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Demand-capacity coordination method in autonomous public transportation

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Abstract

Technology of autonomous vehicles (AVs) is getting mature and some types of autonomous public transportation have been successfully tested. However, the replacement of conventional public transportation requires new planning and operational methods. The research questions were how to designate stops, routes, operational time, travel frequency and how to model the seat reservation process in order to satisfy personal requirements of travelers. As the operation of the new transportation system is to be derived from the user demands it has been investigated and described in detail, which was the base of the demand-capacity coordination method. Both the preliminary capacity planning and the real-time coordination methods have been developed with special focus on the required data structure and the information management processes. The methods are to be applied during creation of this advanced, high quality mobility service.

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Keywords: demand-capacity coordination, autonomous public transportation, planning and operational methods, seat reservation

1. Introduction

Autonomous cars are unmanned (driverless) vehicles that move without human intervention and being equipped with a number of high-tech sub-systems. AVs analyze the current situation on the road and make reliable decisions concerning the vehicles' manoeuvers, such as: lane changing, safely crossing the intersection, overtaking other

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vehicles, pulling over and riding along the planned path (Owczarzaka and Żak, 2015). The largest advantages of unmanned vehicles according to many researchers (Basulto, 2013; Jakubiec, 2014; Szymczak, 2013; Yeomas, 2014) are as follows: improvement of road safety, elimination of restrictions related to age and disability of passengers, possible increase of the road space (if the utilization of AVs is reasonable), reduction of the required parking space in the city centre and environmental friendliness (assuming they are 100% electric vehicles), associated with reduced emission of harmful compounds into the atmosphere. The most frequently mentioned disadvantages of driverless cars are (Basulto, 2013; Yeomas, 2014): lack of legal regulations concerning unmanned vehicles, high risk of failure, high cost of investment. Despite these concerns, the authors claim that the advantages of AVs exceed their disadvantages.

The advancements in modern technology made possible the comprehensive integration of essential systems and data for AVs operation. The most relevant technological results:

- Global Positioning System (GPS) – Satellite-based global location and time reference of objects (vehicles) for accurate and constant position tracking.
- Inertial Navigation System – Monitors and calculates positioning, direction and speed of a vehicle with motion and rotation sensors on-board.
- Laser Illuminated Detection And Ranging (LIDAR) – Laser detection sensors to identify surrounding objects, or terrain, with data for precision measurements of distance to the objects.

The synchronization of these advanced positioning systems collectively provides the decision-making data. These are necessary for an AVs to be aware of its position and movements in relation to the surrounding conditions (Arseneau and Roy, et al. 2015).

An important function of AVs is communication between themselves (V2V - Vehicle-to-Vehicle interaction) and with the infrastructure (V2I - Vehicle-to-Infrastructure interaction). Both ways of communication are possible due to the installation of communication sensors and antenna transceiver in AVs and in the road infrastructure (Basulto, 2013; Yeomas, 2014). These solutions ensure that vehicles can communicate with each other, send warnings about the existing dangers, inform each other about the traffic congestion, etc.

Considering all above mentioned facts it is reasonable to state that public transportation service can be partially based on AVs in the near future. Consequently, it requires and implies introduction of new demand-capacity coordination method considering personal requirements of travelers.

The remainder of the paper is structured as follows. In Section 2, the situation analysis is provided by review of the existing services. The main features of the new demand-capacity coordination method are determined and summarized in Section 3. In Section 4, the information system model of demand-capacity coordination method is presented. The paper is completed by the concluding remarks, including further research directions. This paper does not provide a novel designation method for predefined stops as well as details about fare system and charging process. The objective of the article is to elaborate the principle of the new service based on autonomous minibuses considering certain segments of route.

2. State of the art

Two approaches can be used for designation of stops and routes related to autonomous bus transportation:

1. Alex Forrest and Mustafa Konca (2007) suppose that it is enough to change convenient buses to AVs providing that specific routes and stops remain as nowadays. The problems would arise from actions of conventional vehicles as drivers may lose control and cause accidents with AVs. The ideal situation is when the AV systems have matured to the point that nearly every vehicle on the road is autonomously driven. This would allow to avoid accidents on the road.

2. Designing an Automated Demand-Responsive Transportation Service (ADRTS) providing individualized rides without fixed routes or timetables.

Many considered concepts of application of AVs in urban transportation system assume that unmanned cars operate as the type of Public Transportation On Demand (PTOD), which is often called as flexible public transportation. In this system demand for transportation services are coordinated with transportation supply associated with the availability of capacity and the adjustable way of moving vehicles in the transportation network