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The deployment of automated vehicles in urban transport systems: a methodology to design dedicated zones

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Abstract

Vehicle automation is not yet a reality which casts huge speculation of what will really happen when implemented in the near future. The effective deployment of such novelty, especially full automation, foresees potential impacts at different levels, the most direct ones being on the mobility level. Since the deployment of fully automated vehicles cannot be realized instantaneously in all areas of a city, a transitional phase must be assumed to mitigate the changes to come. It is critical to devise policies in order to implement such technology to leverage the benefits that it may bring. According to a literature review, deployment on urban networks revealed to be a gap in the literature. In order to address that gap, we want to support city planners by developing a strategy of integration for such technology into urban networks. At a traffic level, a strategy of dedicated zones for automated vehicles will be settled. We develop a model whereby the aim is to minimize the congestion problem through dedicated links where only automated vehicles can drive. A traffic assignment approach is used where the minimization of the sum of link travel times is part of the objective function. The number of automated vehicles is changed in function of a penetration rate. Each scenario is simulated and compared. This study begins the discussion of how to help public authorities plan the deployment of such automated vehicles and bring improvement to traffic in cities.

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Keywords: automated vehicles; transport planning; traffic; optimization; simulation

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1. Introduction

Over the last century, transportation systems evolved due to social and economic pressure alongside technology development. The performance of these systems creates impacts at several levels and influences accessibility and mobility of cities. The enhancement of mobility sustainability, a concern that was raised in the meantime, is occurring gradually and is mainly fostered by urban planning strategies, new technologies and the improvement of public transport within cities. In the past two decades, an increased interest has been growing towards vehicle automation which brings great potential changes on mobility in urban centres. In fact, the advancements in vehicle automation might enhance the current mobility system but there are concerns that it might disrupt the current transportation paradigm in a way that is still difficult to foresee.

In urban environments, automated vehicles (AVs) are believed to begin as speedy last mile taxis by 2020 whereas automated taxis will only become a reality by 2028. The deployment of AVs in urban environments is expected to start with segregated lanes and then with dedicated lanes by 2020 and mixed with conventional vehicles (CVs) by 2028 (Zlocki 2014).

The research done so far involving these topics is nearly inexistent. The following study is an initial experiment of a research focused on the AV deployment in urban centres. Therefore, this initial paper is focused on the design of dedicated links that will help to form zones/cordon areas for automated vehicles-only policy. We believe that such strategy is promising to achieve more effectively the benefits that AVs might bring, especially assuming the existence of V2I (vehicle-to-infrastructure) communication where is possible to control AV traffic.

This paper is majorly focused on traffic improvements, i.e. to minimize the sum of link travel times of the network in a "system approach". The following model comprises a benefit analysis which compares a previous scenario where AVs don't exist with a futuristic scenario where AVs circulate in their dedicated zones more efficiently but also in the rest of the network mixed with CVs. The model computes the amount of travel time saved between the preceding scenario and a scenario with dedicated roadways for AVs. Additionally, a walking penalty occurs to parts of the network where CV cannot travel. Also, an infrastructure cost for V2I communication is considered to each AV dedicated link.

The paper is organized as follows. Section 2 presents the literature review. Section 3 proposes a mathematical model to select dedicated links. Section 4 documents the numerical experiments in a small network. Finally, Section 5 draws the conclusions and future work.

2. Literature review

The literature regarding automated vehicles is scarce and disperse. Most of the significant existent research covers the vehicle technical features and the forthcoming impacts in interurban traffic environments, mainly focused on traffic capacity (Correia et al., 2015).

The few studies specifically related with deployment staging of AVs are intended to interurban highways. In 1997, van Arem and Tsao stated two approaches of deployment: the geographical approach where it is implemented in one step and expand geographically; and the functional approach, that considers that the deployment cannot be realized suddenly once considerable difficulties may be encountered in reality. Also in 2000, Shladover stated different paths for functional deployment, noticing that it can occur differently over regions: ones with connectivity and adaptive cruise control and, in other regions, with only dedicated lanes. Our paper follows the functional approach where a transitional stage and intermediates steps (e.g. penetration rate) must be identified and optimized to best adapt the technology towards reality.

Research studies are scarce in urban areas where such deployment is expected to have significant impacts that are difficult to determine because of the uncertainty about AV and its interaction with pedestrians, cyclists and CV. Milakis et al. (2017) listed the impacts that AV deployment might bring and divided in three ripples that are interdependent with each other. This "ripple effect" model portraits the effects that AVs might bring in mobility, urban form and societal implications, respectively. Our paper is majorly focused on the improvement of traffic (mobility ripple) to calculate the optimal scenario that achieves more societal benefits.