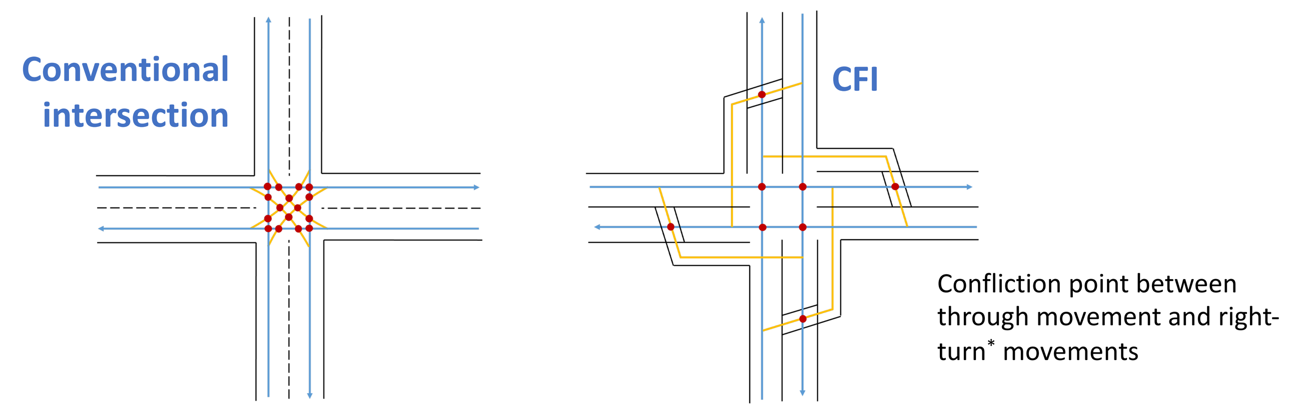
OPTIMIZING SIGNAL CONTROL AT CONTINUOUS-FLOW INTERSECTIONS CONSIDERING TRAFFIC PROGRESS

Yining Hu [1], Meead Saberi Kalaee [1], Reza Mohajerpoor [2], David Rey [3]
1. rCITI, School of Civil and Environmental Engineering,
University of New South Wales (UNSW), Sydney, Australia
2. School of Civil Engineering, University of Sydney, Sydney, Australia
3. SKEMA Business School, Université Côte d'Azur, Sophia Antipolis, France

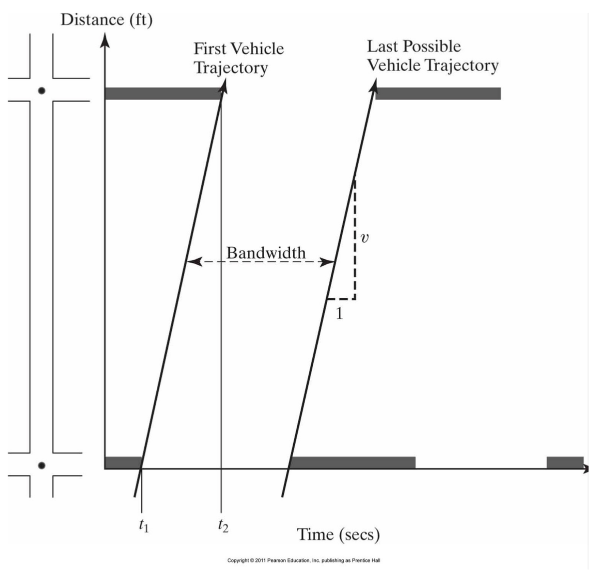
Background



DLT Intersection

A Continuous-Flow Intersection (CFI) uses separated sub-intersections to split the left-turn traffic out from the main intersection, improving the intersection efficiency and safety, especially for intersections with high right-turn* volume. It is worthy to investigate the optimisation of CFI signal design.

Concept of Green Band



- A green band is the time gap within which vehicles can pass 2 consecutive intersections without being stopped by the red light.
- Maximisation of the green bandwidth is commonly used in optimisation of the coordination between intersections.
- Since a full CFI consists of 5 intersections, a main intersection and 4 sub-intersections, it is important to optimise the offsets (difference between green initiation times $t_2 - t_1$) between them.

