Putting the Connectivity in C-ITS – Investigating pathways to accelerate the uptake of road safety and efficiency technologies

Traffic Simulation Report

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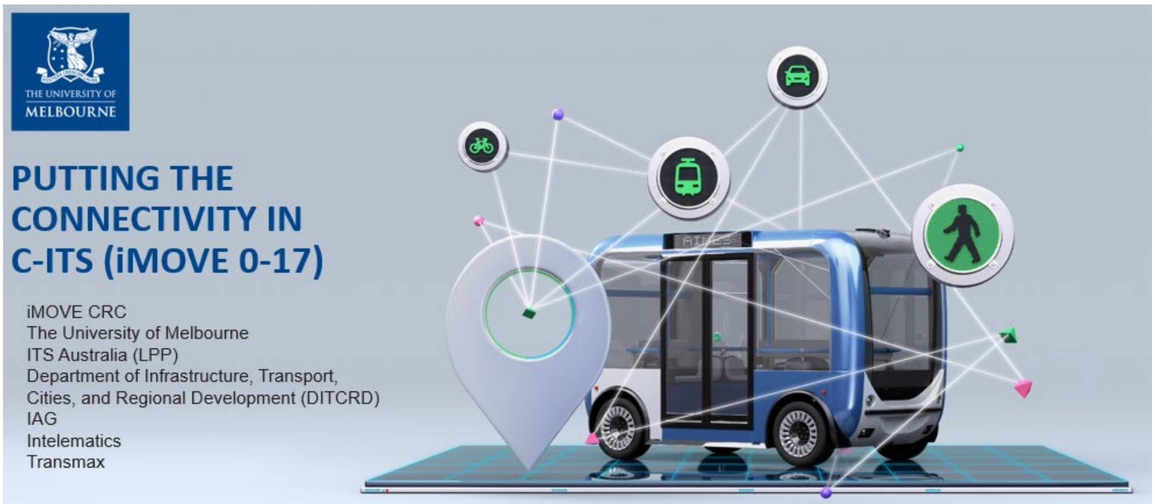

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Connected Vehicle Data in Traffic Control

The emergence of connected vehicle (CV) technology is promising for traffic control and can provide benefits for traffic circulation. CVs are a rich data source that can be collected and used for smart, pre-emptive, and proactive traffic control schemes. We integrated the CV data into traffic signal control to investigate the improvements and benefits that can be observed in traffic circulation over variety of different metrics. Traffic signals (installed at intersections) are critical points in any traffic control system. We tested the integration of CV data with the traffic signal control scheme (TSCS) over varying levels of available CV data (known as CV penetration rate, PR), called TSCS+CV in this paper. The outcome of this investigation is to identify the minimum penetration rate of CV technology at which the benefit of the CV data can be observed.

1 Methodology

A traffic control schemes (TSCS) generally consists of two components: i) an optimisation framework to minimise vehicles' delay behind the signals or to increase the throughput (number of vehicles that signals can process), and ii) loop detector models to estimate or measure number of vehicles entering the signals and those stuck behind the queue as input to the optimisation framework. The total number of CVs compared to the total number of vehicles in a network/fleet (i.e. CVs and ordinary vehicles combined) is called the "penetration rate" (PR). We tested the addition of CV data into a traffic signal control scheme (TSCS) over varying levels of penetration, called TSCS+CV, to evaluate the minimum level of penetration at which benefit of the CV data could be observed. CV data (such as speed and position) was added to the inputs to increase TSCS awareness of traffic conditions; we expect that the additional information to such systems achieves a reduced delay at intersections and allows for a higher number of vehicles to pass through the signals. We compared the performance of the TSCS+CV with actuated technology (a TSCS without CV) and an advanced academic method (Balance[1]) over several PRs.

This traffic simulation has two parts: 1) corridor management comparison of TSCS+CV against the Balance method, and 2) network management comparison of TSCS+CV against the Actuated system.

The performance of the TSCS+CV method is compared with both the Balance signal control strategy and Actuated system in Vissim; Balance is one of the best available methods in literature. We demonstrate the potential strength of three levels of penetration, integrating CV data with TSCS against the two other methods. The layout of the network is first is exported from the Visum simulator with real demand data for peak hours. The adjustment of the Balance signal controller is then conducted in Visum, with the required files then exported to Vissim. Meanwhile, the Actuated system is planned in VisVap. The three algorithms are compared in terms of the total intersection throughput within the given time interval; this is the objective function in traffic optimisation.

