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Quantifying pedestrian delay at signalised intersections

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Abstract

Centrally controlled, coordinated traffic signal systems offer dramatic benefits to traffic flow in urban areas by mitigating driver delay at intersections and minimising queue spillback. Historically, these systems have been designed to optimise performance based on vehicle delay. Rising interest in a broader approach to designing the signal timings has led to the incorporation of public transport or pedestrian delay.

This work describes a pilot study quantifying delay incurred by pedestrians at signalised intersections. Data is collected from two sites in Sydney on pedestrian delay and the presence of pedestrian queue spillback.

The observations indicate the presence of queue spillback for 34% and 55% of pedestrians at the two sites and 13 hr 17 min of pedestrian delay over 70 min of observations. These findings support the inclusion of pedestrian metrics in the signal timing design.

1 Introduction

Congestion is a growing concern in Australian cities with the cost of avoidable congestion projected to increase from $16.5 to $30 billion dollars between 2015 and 2030 (BITRE, 2015). In the dense networks of Australian CBDs, the congestion costs represent the combined impact of high demand, limited road capacity and spillback effects related to short link lengths. Real-time control systems manage vehicle flows in order to minimise delay and queue spillback.

Despite the ambitious scale of traffic control systems, the objective of most implementations is limited in scope— signal timings are designed to optimise vehicle delay. Recent advances (He et al., 2014; Christofa et al., 2016; Portilla et al., 2016; Zhao and Liu, 2017) consider multimodal objectives such as actuation and coordination of signals to reduce delay for public transport passengers (Aimsun, 2013; Transport for NSW, 2018). Moving forward, the movement-and-place framework underscores the multiple roles of the street. This perspective suggests that traffic control strategies should be incorporating multiple objectives, especially measures of the pedestrian experience, into their design.

For most intersections in a city, the flow of pedestrians is negligible compared to vehicles and the likelihood of externalities from pedestrian congestion are minimal. However, key intersections in the CBD experience high pedestrian volumes rivalling the vehicle capacity of the roads during peak periods. This aspect of congestion is often unaccounted for in the signal timings, and this work attempts to estimate how important the contribution might be.

2 Approach

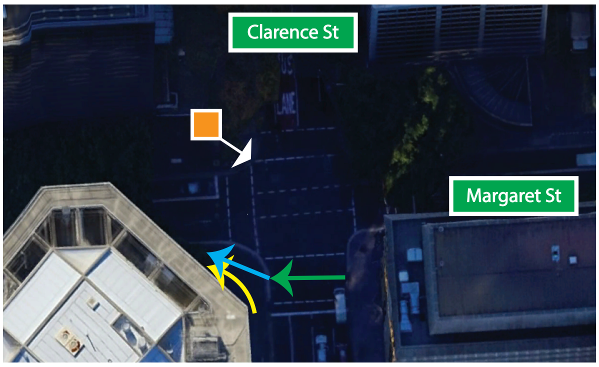
Data was collected from two intersections in the Sydney CBD using video recording. Two attributes were measured: pedestrian delay and queue spillback.

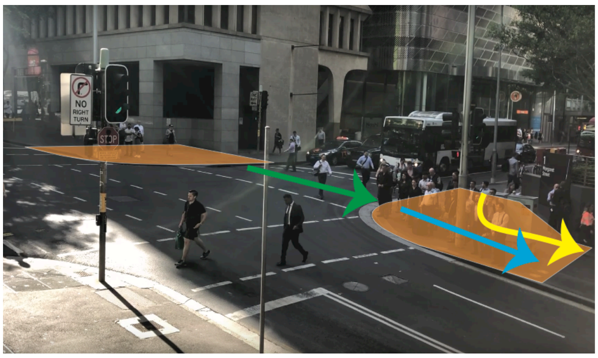
Each pedestrian is recorded when they arrive in and depart the counting zone. The arrival time is when the pedestrian stops walking. If a passenger does not stop because they arrive during a green light, their arrival time is defined as their departure time and the delay is zero. We assume that all passengers waiting for the signal to change will depart the zone at the same time. Those pedestrians crossing against a red light are a delay as if they had waited for the green.