Identified Research Gaps

- Most of the existing research tested models with very limited scenarios of demand, However in reality, the demand pattern at an intersection can be diverse and much more complex, which may impact the real performance of the CFI implementation.
- Little research has compared models with a benchmark CFI signal design method that has been applied in practice.

* Based on Australian traffic rules

Main Contributions of this Study

- Over 700 different demand scenarios were tested and simulated, including different OD demand allocation and different level of total demand, which can reflect the performance of a CFI as well as the signal design optimisation model across various demand patterns.
- Improved an optimisation model for asymmetric CFI signal design (Yang and Cheng, 2017*) and adatped it for symmetric CFI, by making better use of green bands between intersections.
- Compared the proposed model with a benchmark CFI signal design method that has been applied in practice, and the results show that the proposed optimisation model can outperform the benchmark design method, especially when the right-turn traffic is heavy.

* Yang, X. and Cheng, Y., 2017. Development of signal optimisation models for asymmetric two-leg continuous flow intersections. Transportation Research Part C: Emerging Technologies, 74, pp.306-326.

2-Step Optimisation Model

This 2-step model is altered from an optimisation model for asymmetric CFI signal design (Yang and Cheng, 2017).

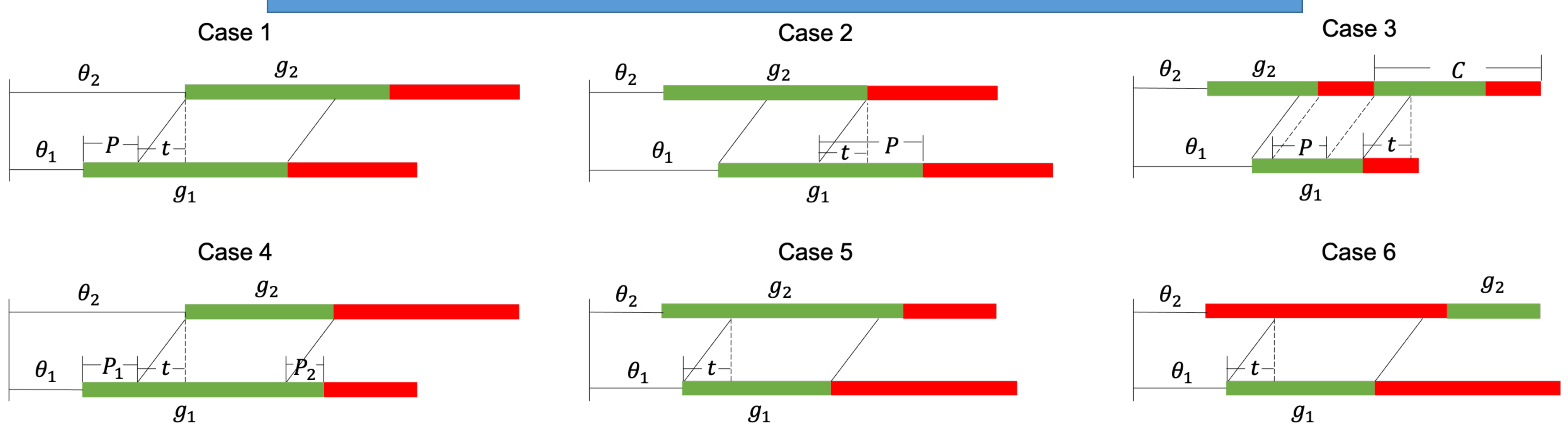
Step 1 $\quad Maximise \sum_{l \in L} \mu_l$

- Objective function of step 1 is to maximise a multiplier μ_l that indicates the capacity of the intersection.
- This step comes with constraints of maximum and minimum cycle length and green time, as well as the spillback at the end of each leg of the CFI.
- Common cycle length for the CFI and the green split for each movement at each intersection are optimised in step 1.

