Spatial impacts of autonomous vehicles compared to railways

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Summary of Abstract

Within the Netherlands, commuting between cities is a daily routine and mode of choice is either the private vehicle or public transportation by using for instance trains of the Nederlandse Spoorwegen (NS). In the future, automated vehicles (AVs) could develop themselves into an *individual* form public transportation and thus, weaken established *collective* transportation such as commuter rail.

Aim of this paper is to estimate how much space AVs will require for a fictional replacement of a given railway service.

At first, the number of AVs was estimated, based on different AV types and in relation to different passenger demands. At second, spatial occupation of all AV types was estimated, based on vehicle speed and occupancy. The result was compared to the spatial occupation of an established railway service.

The faster AVs operate, the faster their spatial impact increases. With the objective to keep spatial occupation on the level of a given railway service, the number of passengers transported by AVs decreases with increasing speed. A (public) transport system on AV could transport up to 11 times less passengers than the investigated railway service.

As a mode for mass transportation, AV's space occupation would be highly inefficient. Associated to railways, similar results are expected for MRT, LRT and BRT. In this context, collective transport modes should be prioritized and automation of trains shall be investigated. However, AV offers potential for low occupied busses or public transportation in rural areas and therefore is potential for first- and last-mile transportation.

Abstract

Introduction:
"Automated Vehicles" (AVs) are proposed as promising new mode of transportation worldwide and along with increasing automation expectations rise towards vehicle capabilities. As an example, AVs are thought to enable less congestion, shorter headways and energy efficiency [1]. AVs are tested in Sion, Lausanne or Masdar as well as in the Dutch environment of Ede-Wageningen [2, 3, 4, 5].

The Netherlands are one of Europe's smallest but most dense populated countries. [6]. Commuting between cities is a daily routine of many people are done by private vehicles or trains [7]. AVs could become a more *individual* form public transportation in the future. And therefore, weaken established *collective* transport modes such as commuter trains. On the other hand, AVs could strengthen public transport by enhancing the first and last mile.

A major concern within a small and dense country like the Netherlands is the efficient usage of urban and rural space. However, the effect of AVs on spatial issue's is still not clear either and due to the density of the Netherlands, it can be discussed, that fully automated vehicles potentially replace national railways services in the future. Thus, replacing a given railways service by AVs will impact spatial usage and availability since it will also require space along a given or proposes (road) infrastructure.

Objective:
In this paper, the focus is on the number of AV needed and space those AVs require in order to replace a given railway service of the Netherlands. Spatial occupation of different AV types is estimated in relation to different passenger demands and the results are compared to the spatial occupation of an established railway service.

Methodology:
The *number* and *spatial impact of different AV types* (Automated Car, Masdar PRT, EasyMile EZ10, Singapore GRT, Navya Arma) is calculated by using variable *passenger demands*, variable *vehicle speed* and variable time headway. Subsequently, this value was compared with the spatial impact of the current fleet of intercity and regional trains from the Nederlandse Spoorwegen N.V. between The Hague Centraal and Utrecht Centraal.

The *number-AV per type-AV* was estimated by dividing various passenger demands by capacity per type-AV and multiplied with occupancy factor per type-AV.

The *spatial occupation of the estimated number-AV* per type-AV is calculated as follows:

1. Time headway is transformed into space headway (via m=v*s).
2. Estimated space headway (depending of *speed*) is added to vehicle length (depending on *type-AV*).
3. This summation of space headway and vehicle length is then multiplied with the vehicles' width, resulting in *spatial occupation per type-AV*.
4. The occupied space per type AV is then multiplied with the estimated *number-AV per type-AV*, resulting in the *spatial occupation of the estimated number-AV* per type-AV.

The spatial occupation of the estimated number-AV per type-AV is then compared to the above mentioned special occupation of the train service. Calculations were made using Excel 2016 (Microsoft Office 2016, USA).

