THE SUSTAINABILITY IMPACT OF AUTONOMOUS VEHICLES

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ABSTRACT

With powerful computing and AI systems becoming ubiquitous in our increasingly networked world, fully autonomous vehicles (AVs) are rapidly becoming a reality. This technology has great potential to improve road traffic safety, private mobility, and our excessive parking needs. However, claims that AVs will improve the environmental impact of transportation CO_2 emissions and the social and economic impact of traffic congestion require further examination. Whether or not AVs will also have a positive impact on traffic congestion and transport emissions depends on how the introduction of this technology is tackled by policymakers.

It has been proposed that AVs will improve congestion and consequently CO_2 emissions as safety improvements will allow for smaller, lighter, and faster vehicles, increasing vehicle throughput. It has also been suggested that the increased attractiveness and mobility associated with AVs could result in a rebound effect. This could lead to a shift from public transport and low impact modes such as walking or bicycle to private vehicle transport, increasing congestion and CO_2 emissions. To better understand these impacts of AV technology, a traffic simulation was constructed, with questionnaire survey conducted to provide simulation inputs.

309 residents of Kanagawa, Saitama, and Chiba prefectures were surveyed on their short-distance travel behaviour. More than three quarters of respondents reported possessing a driver's license, and two thirds reported their household as owning one or more vehicles. Respondents were asked to select a transport mode for a specified trip in order to estimate demand for different modes under different trip conditions (length and purpose). To

understand route choice, respondents were presented with a discrete choice experiment of routes of different lengths and journey times. Responses were used to estimate the utility function of route choice. The demand estimation and utility function obtained were used to inform route and mode choice in traffic simulation.

Using the demand estimation acquired from simulation, trips were created on a 5 x 5 map grid with four origins and two destinations (supermarket and station). Trip time was recorded for each journey, assuming a relationship between velocity and vehicle density, vehicle length, and headway time. Route choice was made based on the direct route between the origin and destination with the highest utility.

Three scenarios of AV adoption were considered:

(1) Base scenario

In this scenario, demand shift to AVs was assumed to be 0 % (no AV technology), with a conventional vehicle headway time of 2 s.

(2) Partially automated AV 100 % adoption scenario

In this scenario, partially automated AVs were assumed, where a driver was still required, but a headway time for these partial AVs was assumed to be 0.5 s.

(3) Fully automated AV 100 % adoption scenario

In this scenario, demand shift to AVs was assumed to be 100 % (full AV technology), with an AV headway time of 0.5 s.

In addition to this, two cases of decision-making were implemented for route choice and mode choice demand shift (i.e. travel time for the utility function):

(1) “Imperfect knowledge” decision-making

For this decision-making case, imperfect knowledge about traffic conditions by travellers was assumed. Travel time for the route choice and mode choice demand shift calculations was estimated using a “typical” velocity rather than the true travel time (for cars, taxis, buses, and AVs).

(2) “Full knowledge” decision-making

For this decision-making case, full knowledge about traffic conditions by travellers was assumed. True travel time was used for the route choice and mode choice demand shift calculations.

For each scenario in each decision-making case, traffic congestion, traveller utility, and CO_2 emissions were investigated.

Compared to the base and partial scenarios, a modal shift away from lower-impact modes (such as bicycles) and public transportation (such as buses) was observed in the AV scenario. This was due to the increased “attractiveness” (shorter travel time) of AVs over conventional vehicles resulting in a rebound effect. However, this effect on did not directly translate to increased travel times and congestion as it was balanced by the effect of the increased speed of AVs due to the reduced headway time, which was also observed in the partial scenario. In the “imperfect knowledge” case, slight congestion increase was observed in the AV scenario by observing velocity change from high- to low-congestion conditions, likely due to greater demand shift and poorer route optimisation in this case.

Traveller utility was understood to decrease with congestion and trip time. Over the simulation, trip time increased due to increasing congestion on certain route segments. In both decision-making cases, trip time was reduced in the AV scenario, although since the number of AV trips was much greater in this scenario this effect was reduced over time. With a slight increase in congestion observed in the “imperfect knowledge” case, traveller utility can be interpreted to decrease in the AV scenario compared to the partial scenario over the base scenario.

In simulation, conventional vehicles (cars, partial AVs, taxis, and buses) were assumed to have internal combustion engines (ICEs), while AVs were assumed to be electric vehicles (EVs). A relationship between fuel consumption and velocity was assumed for each vehicle type, and this was used to derive the amount of CO_2 emissions produced in each

scenario. Emissions were reduced by similar factors in both the AV and partial scenarios, demonstrating that the positive effect of electric powertrain balanced with the negative rebound effect of the increased demand for AVs when compared with the positive effect of the increased speed of partial AVs. Additionally, CO_2 emissions overall decreased in the “full knowledge” case, showing that route-optimisation in this case had an important role in reducing overall emissions.

Key words: autonomous vehicle, AV, sustainability, traffic simulation