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HIGH CAPACITY ROBOTIC URBAN CLUSTER-PIPELINE PASSENGERS TRANSPORT

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A project of intelligent transport system is discussed in the article. The system is based on mass transportation of passengers by means of mobile autonomous robots. The robots are assembled in caravans on cluster basis. This new type of public transport system is aimed to increase mobility and flexibility of public conveyance. It also ensures significant economic benefits - since efficiency is almost equal to metro transportation but at the same time the cost of manufacturing and maintenance is much lower. The project is at the stage of conceptual design. Ongoing research is related to computer simulation of the system in different conditions and intensity of passenger traffic.

Keywords*: traffic, adaptive control, passenger traffic, rate of vehicle utilization, intelligent transportation system.*

1. Introduction

The increase in motorization and transport mobility of the population has led to increase of the city streets transport flow, causing revaluation of principles of traffic management, as well as an incentive to develop new forms of public transport. Statistical data of traffic on the main streets of the United States and Europe show that people spend (on average) from 1 to 2.5 hours a day to move around the city. That causes significant interest in improving traffic management and public transport in the city roads and main streets. The annual increase in the traffic load on the main highway is leading to a steady decrease of transport speed and the creation of traffic jams.

Private transport is not able to provide a high capacity as each car moves with an average of 1.2-1.5 person[1]. Therefore in order to avoid traffic jams it is necessary to unload the transport lines by expanding the performance of ground public transport approaching the performance of the metro. The costs of metro construction are too high (1km. of metro costs 40-60 mln. dollars) [2].

Transport with high performance should not interfere with other traffic participants or with the road network infrastructure, for example traffic lights. Achieving such an effect may be done by the diversification of different traffic flows through the levels. Hence, accordingly we have an underground, ground and elevated transport. The last one moves using overpasses. Construction of overpasses is about 4-8 times less expensive than construction of underground transport (metro). And from the standpoint of the safety of passengers such trucks are much safer than the subway. But elevated transport lines badly fit in urban infrastructure and distort the appearance of the city.

Thus, ground public transport with mass transportation of passengers is the best alternative urban transport of the future. Is it possible under conditions of intense ground transport flow? Oddly enough, but the answer is yes.

In this work we propose a new type of urban public transport - based on robots and information. It is capable of operating in an intensive environment of the streets and roads without interference from the other vehicles and also of transportation of the large numbers of passengers comparable to the subway. In contrast to the metro this type of transport is more energy efficient, as there are no escalators to move passengers to a station and to lift them from it.

The proposed type of transport is a system in which information processes (information gathering, information processing, decision-making) are carried out continuously and form the basis of the information transport systems. Violation of any of these processes, making the system unworkable. The vehicle in such a system is an electric car (without driver) called infobus with ability to carry up to 50 people. In contrast to the known means of passenger transport (bus, trolleybus, tram, etc.) that operate autonomously INFOBUS can only function as part of an information transport system.

2. Analysis of the urban transport of passengers

In transport practice in order to characterize needs of the urban population in the transportation and toanalyze systematically the conditions of passengers carriage category ‘passenger traffic’ is used [3], which is described by its’ intensity. Data on the intensity of traffic flow is used to select means of transport with required capacity and to determine the necessary number of vehicles.

On each route can be used vehicles with the similar or different capacity. Selection and justification of the vehicle with necessary capacity for qualitative passenger service, more rational and efficient use of vehicles is a complex management task in conditions of incomplete and often inaccurate information. The capacity of the vehicle is set according to the distribution of passenger traffic and the uneven nature of its time, the length of the route and the direction it follows. Information is probabilistic in nature and presented in the form of points of the first, second and third distribution order of the random variable (ie the math expectation, variance and capacity excess in passenger traffic).

The decision-maker (DM) [4] in such difficult circumstances, should have the relevant qualifications, experience and even intuition. Wrong decisions lead to losses. For example, the use of small vehicles in case of a high traffic capacity increases the required number of passenger vehicles (drivers) and increases the load of the streets. On the contrary, exploitation of large vehicles on the route with the low intensity of passenger traffic results in too large intervals of motion, unnecessary passenger waiting time and, in connection to that, in the great inconvenience to the public. The main criterion for the choice of optimal capacity of the vehicle for a particular route is primarily suitable motion interval.

Thus, the current state of passenger traffic has the following disadvantages:

- The lack of accurate, objective information in real time about the capacity of passenger traffic on the route which prevents the adoption of optimal solutions and leads to economic losses;

- The presence of the human factor in making responsible decisions.

And third, very important, and perhaps the most important drawback is the small range of vehicles of various capacities for more accurate coverage of the changing traffic flow. This disadvantage in the modern logistics of urban passenger transport can not be overcome, because the industry is not able to produce, say, twenty types of buses of various capacities.

Even if hypothetically assume that the desired range is made, it is difficult to find a person to effectively manage it. Moreover, the control decisions are based on an integrated (averaged) last information on passenger traffic. And the second question. Where and how to store such a diverse fleet of vehicles?

