Enhanced short and longer term network performance prediction capabilities through data-driven analytics and simulation:

Simulating the Traffic Impact of AVs and CAVs on Perth's Freeways and Arterial Roads

EXECUTIVE SUMMARY

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As Australia's transport ministers 'have agreed on the strategic priority of preparing for the deployment of automated vehicles and other innovative transport technologies' (Australian Government, 2019), it becomes more important than ever to understand the implications of these technologies and what they mean to our planning practices. Although praised for their foreseen ability to 'solve' our traffic woes, disruptive technologies such as Automated Vehicles (AVs) and Connected and Automated Vehicles (CAVs) also bring many uncertainties. Governments often plan decades ahead and the uptake of AVs/CAVs is likely to happen within our planning horizon. Hence, any long term investments without adequate consideration of their potential impact are inherently risky. It is reasonable to question whether planned major transport infrastructure will be appropriate in accommodating and facilitating a fully automated future.

Understanding the potential impact of AVs and CAVs will help us future-proof infrastructure investments and mitigate policy risks. Transport agencies do not have direct control over the development of technologies per se, but by providing the necessary infrastructure and enabling environment through appropriate policy settings, they can choose the desirable future from many forecast scenarios and work backwards to design policies and programs to achieve it. This is a concept known as backcasting.

While car technology developers focus more on the engineering of individual AVs and CAVs, it is up to governments to assess and respond to their systematic impacts. This project marks the first step towards modelling the potential traffic impacts of AVs and CAVs on Perth's freeways and arterial roads. Main Roads Western Australia supplied three traffic models for testing – Mitchell Freeway, Stirling Highway and Canning Highway. The models were calibrated to reflect the current situation with 100% human-driven vehicles (HDVs) which served as the base case. They are representative of typical freeways and arterial roads so the results are assumed to be generalizable across the Perth road network. Two AV (AV1 and AV2) and one CAV driving models derived from the literature were programmed into the modelling package Aimsun by the research team for scenario testing. The aim was not to predict the precise future but to estimate the range of possibilities by establishing the upper and the lower bounds that form the best and worst case scenarios. The results would also help determine the scale of potential improvement that AVs and CAVs could bring.

The significant findings of this research are:

- Both AVs and CAVs could improve the operations of both freeways and arterials but more so, freeways. This is despite the fact that they were tested using a wider range of performance parameters than human-driven vehicles (e.g. lower acceleration and deceleration rates to improve comfort, see Appendix Table 2). The results imply increased road capacity when AVs and CAVs are prevalent but the disproportionate increase between freeways and arterials could cause a mismatch between their performance which may lead to bottlenecks at places where they connect (i.e. ramps).
- The best case scenarios were produced by CAVs at 100% market penetration with significant improvement. The average delay (the difference between actual travel time and free-flow travel time) on the Mitchell Freeway was reduced from the current value of about 28

sec/km to just 1 sec/km, about 96% reduction from the base case of 100% HDVs. For Canning Highway, it was the difference between 89 sec/km and 41 sec/km, less dramatic but still a 54% reduction over the base case. Stirling Highway results are similar to Canning Highway's.

- 100% CAVs not only significantly improved the traffic operations but also travel time reliability, leading to more predictable journey times.
- Canning Highway results show that increasing AV1 and CAV market shares, both reduce the average delay time compared to the base case of 100% HDVs, with CAV outperforming AV1 at every level. CAVs at 60% market penetration can delivery almost the same performance to AV1s at 100% market penetration.
- For freeways, it would take even lower percentage of CAVs to match the performance of 100% AVs, since CAVs benefit freeways more than arterials. Although the 80% CAV scenario has a reasonably close average performance to the 100% CAV scenario, only the latter avoided any significant spike altogether and produced much more constant traffic condition throughout the whole simulation period (6:45 – 9:45) for the Canning Highway model. This suggests that the last 20% connectivity is important in realising its full potential.
- Reaction time appears to be the most significant factor affecting performance among all simulated variables. CAVs benefited largely from having zero reaction time in the simulations. Although our literature search suggests that CAVs and AVs can achieve shorter reaction times than human drivers, if reaction time is set by the user to be slower for purposes of comfort etc., it is possible that they (especially AVs) could perform worse than HDVs.
- There might be unintended consequences. For example, the high density flow achieved by a platoon of CAVs could create difficulties in merging and lane changing because gaps between CAVs are too small for vehicles in adjacent lanes to get into.

The best case scenario is likely to be an overestimate but the potential performance improvement of AVs and CAVs does mean certain road capacity expansion might be avoided or delayed. It is advised that the technology-readiness for uptake of AVs/CAVs is regularly assessed and that business cases should account for their impact when mass deployment is within reach. We have chosen three AV/CAV driving models from the current literature. However, they might not remain the best choices as technology advances and our understanding improves. Therefore, this research should also be updated when new information about AV and CAV driving behaviour is available.

Due to the limited scope, this project focuses solely on the supply side changes, i.e. how much would AVs and CAVs change the road capacity, without sufficiently considering the human factors and changes to the demand side. The latter two are arguably more important because they are less predictable and the consequences are far reaching. For example, some people might choose to extend their CAV's car-following distance and consequently lower network performance because they do not feel comfortable travelling too closely behind another vehicle. Fully automated vehicles are also expected to induce demand since they lower people's perceived value of travel time by enabling them to make better use of their in-vehicle time. The currently mobility restricted population could also have the new-found freedom to travel independently. Although these could have positive social and economic benefits, the induced demand will at least partially offset the potential capacity increase. Wider implications such as the potential of worsening urban sprawl also need to be carefully assessed. Extensions to the research should thus include demand-side considerations.

Compared to V2I (vehicle-to-infrastructure), V2V (vehicle-to-vehicle) as a consumer technology has the advantage of not requiring expensive public infrastructure and its maintenance costs. Since our CAV model results show V2V plus some simple V2I technologies alone could make significant improvement to the network, further research needs to examine whether this diminishes the necessity for more sophisticated and expensive V2I technologies. Another suggested extension of the research is simulating the operations of dedicated AV lanes on Perth's freeways.

The research presented in this report delivers on Subproject 2 of a larger research project comprising two sub-projects:

- Subproject 1: Data-driven empirical models for short-term traffic prediction (Part 1) and non-route-based area optimisation of network productivity (Part 2)
- **Subproject 2: Simulating the traffic impact of AVs and CAVs to Perth's freeways and arterial roads**

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