Results:
The faster AVs operate, the faster their spatial impact increases. With the objective to keep spatial occupation on the level of a given railway service, the number of passengers transported by AVs decreases with increasing speed. Figure 1 illustrates where spatial occupation of AVs (veh/hour) and railways (trains/hour) is equal. The area left of the graph indicates where AVs occupy less space than railways (AV < Rail); right of the graph indicates where AVs occupies more (AV > Rail). The further away from the graph, the more (or less) space is occupied by AV.

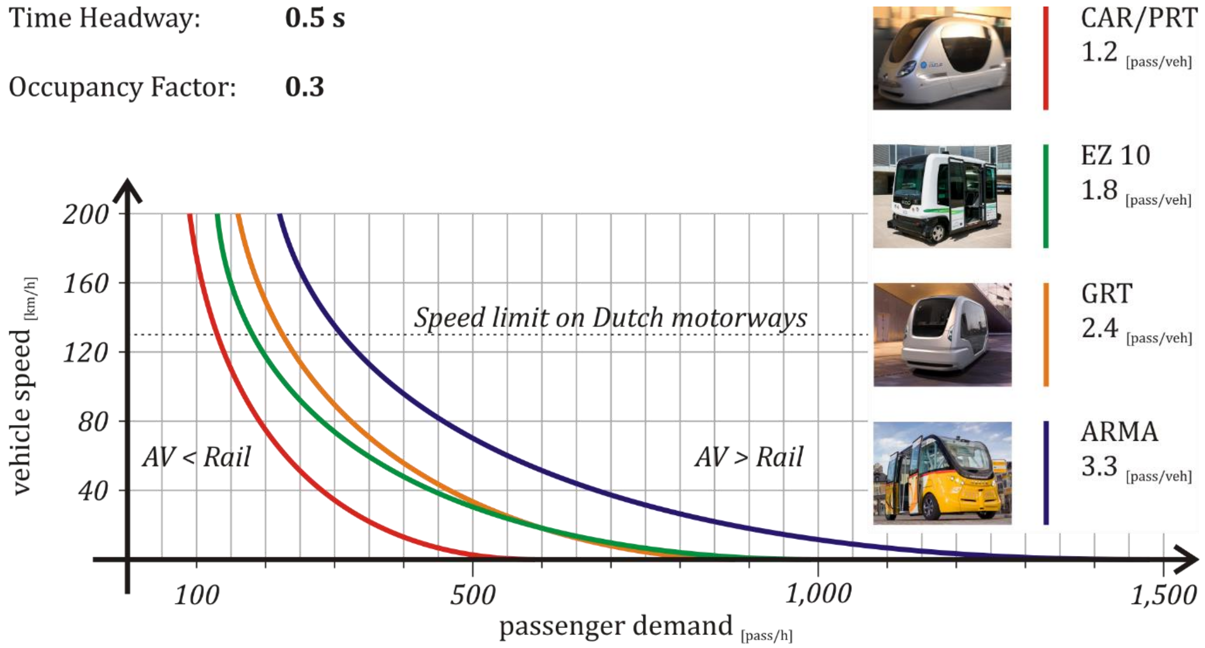

Figure 1: Equal spatial occupation of AVs (veh/hour) and railways (trains/hour)

As example: The investigated railway service has a spatial occupation of **4,420.65 m²** and offers **1,610 pass/h** transit (calculated with an occupation rate of 0.3). AV occupy the same amount of space but are capable to transport **100** to **140 pass/h** (160-120 km/h respectively). Thus, a (public) transport system based on AV could transport up to **11 times less** passengers than the investigated railway service, considering spatial occupation of both modes is equal.

Conclusion & Recommendations:

The number of AVs needed to replace a railway service would require a huge fleet of vehicle at first, which themselves would occupy more space than a given train service.

As a mode for mass transportation, AV's space occupation would be highly inefficient and collective transport modes should therefore be prioritized. Associated to railway services, similar results are expected for MRT, LRT and BRT. In this context, the automation of trains shall further be investigated. However, AV offers potential for low occupied busses or public transportation in rural areas and therefore a potential efficient mode for first- and last-mile transportation.

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