[1] Based on a traffic simulation model (more precisely a dynamic traffic assignment) to find the traffic state (i.e. traffic volume, speed, etc.) for a prolonged period in the future. Data is then fused with an optimisation algorithm (the Genetic Algorithm) to set traffic signals (i.e., phase structure, green/red time, etc.).

1.1 Corridor Management

Existing signal control strategies are known to be effective when dealing with a series of intersections along a specific corridor. This test was carried out with data from three intersections from the AIMES testbed in Victoria, along the intersection of Queensberry Street with Lygon Street, Drummond Street, and Rathdowne Street (shown in Figure 1.1). Comparison of results was made to the Balance method to show the effectiveness of incorporating CV data into traffic control schemes.

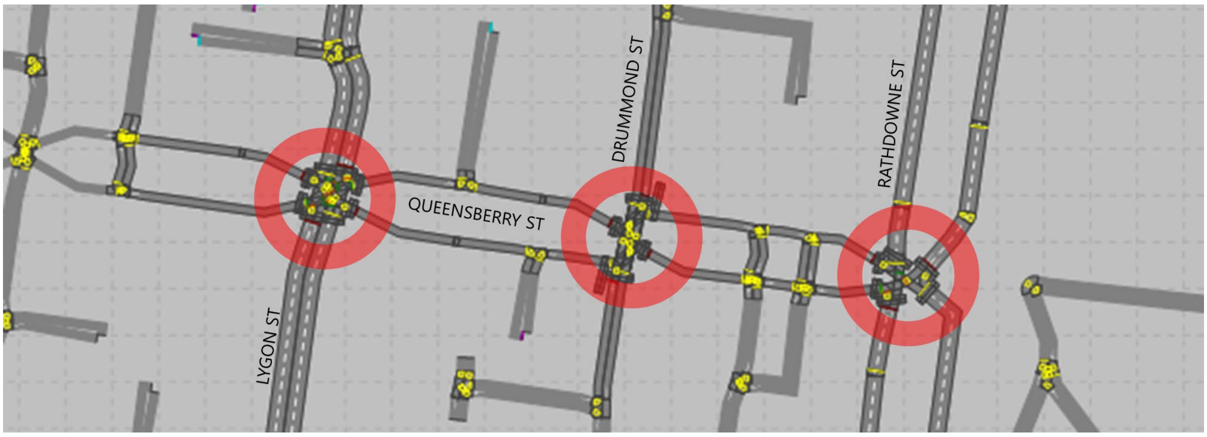

Figure 1.1 Test corridor network layout in Vissim

1.2 Network Management

Unlike corridor management, traffic signal coordination for a network of intersections can be challenging. We tested the TSCS+CV over a network of 17 intersections near Melbourne City (shown in Figure 1.2) and compared this with the best of the available technology in place, an actuated system[2] based on inductive loop detector sensors.

Figure 1.2 Testbed network layout

[2] An actuated traffic signal is one which has a type of computer, called a "signal controller", that determines the timing and even the sequence of traffic movement for each phase and cycle, based on whether vehicles or pedestrians are detected at the intersection. Actuated signal timing is completely influenced by traffic volumes and is detected through sensors at all or some of the approaches called loop detectors; these are magnetic tubes installed on the pavement right at the stop line to sense the presence of vehicles.

2 Results and Discussion

Following the methodology presented in Section 1, the results from the corridor and network traffic simulations are presented below.

2.1 Corridor Management

The comparison between TSCS+CV and the Balance method is made for several metrics: signal throughputs, vehicle speeds, CO emissions, NOx emission, Volatile Organic Compounds (VOC) emission, and fuel consumption. Results are presented in Figure 2.1 to Figure 2.6

