Inconveniences from the design of AV subnetworks: when walking is the only alternative

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Abstract

AV subnetworks is a way to deal with an automated traffic and its technological need that will likely increase during the AVs deployment period. This strategy carries many benefits, yet some inconveniences are worth to mention. One of them relies on the fact that the design of AV subnetworks is often in practice focused on mitigating congestion in the peak-hours. However, designing for the most congested hour can be quite delicate when such a strategy is fixed throughout the day. This paper focuses on the lower-level decision problem, i.e., the traffic distribution during the transition period while AVs are being deployed in urban areas and AV subnetworks are expanding. A novel formulation guarantees that CV trips starting inside AV subnetworks throughout the day aren’t ignored – this means giving a new alternative mode of transport, for example, walking. This paper evaluates throughout the day when such situations would likely occur in a case study of the city of Delft, in the Netherlands, in two scenarios with AV subnetworks. The experiments revealed that walking is somehow inevitable when AVs reach 75% of the vehicle fleet – increasing travel costs up to 26.0% and 43.8%.

1. Introduction

Subnetworks for automated vehicles (AV) are a way to deal with automated traffic and its technological need that will evolve during the AVs deployment period. The main objective of this paper is to debate when the design for peak-hours, commonly used for this type of road network design problems (RNDP), can create situations where the segregation of the network no longer allows the circulation of some CVs owners and walking becomes the only alternative. This paper is an extension of a previous article (Conceição et al., 2020).

2. Methodology: a nonlinear programming model

We present a new model formulated in nonlinear mathematical programming to perform the trip distribution throughout the day and the transition period (different AV penetration rates) where walking appears as a very expensive alternative to detour AV subnetworks. A user-equilibrium among AVs and CVs is performed. The following model is an extension of a previous formulation (Conceição et al., 2020) to include the walking cost – see (1).

Minimize(Cost) = \( VOT^\text{car} \sum_{(i,j) \in R} \int_0^{t_{ij}} t_{ij} h_{ij} df + VOT^\text{walk} \sum_{(i,j) \in R} \sum_{(o,d) \in P} w_{ijod} \frac{h_{ijod} L_{ij}}{r} \) (1)

3. Application to the case study: the city of Delft, the Netherlands

The results of a case study, the city of Delft, in the Netherlands, are discussed for the whole day with shifting demand, on two scenarios created with distinct planning strategies (Conceição et al., 2020) - see Fig. 1.

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4. Conclusions

Through the application in the scenarios created for the case-study of Delft, such situation (walking) only happened for significant shares of AVs, 75% onwards - which is explained by the widespread of AV subnetworks in these stages. Travel costs can rise up to 26.0% and 43.8%, depending on the scenario – which is significant enough to reconsider the usual practical design for the peak hour in transport planning. Such a design will ignore different mobility patterns and shifting trip patterns. Nevertheless, it is also shown that AV subnetworks can decrease the daily average degree of saturation (a congestion traffic indicator) by 8.8% and 13.1%. It is also obvious that throughout the day, congested roads (with a degree of saturation over 75%) are essentially reduced when AVs surpass 50% of the vehicle fleet. CV delay is also reduced in the latest stages of the transition period, whereas AVs seem to benefit from the beginning. CV distance is mainly affected and worsened by AV penetration rates 75% onwards.

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References