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THE CASSETTE METHOD PRINCIPLES OF PASSENGERS TRANSPORTATION THROUGH THE INTELLIGENT TRANSPORTATION SYSTEM

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ПРИНЦИПИ КАСЕТНОГО МЕТОДУ ПЕРЕВЕЗЕННЯ ПАСАЖИРІВ ЗА ДОПОМОГОЮ ІНТЕЛЕКТУАЛЬНОЇ ТРАНСПОРТНОЇ СИСТЕМИ

У статті представлено опис використання касетного методу пасажирських перевезень за допомогою інтелектуальної транспортної системи, що базується на використанні безпілотних електрокарів, з урахуванням динаміки пасажиропотоку протягом доби. Представлений розрахунок необхідної кількості електрокарів у касеті для одноразового виконання плану перевезення пасажирів.

Ключові слова: касетний метод перевезення, інтелектуальний транспорт, розумний транспорт, інформаційна транспортна система, транспорт із частинами, що мають поділ

The article describes the application of the cassette method of passenger transportation, taking into account the dynamics of passenger traffic during the day by means of an intelligent transport system based on unmanned electric vehicles. The calculation of the required number of electric cars for the cassette for a one-time fulfillment of the delivery plan is presented.

Keywords: cassette transportation method, intelligent transport, smart transport, information transport system, transport with divided parts

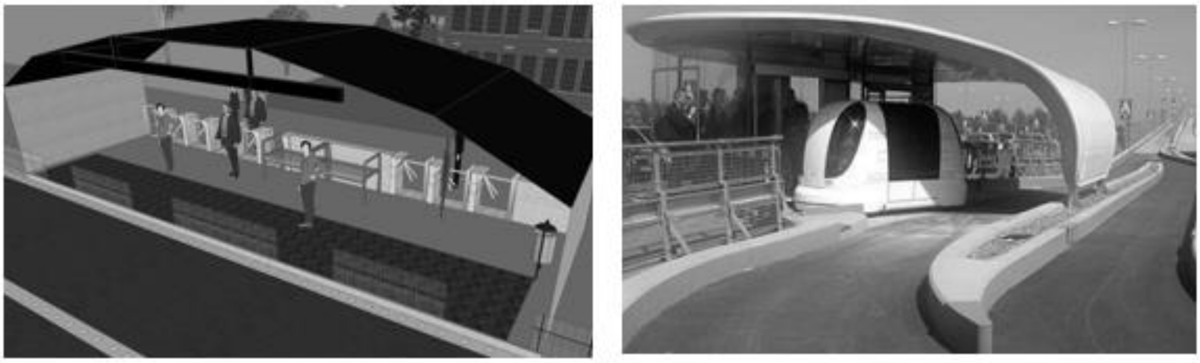
Introduction

The increase in population density has conditioned a revision of the current paradigm of urban mobility, based on the principle of “transport self-sufficiency of households,” formulated at the beginning of the 20th century by G. Ford. The modern perspective implies a radical revision of approaches to urban transport infrastructure as a whole: "Right of Way" (pedestrian priority), "Mobility-as-a Service" (car as a service, not a status attribute), "Shared Autonomous Electric Vehicles" (rent of unmanned vehicles). In general, the transport infrastructure of the city will be formed with the priority given to pedestrians and intelligent public transport systems over private road transport.

The article describes the concept of using the cassette method of transportation in the Intelligent Public Transportation System (IPTS) in a high-density traffic flow [1-5]. The application of this method aims at the rational use of the rolling stock of the transport system and minimization of the passenger travel time to the destination.

Description of the transport system

The Intelligent Public Transport System (IPTS) includes a cashless payment system to pay for travel tickets and register a passenger's application for service in the system (Fig. 1a), unmanned electric cars of small seating capacity (4-15 passengers, depending on the type of model). These vehicles are called infobuses [6], which move along a dedicated line (Fig. 1b) and the route of movement (Fig. 2).