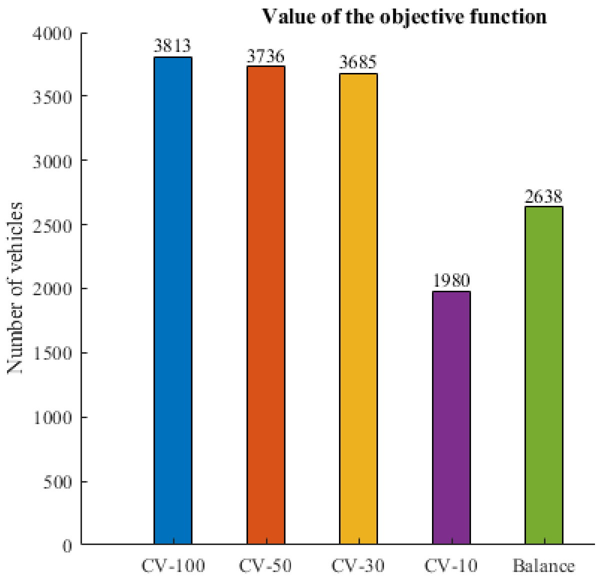

Figure 2.1 Vehicle throughput (Objective function) comparison of TSCS+CV to Balance method

Figure 2.1 demonstrates that event at a 30% penetration rate, the total number of vehicles processed through the intersections (the throughput or objective function) is higher than that of the Balance method. This is true for PRs of 30% or higher.

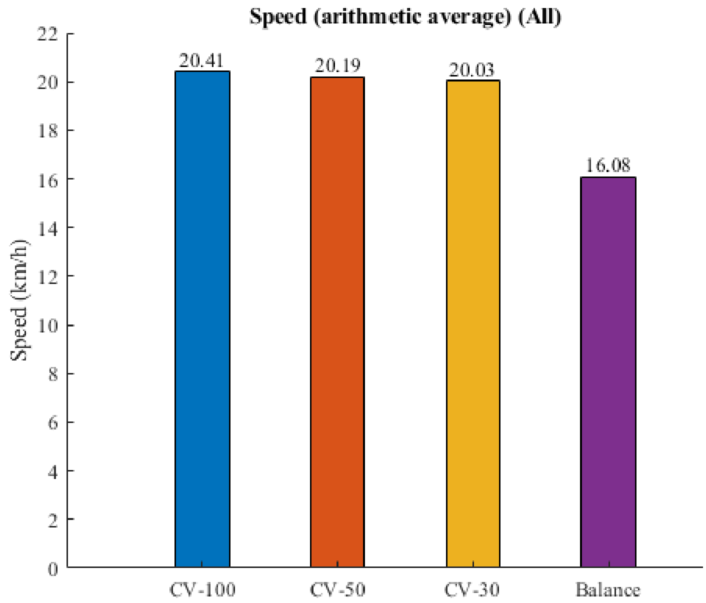

Figure 2.2 Speed comparison of TSCS+CV to Balance method

A similar result is observed when comparing the average vehicle speed through the intersections. At a PR of 30% or greater, CV data can improve the overall mobility of the network based on a comparison to the Balance method.

