg.
2. Material: Stainless steel.
3. Protection class: IP68.

Fig 4. Synchronization with servers to update information

In addition to weight sensors, at the entrance to the car is a POS-terminal for payment by bank card (Fig. 4), as well as QR-codes for payment using Internet banking applications, including payment systems Apple Pay, Google Pay, Pay Pass. Adding such payment methods increases the efficiency of drivers, because they are not distracted by payment.

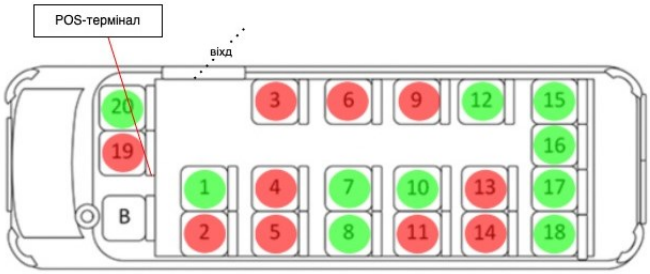

Fig 5. Location of the POS-terminal in the Volkswagen bus

Method is based on the detection of the maximum intensity of passenger traffic

This method of determination is performed by estimating the change in total intensity relative to the X and Y axes and by recording their maxima. This method allowed to observe the trajectory of the object and to estimate the duration of the object's entry into the vehicle [5]. The full projection on the X-axis only helps to find a person relative to the X-axis. The full projection on the Y-axis changes when moving to / from the tire, so the continuity of the Y-axis change is much more important than the continuity of the X-axis change. there are jumps of total intensity (the reason - steel accessories of an entrance ladder, fig. 6).

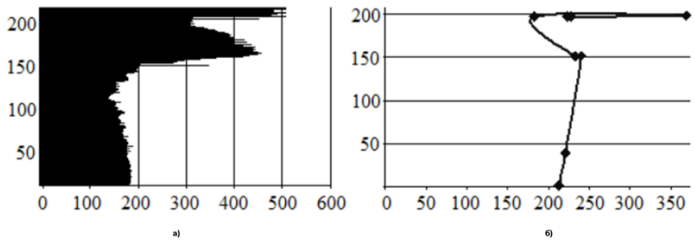

Fig 6. Graph of total intensity: a - graph of the sum of the intensity of the projection Y; b - defined trajectory of one person

Analysis of the trajectory showed that there was an improvement, although due to a number of shortcomings still inaccuracy prevails. The linear moving average filter is represented by formula 1. As the results of the experiment showed, it is rational to choose the filter parameter a to 1/4.

$$y(n) = ax(n) + ax(n-1) + ax(n-2) + ax(n-3), \quad (1)$$

where *a* is the weighting factor,

n is the sum of the intensity of the line number of the projection of the *Y* axis.

This filter allowed to reduce the impact of background noise and correctly indicate the trajectory of passengers (Fig. 7).

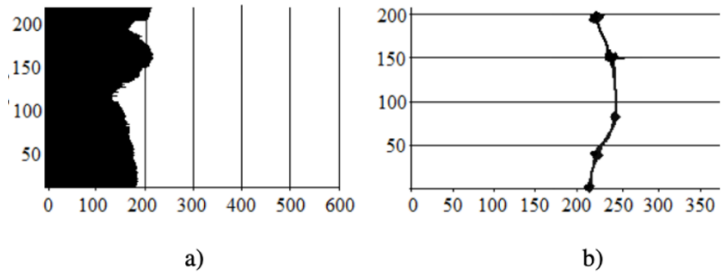

Fig 7. Graph of the total intensity in the projection Y and the obtained trajectory: a - graph of the sum of the intensity of the projection Y; b - defined trajectory of one person

An experiment using this method was conducted on the example of people entering and exiting the vehicle one by one. Thus after qualitative estimation of a method in 70 such situations accuracy of 90% was revealed. The disadvantage of this method is that it does not work for situations where more than one person enters / exits at the same time.

Advantages and disadvantages of the presented methods

Consider the advantages and disadvantages of these methods.

The advantage of the method of electronic selection of the place is the presence of an electric board for quick selection of the place, also thanks to the POS-terminal or the presence of the NFC-sensor it is possible to pay the fare. Having an information screen for the number of free seats is also an advantage, because passengers can see how many next citizens can enter the vehicle.

The biggest disadvantage of this method is that in the presence of a sufficiently large passenger flow, the choice of free space yourself takes a lot of time, which affects the route schedule. Another disadvantage is the cost of all strain gauges. The cost of 1 sensor is 350 UAH. A bus with 20 seats requires at least 12 of them, which amounts to UAH 4,200 per 1 bus, not including two information boards, switches and routers to connect to the server. The cost of installing all sensors for 1 car will be approximately UAH 15,000. If there are 7-10 cars on the route, it will be a big expense for the carrier.

Infrared distribution technologies have the ability to distinguish the thermal radiation of objects in the middle IR range. The recognition results are transmitted to a computer system, where the number of vacancies or occupied is already recorded.

The disadvantage of this method is that there are no ready-made specialized cameras with infrared sensors, they are only to order and are developed according to the scheme of the vehicle, because the routes are buses with different passenger capacity (from 19 to 53). Another disadvantage of this method is the data delay, because the system needs to compare the scheme of the car and the actual data from infrared sensors.

The method of allocating seats in transport using a mobile application, which paves the route and helps to choose the right place to travel to the destination, has the following advantages:

1. Route selection system.
2. Information on available seats in the vehicle.
3. Ability to pay by card using POS-terminals placed in accordance with the number of passenger capacity of the vehicle.
4. If there are no seats available in the bus, the system automatically searches for other similar routes.

The disadvantages of the system are - technical support of the application and updating the version according to the needs and tasks of the system. The application does not work on older versions of Android and iOS. There may be technical issues with the system that are related to the servers. The distribution method does not help to ensure 100% accuracy, for any operating conditions.

Conclusions

In large cities, especially during a pandemic, the problem of allocating seats in transport and building the most successful route is an urgent task. The study of four methods of distribution of seats in public transport. Their advantages and disadvantages are investigated. According to the results of the research, it became clear that the existing methods alone do not allow to effectively solve the problem of distribution of seats in transport, so it is necessary to either improve existing methods or develop new methods. Improving existing methods is possible by either combining several methods into one or adding certain elements that eliminate existing shortcomings or

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