Step 2 $\quad Maximise \sum_{i \in I} \eta_i b_i$

- Objective function of step 2 aims to maximise the sum of weighted green bandwidth b_i that every movement i can receive.
- Constraints are given for the coordination between intersections, including the spillback between intersections. Each pair of intersections is assigned to one of the six types of green band (see next section).
- Offsets of each intersection θ_l are determined in step 2.

Main Changes in the Model



- One of the main changes based on Yang and Cheng (2017)'s model is that we increased the selectable green band cases from 3 to 6. Cases 3 to 5 in the graph above are added to allow the model to make better use of green bandwidths and improve the efficiency of final optimisation results.
- Other changes were also made to adapt the original asymmetric CFI signal design model to symmetric.

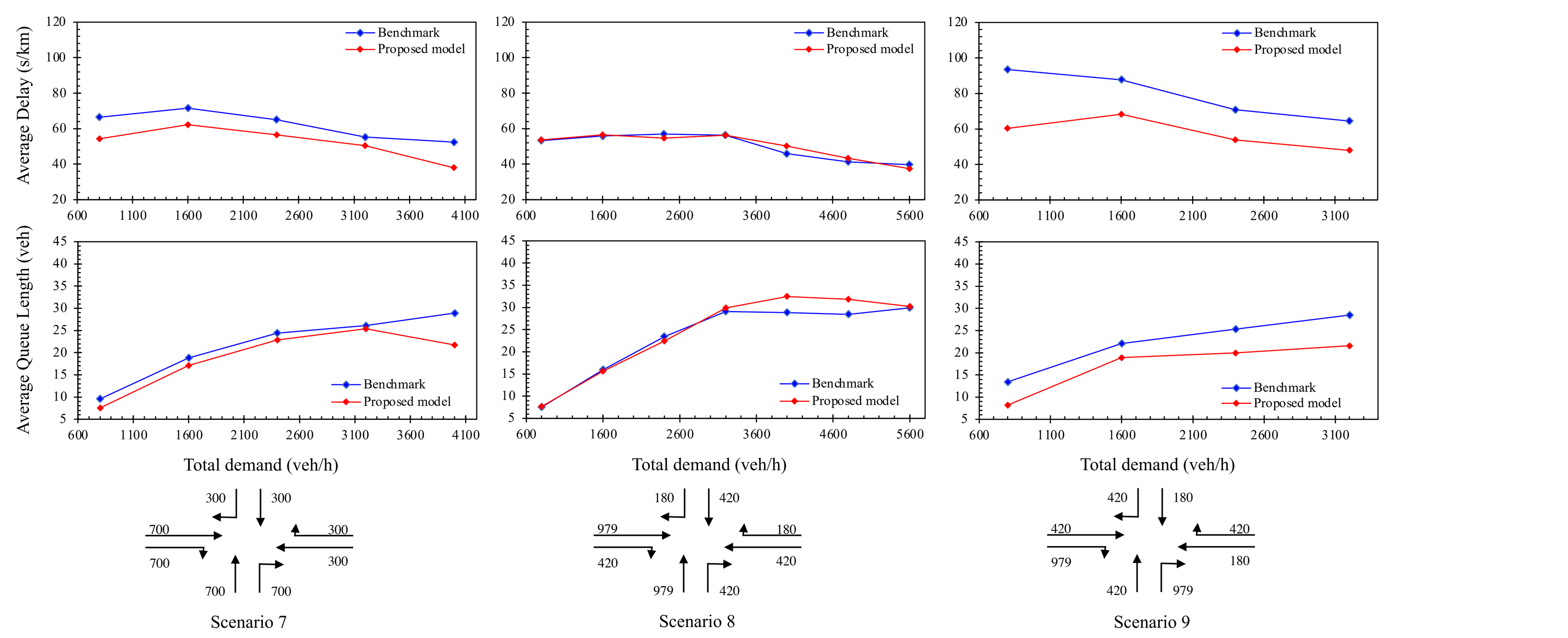
Results and Analysis

Overall Comparison between Benchmark and Proposed Model

	Average Delay (s/km)		Average Queue Length (veh)	
	benchmark	proposed model	benchmark	proposed model
Average	82.0	57.1	79.6	65.9
Standard Deviation	70.6	47.1	116.9	121.6