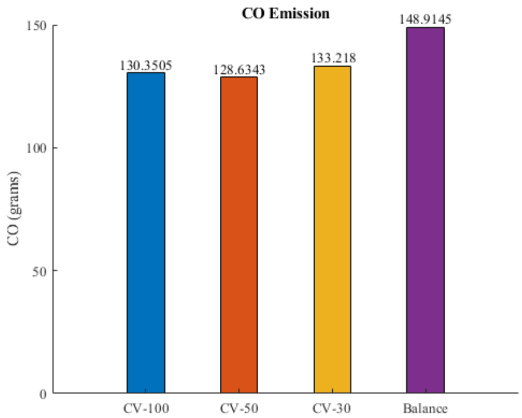

Figure 2.3 CO emission comparison of TSCS+CV to Balance method

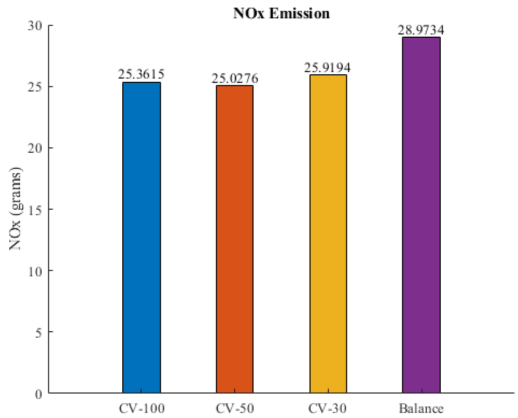

Figure 2.4 NOx emission comparison of TSCS+CV to Balance method

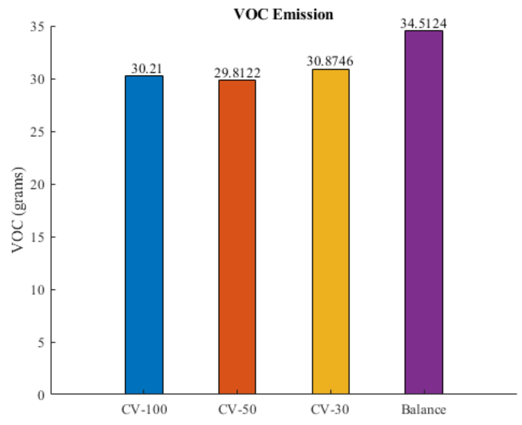

Figure 2.5 VOC emission comparison of TSCS+CV to Balance method

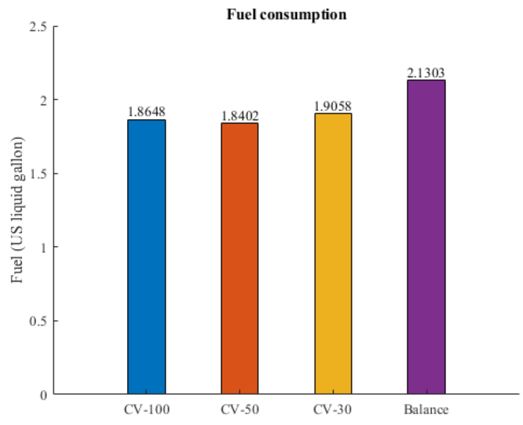

Figure 2.6 Fuel consumption comparison of TSCS+CV to Balance method

Figure 2.3 to Figure 2.6 show the impact of CV data when used in traffic control on the environment. That is, the change in levels of emissions and fuel consumption. In all accounts a PR of 30% can reduce negative environmental consequences by almost 11% compared to the Balance method.

2.2 Network Management

In a similar manner to the corridor management simulation, we compared TSCS+CV again the Actuated system across a number of metrics with results shown in Figure 2.7 to Figure 2.9.

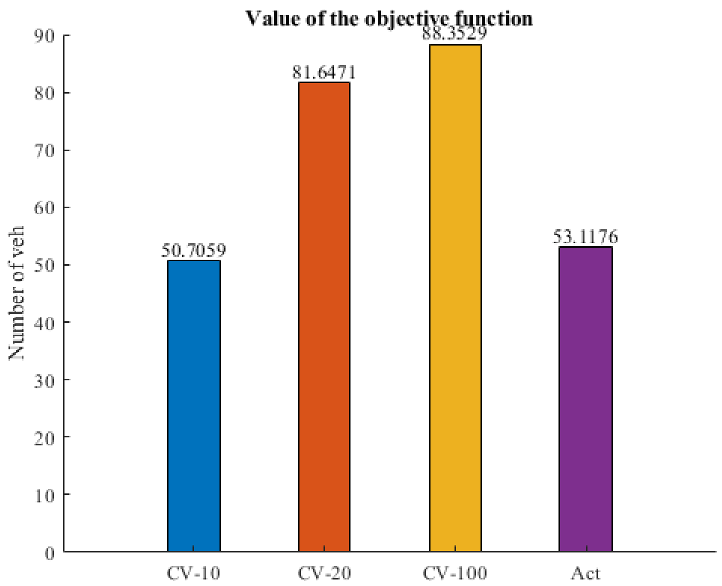

Figure 2.7 Vehicle throughput (Objective function) comparison of TSCS+CV adaptive to actuated signal control strategies

Figure 2.7 demonstrates that at a PR of 20%, the addition of CV data to TSCS can improve the throughput at an intersection by approximately 50% when compared to a traffic signal control without CV data (actuated signal).