Since the first urban passenger vehicles appeared (more than 100 years ago) and provided transportation through urban transport routes for the population, the organization of transportation has not been changed. Here the ‘organization’ refers to the whole range of activities related to the planning, control and management of passenger vehicles in the city. This stability is caused by the immutability of the vehicles themselves.

The development of information technologies makes it possible to reconsider the concept of the organization and management of modern public transport. At the same time the diversity of urban passenger transport vehicles should be abolished and reduced to a transport unit of rated capacity - infobus. Depending on the capacity of passenger traffic on the route (measured by sensors in the automatic mode) computer sends on the route a number of infobuses so that to their total capacity was equal to or slightly greater than the capacity of passenger traffic.

This infobuses then are to be gathered into cassettes (hence the term "cassette type of transport"), consisting of a number of different units. The cassette can consist of different number of infobuses: one, two, etc. It depends on the capacity of passenger traffic at the current time. Perhaps collect a vehicle of any capacity required on the route now, quickly and at no cost, as the mechanical connections in the cassette absent. Connection virtual as in road trains [5]. The minimum safety distance between INFOBUS cassette provides electronics.

This transport system is adaptive to passenger traffic. It is timely and operative changing and adapting to the passenger traffic capacity. In connection with this points system is the most economical one and best meets the transport needs of the population as vehicles will not be run half-empty or too crowded.

3. The base of cassette assembly of buses - European system SARTRE

One of the promising projects that could change the current situation in the use of private and public transport by creating a safe caravan or the so-called road trains is a system SARTRE. Founded by the European Commission in September 2009, the project Safe Road Trains for the Environment (SARTRE) allows several machines to move along the road in an organized column. SARTRE was initiated to study the creation of strategies and technologies for testing the caravan of vehicles on regular public roads [5]. The project could not be better suited to address a similar problem - cassette assembly of infobuses into a single trailer.

The project is a system in which the cars follow the leading truck vehicle with professional driver. Cars line up with a distance of 6 m and fully repeat the movements of the leading truck that allows drivers to rest, eat, talk on the phone. Each one of the vehicles is able to leave the column on request. The composition of the column changes from time to time: some drivers take control in their hands, others join and "inferior wheel '(Figure 1).

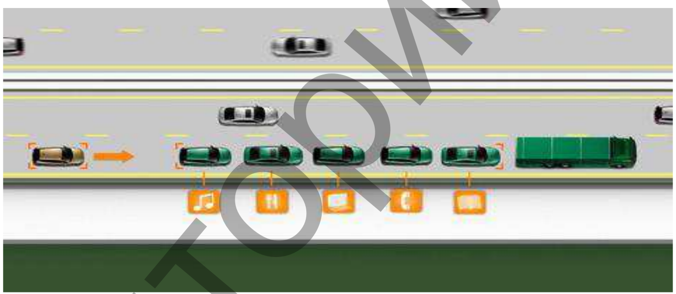

Figure 1 – The road train of the SARTRE project

The driver knows it is possible to join the road train moving ahead by satellite navigation, the driver transmits a signal of the intention "to become the wagon" to the head car chauffeur. Similarly, it should signal the intention to continue the path on their own.

Insertion of trucks on the roads with private vehicles provides a number of benefits (approximately 20% reduction of emissions), security benefits (reduction of accidents caused by the action of the driver) and the reduction of congestion (smoother traffic flow with a potential gradual increase in traffic bandwidth) .

In January 2012, the SARTRE project entered its final phase with the demonstration of a leading train truck driven three cars. Testing was conducted on Hällered polygon in Sweden. The test vehicles have proved to be excellent at a speed of about 90 km / h, fully repeating the move of the leading truck.

To implement the system in the information transport system (or in other words - cassette assembly of infobuses) it is required to equip each infobus with rangefinders, onboard computers and wireless communications. Fig. 2 shows a train consisting of N infobuses. The number of infobuses joined into a train is determined by the capacity of passenger traffic on the route line at the current time. Information about the number of passengers from the route stops comes from the camera to the server, which calculates the required number of infobuses to join the trucks.

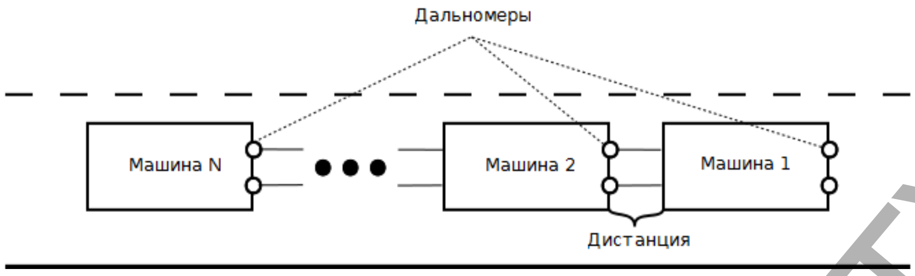

Figure 2 – The road train with N infobuses

The process looks like this. The driver of the infobus at the last stop gets the signal to start the route. When he moves to the beginning of the route his leading car is followed by the number of infobuses that is necessary exactly to cover passenger capacity on the route. The server performs calculations for each stop on the route to predict the possibility of increasing of the number of passengers as a stop service is performed with a delay in the arrival time on a specific train stop. After the route assignment and before the next lap to the train can be joined or detached a number of infobuses depending on the situation with passenger traffic on the route for the upcoming tour.