Pedestrians are marked as either experiencing or not experiencing queue spillback according to the judgement of the data collector, and their time spent within the counting zone is recorded in order to validate the impact of spillback on walking speed.

The first intersection is located at Clarence and Margaret Streets. Due to proximity to Wynyard Station, it is busy with commuters during the peak periods. Data was collected during the peak time (8:21-8:56am) on a weekday (3 Dec 2018). The site is shown in Figure 1.

Figure 1 Site plan and street view of the Wynyard data collection site showing the crossing that was measured (green) as well as two possible spillback situations (blue, yellow). The location of the camera is marked with an orange square, and the shaded footpaths are the counting zones.





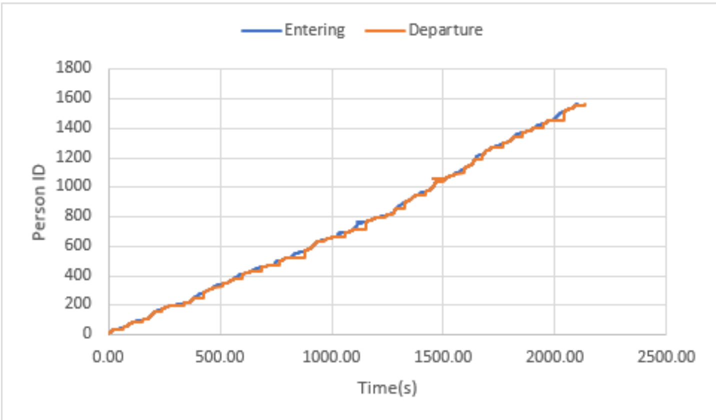
The second intersection is located at Castlereagh and Market Streets. This area is near the Westfield shopping centre and is popular with shoppers and tourists. Data was collected during the peak time (1:12-1:47pm) during the busy pre-Christmas shopping period (23 Dec 2018). The site is shown in Figure 2.

Figure 2 Site plan and street view of the Westfield data collection site showing the crossings that were measured (green, blue) as well as two possible spillback situations (yellow, pink). The location of the camera is marked with an orange square, and the shaded footpaths are the counting zones.

3 Results

In total, 1564 pedestrians were observed at Wynyard experiencing 4 hr 42 min of delay over the 35 min observation period. At the Westfield site, 1774 pedestrians experienced 8 hr 35 min of delay over the 35 min observation period. Figure 3 shows delay incurred at Wynyard. These values indicate that pedestrian delay is substantial and would be worthy of incorporation into signal design algorithms.

Figure 3 Newell diagram of the Wynyard site where the gap between the curves is the total delay accrued over the observations. The fluctuations in the blue arrival curve represent pedestrians arriving in a wave, possibly from an adjacent signal or from public transport.



Queue spillback was observed for 34% of traversing pedestrians at Wynyard (blue and yellow arrows in Figure 1). Queue spillback was observed for 55% of traversing pedestrians at Westfield (pink and yellow arrows in Figure 2). Average times spent in the counting zone are compared for the spillback and non-spillback observations using t-tests. For each case, the null hypothesis (H0: the time spent in the counting zone is the same for the two distributions) is rejected with >99.9% confidence. These observations show that pedestrians experience network congestion effects such as queue spillback, and network-level solutions would be appropriate.

4 Conclusions

This pilot study quantified the pedestrian delay and queue spillback at two signalised intersections over 35 minutes. The findings suggest that, when pedestrian volumes are high, pedestrian delay contributes significantly to the total delay. Moreover, pedestrians waiting for the signal to change cause measurable delay to other movements through the intersection underscoring the relevance of network-level approaches to pedestrian traffic control.

Streets in the CBD facilitate both movement and place. Because these streets are part of a larger, economically vital road traffic network, they are appropriately incorporated into network-wide control strategies. However, their status as places for people warrants consideration of other objectives such as pedestrian delay.

Walking is a travel mode, but it is also a mechanism for exercise and being present in the city. As such, delay may be experienced in a fundamentally different way for at least some walkers. This requires further research into travel behaviour of pedestrians based on trip purpose and location. The work piloted here targets the busiest pedestrian intersections at busy times. The next stage requires a framework to determine how these measurements could be scaled up across the network.

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