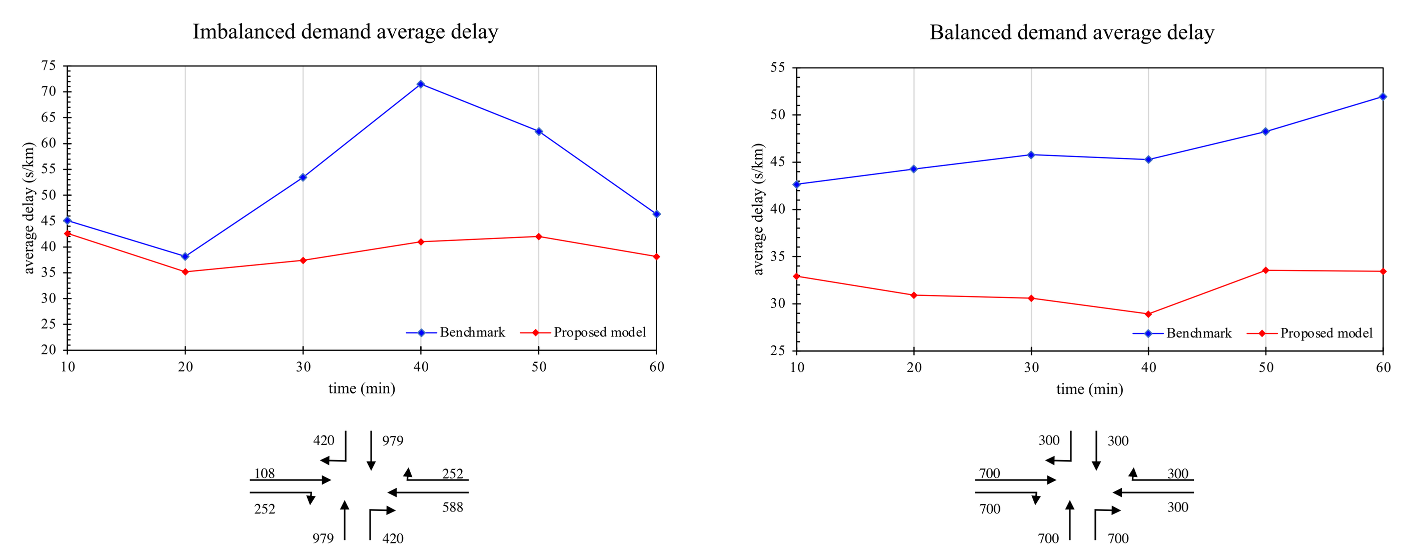
On average, the proposed optimisation model achieves lower delay and shorter queue length, with the standard deviation lower in average delay and close to benchmark in average queue length, indicating that our proposed model can provide more efficient and reliable signal plan than the benchmark.

Average Delay and Average Queue Length of Different Scenarios



- In scenarios with the same percentage of demand of through movements and right-turn movements (e.g. scenario 7), the proposed model performs better than or similar to the benchmark.
- In scenarios with a lower percentage of demand of right-turn movements (e.g. scenario 8), the proposed model generally performs similar to the benchmark.
- In scenarios with a lower percentage of demand assigned to right-turn movements (e.g. scenario 9), the proposed model outperforms the benchmark in most cases.

Average Delay and Average Queue Length of Different Scenarios



- Two example charts of time-dependant average delay are shown above. In both balanced and impalanced cases, the proposed model consistently outperforms the benchmark during the simulation period, and the results fluctuates less than the benchmark.

Conclusions

- A 2-step optimisation model is developed for full CFI signal design in this research.
- The developed model was tested with 704 different demand scenarios.
- The simulation results show that in most cases, the proposed model can provide a more efficient and reliable sigal plan than the benchmark, especially with heavy right-turn traffic.