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

Implementing Multi-Zone Perimeter Controls on Perth's Road Network

EXECUTIVE SUMMARY

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Perth's first Smart Freeway project is expected to bring significant improvement to Kwinana Northbound traffic operations by utilising a range of intelligent transport systems. Ramp metering is one of the cornerstone solutions, which in simple terms means regulating traffic inflow at on-ramps to prevent flow breakdowns on the freeway so it can remain reliable while delivering higher throughput. This iMOVE subproject investigates the possibility of applying perimeter control that is based on a similar idea but expands it to the whole network.

Perimeter control (also known as gating) works by dividing the network into multiple zones and regulating their flow exchange at the boundaries. It aims at load-balancing between zones across the network to achieve a stable and optimum operation at the global level. Controllers prevent overflow of traffic into busy zones by leveraging spare capacities in less busy zones as temporary storage space. This contrasts with local congestion relief strategies that focus on individual pinch points, which can result in pushing too much traffic downstream and creating another bottleneck.

By keeping the whole network at a steady state, gating has the potential benefit of maximising the total productivity and reducing the need for local capacity expansions. However, its effective implementation requires a good understanding of the behaviour of each zone. Macroscopic Fundamental Diagrams (MFDs) are commonly used for such purposes. They describe underlying relationships between a zone's speed, flow and density at the aggregate level. The accurate measurement of MFDs has become possible in recent years with the advent of 'big data'. As Main Roads' Network Operations Directorate is making rapid progress in this zone, the feasibility of implementing perimeter control becomes increasing likely.

The significant findings of this research are:

- The four Main Roads' metropolitan network performance sub areas (quadrants) have clear MFDs but their MFDs do not ever reach critical density (the maximum vehicles/lane-km before congestion happens). It is primarily because these large regions seldom enter a congested state as a whole. Therefore, they needed to be subdivided into smaller zones for perimeter control.
- We adopted a top-down approach by bisecting the four network performance sub areas until desired MFDs with low scatter and clearly defined critical density were found. The end results are 38 zones across the whole metro network (Section 4.1). Zones with high traffic demand tend to have more usable and well-behaved MFDs that clearly indicate a critical density or 'tipping point' while still having low scatter. Conversely, zones with low traffic demand tend to have less-than-ideal MFDs with higher scatter and no clear indication of critical density, these zones would derive less benefit from the implementation of perimeter control.

- We have also simulated the performance of MFD-based perimeter control using mathematical models (Section 5.2). The results show the control strategy, regulating traffic flows at boundaries by means of signalling, can avoid flow breakdown of the congested zones. Although the traffic was slowed in zones that act as the buffer, the whole network performed substantially better. Travel time for completed trips decreased by 12% in the twelve-zone model (Table 2). *However, the numbers should not be taken literally since the models are hypothetical and include many assumptions. They are only intended to illustrate the potential of benefit of gating.*

Although much more research needs to be done to operationalise this concept, it is a potential paradigm change for network operations. If successful, it can maximise the productivity and reliability of the whole network by utilising spare capacity in zones with low demand-to-capacity ratio to alleviate stress for those under high demand. The productivity gain and avoidable cost of unnecessary road expansions could generate significant social, economic and environmental benefits.

The research presented in this report delivers on Subproject 1 (Part 2) of a larger research project comprising two sub-projects:

- **Subproject 1:** Data-driven empirical models for short-term traffic prediction (Part 1) & **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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