a) Payment terminal b) Infobus

Fig.1. The elements of IPTS

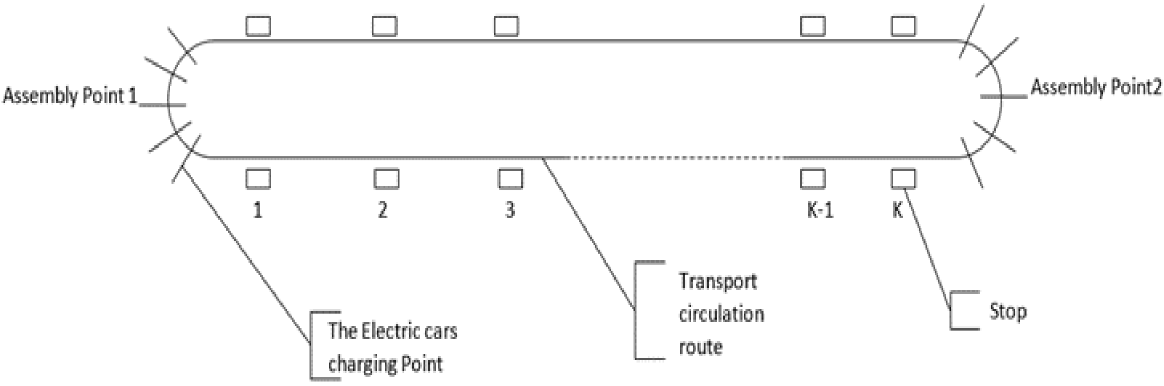


Fig. 2. The route of movement

When paying for the trip and passing through the terminal (Fig. 1a), the passenger also indicates the stop of the route, which he/she intends to reach. Thus, he/she makes a request to the transport system for transportation, which is transmitted to a single information center (system server) and is recorded there in the matrix of correspondences [7, 8]:

$$M = \begin{pmatrix} 0 & m_{12} & m_{13} & \dots & \dots & m_{1j} & \dots & m_{1k} \\ 0 & 0 & m_{23} & \dots & \dots & m_{2j} & \dots & m_{2k} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & \dots & 0 & m_{ii+1} & \dots & m_{ij} & \dots & m_{ik} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots & \dots & \dots & 0 & m_{k-1k} \\ 0 & \dots & \dots & \dots & \dots & \dots & \dots & 0 \end{pmatrix}, \quad (1)$$

$m_{i,j}$ – is the number of passengers, get on a bus at the stop i with intention to reach the stop j, $i, j = \overline{1, k}$. It should be noted that all elements of the matrix M from the main diagonal and under the main diagonal are equal to zero (because the passenger cannot get off at the stop where he/she got on the vehicle and cannot go "back"). The single information center (server) not only collects the requests from passengers, but also controls the remote fleet of infobuses (Fig. 1b). The server gets infobuses on the road, depending on the dynamics of passenger traffic (Fig. 2), for the service of requests registered in the system, so to slightly reduce their number.

If necessary, infobuses can be combined into cassettes [9]. The coherence of elements in the cassette are virtual, similar to that in road trains [10-11]. The electronics ensure the minimum safe distance between the infobuses in the cassette.

The cassette, which is a vehicle with separable parts [13], picks up all passengers from the stop. The last infobus of the cassette accommodates passengers traveling to the first stop of the cassette after the point of embarkation; in the penultimate, accordingly, on the second, etc. When approaching the first stop along the route, the last infobus separates from the cassette, slows down the speed and makes a stop to disembark passengers. The rest of the cassette keeps running with passengers to the next stops without reducing speed. After disembarking the passengers, the infobus catches up with the cassette that has gone ahead. Thus, passengers travel with a minimum number of stops during the journey, and the cassette saves energy reserves for movement, reducing the consumption of energy for braking and acceleration.

Figure 2 shows a linear route with k stops. This route has two route terminals and *k-2* intermediate stops. l_{ij} denotes distances between i stop and j stop, $i, j = \overline{1, k}$. The arrows indicate the intensity of the inbound passenger traffic for each stop, the quantity of passenger traffic is denoted as

$$\lambda_i \left[\frac{person}{min}\right], i = \overline{1, k}.$$

The principle of forming an infobus cassette for introduction on the route

V – total passenger volume of the cassette, V_{inf} – the capacity of one infobus included in the cassette

$$V = n_i * V_{\text{inf}}, \quad (2)$$

n_i – the number of infobuses cassettes delivering passengers from stop i.

The passenger flow density at each stop has its own characteristics, depending on the time of the day [14]. So, if there is an crowded public area geographically close to the stop, then one can expect an especially intensive arrival of passengers at this stop at a certain time interval of the day. For example, when citizens left work or, in an opposite way, go to work. Therefore, for each stop at a certain time, a different number of infobuses included in the cassette is required.

