Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 10 (2015) 472 – 482

Transportation Research Procedia

www.elsevier.com/locate/procedia

18th Euro Working Group on Transportation, EWGT 2015, 14-16 July 2015, Delft, The Netherlands

Design of passenger public transportation solutions based on autonomous vehicles and their multiple criteria comparison with traditional forms of passenger transportation

Łukasz Owczarzak[a], Jacek Żak[a]*

[a]*Poznan University of Technology, Faculty of Machines and Transportation, Logistics Division; 3 Piotrowo street, 60-965 Poznan, Poland*

Abstract

In this paper, the authors present their concept of public transportation on demand based on autonomous vehicles. They develop several passengers' transportation solutions based on driverless vehicles and compare them with traditional forms of passenger transportation (tram, bus, taxi and individual car). The authors carry out a multiple criteria evaluation of all eight considered variants. They formulate the decision problem as a multiple criteria ranking problem. Thus, a consistent family of evaluation criteria is constructed. It includes the following measures: travel time, travel costs, comfort of travel, reliability, timeliness, availability, environmental friendliness, safety. Based on the analysis of stakeholders' interests the model of preferences is defined. It is composed of two major elements: importance of criteria and sensitivity of the decision maker (DM) towards changes of the criteria values. A series of computational experiments is performed. In the computational phase a multiple criteria ranking method – Electre III/IV is applied to generate the final ranking of all considered variants – transportation solutions. The position of variants based on autonomous vehicles is thoroughly discussed.

Peer-review under responsibility of Delft University of Technology

Keywords: autonomous (driverless) vehicles; public passenger transportation on demand; multiple criteria evaluation

1. Introduction

The continuous development of metropolitan areas and the constant extension of urban territories, often called "urban sprawl" (Vuchic, 2007), increases the demand for overcoming the critical problem of covering long distances

* Corresponding author. Tel: +48 (0-61) 665 22 30
E-mail address: jacekzak@put.poznan.pl

Peer-review under responsibility of Delft University of Technology
doi:10.1016/j.trpro.2015.09.001

by passengers while minimizing their travel time and costs. The provision of efficient passenger's transfer strongly depends on the performance of transportation services in the city and suburban areas. Many efforts have been made to enhance urban transportation operations and facilitate the movement of people. At the same time one of the critical problems in the urban areas is the growing number of vehicles and inadequate capacity of the roads, which result in traffic congestion and extended travel time for passengers (Rudnicki et al. 2007; Vuchic, 2007). Another issue is the availability of higher comfort/standard of travel for passengers that would be willing to accept significantly higher costs of travel. In addition, most of the means of transport used in the urban areas have a negative impact on the environment - they emit a significant amount of harmful chemicals and fumes into the atmosphere (Wesołowski, 2003). As a consequence of the above mentioned urban transportation problems emerges the need to search for and implement new transportation solutions which could reduce (eliminate) these negative effects. One of the promising and useful concepts and ideas is the implementation of electric, autonomous vehicles (AV) in the urban environment.

Autonomous cars are unmanned (driverless) vehicles that move without human intervention and use for this purpose a number of high-tech sub-systems and devices. These modern, advanced, computer based tools the AVs are equipped with, provide quick analysis of the situation on the road and generate reliable decisions concerning the vehicles' manoeuvers such as: lane changing, safely crossing the intersection, overtaking other vehicles, pulling over and riding along the planned path. The results of several research and road tests concerning AVs have been reported, including the analysis of their suitability for operating in urban passenger transportation systems (Anderson et al. 2014; Basulto, 2013; Lavrinc, 2013).

According to many researchers, there are several benefits associated with the application of AVs in urban transportation systems (Basulto, 2013; Jakubiec, 2014; Szymczak, 2013; Yeomas, 2014). The largest advantages of unmanned vehicles 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 central sectors and environmental friendliness of the cars (assuming they are 100% electric vehicles), associated with reduced emission of harmful compounds into the atmosphere. Critics of AVs highlight their flaws and imperfections. The most frequently mentioned disadvantages of driverless cars are (Basulto, 2013; Yeomas, 2014): lack of legal regulations concerning unmanned vehicles, possible increased congestion resulting from the reduced road space, high risk of failure, high cost of investment, including the vehicles themselves and the reconstruction of the infrastructure.

Despite these concerns, in the authors' opinion AVs may represent a real competition for the existing forms of transportation. They may also substantially contribute to the concept of door-to-door service in the urban environment. As presented above, the authors claim that the advantages of AVs exceed their disadvantages.

2. Theoretical background of research

2.1. Major characteristics of autonomous vehicles

Nowadays AVs are equipped with complex and advanced IT and communication systems. It makes the vehicle multidimensional orientation and its independent movement possible (Anderson et al. 2014; Likhachev et al. 2014). Usually, an on-board system of the AVs comprises a digital map presenting the network of the roads and streets coupled with the GPS system, a set of sensors located in various parts of the vehicle and the central unit. The basic element of the system is a customized digital map with additional information about the network characteristics, such as: the width of the lanes, the speed limits on certain segments of particularly roads, the location of traffic lights and road signs, the heights of the curbs. This information combined with the GPS system enables the on-board computer system to analyze the current position of the vehicle on the road and to demonstrate its movements (Likhachev et al. 2014; Naranjo et al. 2008; Trzeciak, 2012). The sensors constantly analyze the situation around the vehicle, provide information concerning road condition, detect obstacles on the road and recognize other road warnings and threats. One of the most commonly used sensors AVs rely on is the detector based on LIDAR (Light Detection and Ranging) technology. The LIDAR device, mostly placed on the roof of the vehicle, allows for the transmission of data about the environment and situation on the road. In addition to the above mentioned set of devices there are plenty of other sensors that can be possibly included in unmanned cars. Some of them are located