Thus the control system of the vehicles in this project is adaptive to the main parameter - passenger capacity on the route. This ensures high efficiency of the system and its attractiveness to passengers in terms of comfort of travel in the evenly filled infobus cabin, as well as guaranteed acceptable waiting time for the vehicle at the bus stop. Such features are not available in currently operating management systems of urban passenger transport.

4. The movement of buses in the streets environment

It is necessary that the streets environment was as neutral as possible to the infobus motion. It is impossible to fully achieve zero impact on the infobus vehicle, like that can be done with the subway . You can reduce this impact through the provision of special lanes as is done for public transport such as bus or trolley.

The disadvantage of this separation is reduction of the number of lanes for the other road users and with this the decrease in road bandwidth. Hence the requirement for the width of infobus: it should be minimal and be like 1-1.5 meters. This choice is made because of two factors. The highway lane width is equal to 3-3.5 meters. One lane can be divided into two strips - and as a result we get two lanes (forward and reverse) for the infobuses.

Infobuses lanes are directly adjacent to the curb and is separated from it by fencing and from the main road - by a solid line (Fig. 3). In some cases, can be used the simple fencing made of a continuous line of plastic cones. The second reason why the infobus should be narrow is connected with the process of loading the passengers in the cabin. For quick discharging (download) the infobus has a low floor (on the same level the platform is) and also has a lot of doors.

Time of unloading and loading passengers is limited and shall not exceed, in best case, the duration of the cycle of traffic lights (80-120 sec.), or be aliquot to it. This will let infobuses to cross intersections with traffic lights without stopping in a coordinated ‘green’ wave, because after stopping it starts to move from the very place in traffic light cycle where it was stopped.

Figure 3 – The road buses of the two infobuses at the crossroads

The time of loading and unloading passengers in the system is 20 seconds. That means every 20 seconds the infobus departs from a stop with the maximum number of vehicles in a train up to six at rush hour. Limits for the number of Iinfobuses in a train are connected with the recommended length of the stop (30 meters). With a infobus length of 5 meters on the stop up to 6 infobuses can be placed. Whis the capacity of 50 passengers infobus train which consists of 6 vehicled within one minute transports up to 1,000 passengers, and for 1 hour - up to 60 000, which is comparable to the performance of the metro.

If the traffic lights object is off-line (not included in the plan for coordination) the system responds with the start time from the stop in order to pass the current traffic lights smoothly. To do this the "Mobile Assistant to the driver" [6] system is used, which at any stage of infobus movement indicates the time remaining for a green phase of traffic lights. The system indicates the recommended speed for non-stop travel. Some complex intersections infobus can pass through the underground crossing as shown in Figure 4.

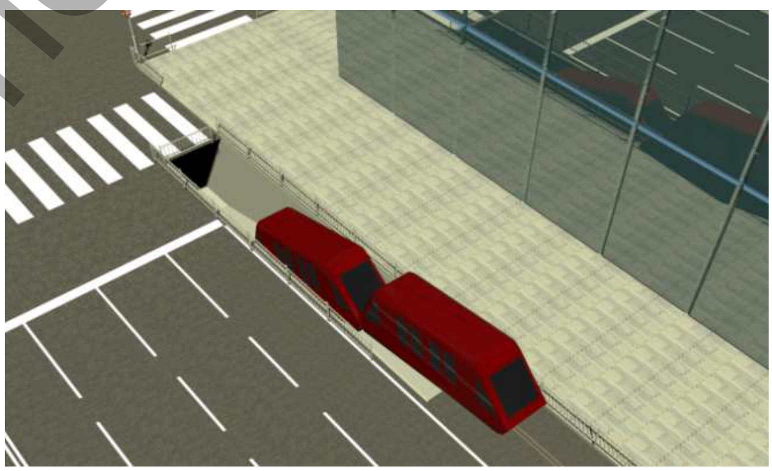

Figure 4 – Underground crossing on difficult crossroads

Each INFOBUS is equipped with a computer, GPS-navigator, the device for communication with the main managing computer in the system and with other infobuses, sensors providing security. On-board computer monitors all activities (tracking the position of the car, speed, doors, etc.). [7] Infobus has a different security systems, including a buffer, which is a rubber seal on the back and the front.

5. Conclusions

A new type of urban public transport is informational. This type of transport is capable of operating in a high-capacity environment of the street without interference from the other vehicles and transport large numbers of passengers comparable to the subway. This type of transport is more energy efficient than the existing transport systems. This transport system has no negative influence of the human factor since the system is fully autonomous and operates automatically to service requests from the passengers.

The proposed form of transport is a system in which information processes (information gathering, information processing, decision-making) are carried out continuously and form the basis of the information transport systems. Violation of any of these processes makes the system unworkable. The identity of a vehicle is an electric car (without driver) which can transport up to 50 people (called infobus). In contrast to the known means of passenger transport (bus, trolleybus, tram, etc.) that operate autonomously infobus can only function as a part of an information transport system.

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