The calculation of this quantity can be made using information about the flow density at a given time at a specific stop, which is formed through the constant collection of requests from the terminals of the stop points and is periodically aggregated by the information center server.

It is possible to select both interval mode (at certain intervals) at times of low passenger traffic density, and the mode of accumulating a certain number of requests in the correspondence matrix for high and medium density of the passenger traffic.

$\lambda_i(t)$ – the density of the flow of passengers arriving at stop i at a certain instant of time t. It can be represented as a set of requests to travel from this stop to the next stopping points:

$$\lambda_i(t) = \sum_{j=i+1}^{k} \lambda_{ij}(t), \quad (3)$$

$\lambda_{ij}(t)$ – the flow of requests made to the transport system at a stop i for transference to the stop j. Then, it is possible to calculate the required number of infobuses for each stop using the formula:

$$n_{ij} = \frac{m_{ij} + \lambda_{ij}(t) * t_i}{V_{\text{inf}}}, \quad (4)$$

n_{ij} – the number of infobuses required to pick up passengers from a stop i to the stop j. t_i – time of travel of the infobus from the initial stopping point to the stop i (Fig. 2), which is the condition:

$$t_i = \frac{\sum_{j=1}^{i-1} l_{jj+1}}{v_{\text{inf}}}, \quad (5)$$

v_{inf} – infobus cassette speed, l_{jj+1} – distance between adjacent stops (Fig. 2).

Thus, a cassette can be formed from $n_i = \sum_{j=i+1}^{k} n_{ij}, i = \overline{1, k-1}$ infobuses to get it to the stop to transport passengers from that point.

It is possible to select both interval mode (at certain intervals) at times of low passenger traffic density, and the mode of accumulating a certain number of requests in the correspondence matrix for high and medium density of the passenger traffic.

Conclusion

The presented article describes an intelligent information and transport system based on mobile autonomous robotic vehicles and considers the methodology for calculating the required number of such vehicles to fulfill the passenger transportation plan formed by algorithms of the transport system, depending on the dynamics of changes in the density of passenger traffic on the route during the day. The relevance of the proposed system is due to the changing social and economic conditions in large cities and metropolitan areas because of the steady increase in the density of the urban population, as well as the modern possibilities of scientific and technological progress. The proposed cassette method of passenger transportation, taking into account the dynamics of passenger traffic, is a new step in organizing urban passenger traffic, since it involves an increase in the efficiency of using vehicles on the route, a more complete satisfaction of the clients' needs by reducing the travel time to the destination, and the reduction of costs from the city budget by saving electricity consumed by vehicles during transportation. The described model allows to make urban passenger transportation more flexible and adaptable to the constantly changing conditions of the saturated road transport environment of medium-sized and large cities and megalopolises, while bringing not only economic, but also environmental benefits providing a signify-cant increase in the capacity of the city transport system, a high level of travel comfort for the passenger. The novelty of the work lies in the use of permanently executed computer-information transport control without human intervention, providing both data collection and processing, analysis and decision making.

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RESUME

A. Shviatsova, **V. Shuts**

The cassette method principles of passengers transportation through the intelligent transportation system

This article is devoted to the description of the functioning principles of the new generation transport system since it is based on the use of unmanned vehicles and is able to adaptively respond to changes in the road and road environment.

The aim of this paper consist of improvement of quality and efficiency of passenger transport in the "loaded" urban transport environment. The relevance of the proposed system is due to the changing social

and economic conditions in large cities and megacities because of the steady increase in the density of the urban population, as well as the modern possibilities of scientific and technological progress.

The proposed in article cassette method of passenger transportation, taking into account the dynamics of passenger traffic, is a new step in organizing urban passenger traffic, since it involves an increase in the efficiency of using vehicles on the route, a more complete satisfaction of the clients' needs by reducing the travel time to the destination, and the reduction of costs from the city budget by saving electricity consumed by vehicles during transportation.

The described model allows to make urban passenger transportation more flexible and adaptable to the constantly changing conditions of the saturated road transport environment of medium-sized and large cities and megalopolises, while bringing not only economic, but also environmental benefits providing a significant increase in the capacity of the city transport system, a high level of travel comfort for the passenger.

The novelty of this development lies in the use of permanently executed computer intelligent control without human intervention or with his minimal participation, providing both data collection and processing, analysis and decision-making. This approach allows sending only the necessary transport volume to the route.

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