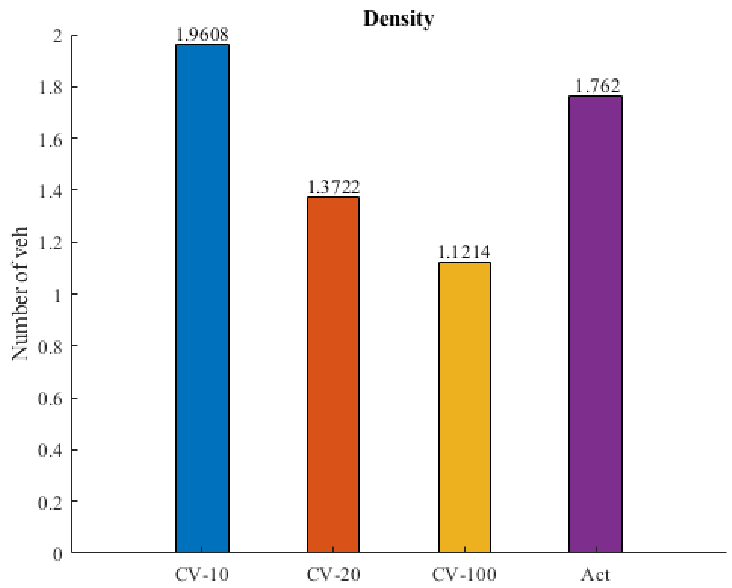

Figure 2.8 Density comparison of TSCS+CV adaptive to actuated signal control strategies

A similar result is observed when comparing the density of vehicles within a network.

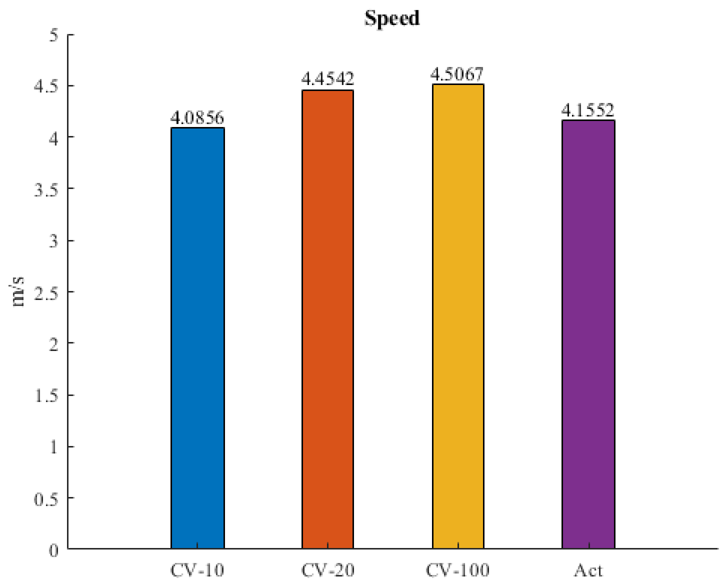

Figure 2.9 Speed comparison of TSCS+CV adaptive to actuated signal control strategies

Perhaps the most important metric is the average speed of vehicles. Figure 2.9 shows the variation of the speed over different CV PRs. At the threshold of 20%, vehicle speeds have increased approximately 10% compared to the actuated method – a significant improvement.

As can be inferred, the TSCS+CV can result in a network that outperforms the traffic signal control provided by the actuated method with a connected vehicle PR of 20% or greater.

3 Conclusion

The numerical analysis shows that even with a relatively low number of CV's (say PR of 20%), TSCS+CV can significantly improve the efficiency of traffic circulation when compared with the existing actuated systems. With a 30% PR of CVs, the TSCS+CV can also outperform the Balance control model.

Why CV data can help us achieve this? The reason is twofold: i) When using CV data, one can arguably obtain a full understanding of the traffic state, particularly as speed and queue lengths can be detected. In comparison, the current practice using the actuated system only has available data for the traffic throughput at the stop line of the intersection rather than the length of the queue or actual vehicle speeds. Moreover, by tracing the trajectory of CVs, one can connect isolated intersections in such a way that they can communicate with one another; this is an important factor in improving the operations of the traffic signals.

Across the corridor and network simulations, CV data was found to increase efficiency in traffic control, minimise delays at traffic signals, increase average vehicle speeds, and reduce pollution when used in a robust framework. The TSCS+CV is a suitable alternative to the best of available technology and the state of the art of methods proposed in academic literature. With a relatively low PR of 30%, a significant improvement in traffic efficiency (up to 10%) can be achieved.