EVALUATION OF SIGNAL COORDINATION FOR PEDESTRIAN AND VEHICULAR FLOWS

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ABSTRACT

Existing signal control strategies do not consider pedestrian flows in optimizing signal parameters, which may impose significant delays on pedestrians. The objective of this study is to investigate the rationality and efficiency of pedestrian coordination. A Japanese numerical case study is analyzed. Field survey is conducted to collect the geometric characteristics, signal timings and vehicular traffic condition information. The performance of signal coordination for vehicular traffic and pedestrian traffic is estimated by using the microscopic traffic simulation program AIMSUN and the microscopic pedestrian simulation program NOMAD in a parallel approach. It is concluded that the coordination for pedestrian flows could significantly reduce the overall pedestrian delay. It was found that coordinating the major pedestrian flow in the case study led to a 15% reduction in the average pedestrian delay. However, this reduction is much lower than what can be achieved for the vehicular traffic under the optimized signal offset. It is because that the efficiency of signal coordination for pedestrian flows is dependent on several factors, such as the variations of pedestrians' desired speed, densities of pedestrian flows, link lengths between intersections and signal cycle length.

Keywords: coordination, pedestrian, platoon dispersion, microscopic simulation

INTRODUCTION

Existing research in optimizing traffic signal operation has focused on maximizing vehicular capacity or minimizing vehicular delay. At the network level, the typical approaches are to maximize green bandwidths or to minimize delays for vehicular traffic. While for pedestrian traffic, existing signal control strategies only focus on safety aspects and fail to pay enough attention on the efficiency aspect, i.e. pedestrians' delay. Such an objective is reasonable for motorways and rural roads where vehicular traffic is dominant over pedestrians. However, it is not the case in metropolitan areas with medium or large volume of pedestrian demands. Such ignorance can lead to unnecessary long delays for pedestrians, dangerous behaviour by impatient pedestrians, and potential reductions in pedestrian traffic and transit usages.

Multi-modal traffic signal operation should consider both efficiency and safety aspects for all travellers at intersections, e.g. vehicles, pedestrians, bikers, etc. Among all the travellers, vehicles and pedestrians are most important from the perspective of demands. The two groups of travellers also have significantly different characteristics. For example, vehicles follow each other to travel within dedicated lanes. Pedestrians walk with much lower speed but are more flexible choosing their paths and speeds. Due to such dramatic differences, the coordinated timing specifically designed for vehicular traffic by existing strategies would not serve pedestrian traffic well.

This study aims to demonstrate how significant and rational to consider the pedestrian delay in traffic signal operation. It is necessary and actually the first step before any development of integrated multi-modal signal operation strategies that consider both vehicular and pedestrian flows for their efficiency and safety.

LITERATURE REVIEW

Existing manuals such as HCM (2000) determine the level of service depending on the average control delay experienced by vehicles at intersection approaches. It is clear that pedestrian flow has not been given the same priority as vehicular traffic. However, at many urban areas where large volume of pedestrian exists, it is more rational and reasonable to evaluate the level of service of roadways from a multi-modal perspective.

Webster's (1958) and other numerous methods for signal optimization focus on reducing vehicle delays without considering pedestrian flows and delays. Long signal cycle durations from optimizing vehicle flows and signal coordination for vehicles, have negative effects on pedestrian movements and may impose large delays on pedestrians (Bayley (1966)). Furthermore, long cycles may cause a safety hazard for pedestrians, thus one of the most effective measures to improve pedestrian safety and compliance is by making signals as comfortable as possible, and this is done by minimizing pedestrian delay (Garder (1989)).

Li, et al. (2010) developed a traffic signal optimization strategy for isolated intersections that considers both vehicular and pedestrian flows. The objective of the proposed model is to minimize the weighted vehicular delays and pedestrian delays. The interaction between pedestrians while crossing was considered in the delay calculations. Generally, it was found that the consideration of pedestrian delays is most significant and necessary for two circumstances: (1) metropolitan areas with high pedestrian demands and (2) major urban arterials with high pedestrian demands crossing the major streets. However, in their vehicle delay calculation is based on simple assumptions such as uniform arrivals.

Another important factor that might affect pedestrian flow especially in the network level is coordination. The resulted offsets from coordinating vehicular flows might lead to long delays for pedestrians who want to cross several consecutive intersections. Simultaneously, coordination for pedestrian flow might be an effective tool to reduce pedestrian delays. Few studies tried to analyse the possible effects of vehicular traffic coordination on pedestrian delay at network level.

Ishaque and Noland (2005, 2007) analysed the effects of signal cycle timing on pedestrian and vehicle delay assuming a simple hypothetical network. All the signalized intersections in the network are assumed as isolated fixed timing intersections. VISSIM micro-simulation model was utilized to analyse the network. It was concluded that the setting of signal timing has a very significant impact on pedestrian delay. Moreover, authors proposed the optimal signal timings under various vehicle and pedestrian demand levels. An important drawback of their analysis is that the utilized version of VISSIM does not consider the interaction between pedestrians. Such absence of the pedestrian-to-pedestrian interaction underestimates the experienced delay, which means that the proposed optimal solutions might not be the real optimal. Furthermore, in a network level, what is more important is the coordination of vehicular flow and its effect on pedestrians.

Virkler (1998) analyzed the potential benefits of reducing pedestrian delay through signal coordination by utilizing filed data from 10 signalized intersections. It was concluded that pedestrian platooning due to upstream signals can increase or decrease pedestrian delay depending on the offsets of the downstream signal. However, the difference between the optimal offsets for coordinating pedestrian and vehicle flows is not presented. Furthermore, the interaction between pedestrians and its effect upon delay is not considered.

The interaction between opposing pedestrian flows at sidewalks or crosswalks is important factor that might lead to significant delays especially at high pedestrian demand. Such delays should be considered in order to design an efficient coordination for pedestrian flows. Lam, et al. (2003) investigated the effect of bi-directional flow on walking speed and pedestrian flow under various flow conditions at indoor walkways in Hong Kong. They found that bi-directional flow ratios have significant impacts on both the at-capacity walking speed and the maximum flow rates of the selected walkways. Furthermore, Teknomo (2006) proposed a microscopic pedestrian simulation model, which was utilized to demonstrate the effect of bi-directional flow at signalized crosswalks. It was found that the maximum effects occur at a directional split ratio of 0.5 where the average speed of the bi-directional flow dropped up to one third compared to the uni-directional flow. Alhajyaseen and Nakamura (2009a) modelled the bi directional pedestrian flow at signalized crosswalks by applying the analogy of drag

Table 1 - Observed vehicle demand at each intersection in the corridor

Approach	Horita Eki Mae Intersection			Horita Eki Minami Intersection			Chikatetsu Horita Intersection		
	Vehicle demand *veh/hr*								
	TH	LT	RT	TH	LT	RT	TH	LT	RT
North	1416	21	37	1288	27	88	1076	184	125
South	1166	85	15	1418	26	26	1124	30	120
East	-	-	-	157	38	34	804	74	133
west	45	10	18	48	11	20	688	172	58

force theory. It was concluded that crosswalk geometry (width and length) and the bi-directional pedestrian demand have significant effects on the walking speed and it might cause a dramatic decrease in the walking speed.

METHODOLOGY

A numerical case study is conducted to analyze the difference between pedestrian and vehicular delays. Three coordinated intersections along a busy corridor in Nagoya city are chosen. The intersections are Horita Eki Mae, Horita Eki Minami and Chikatetsu Horita. The geometric characteristics information and existing signal timings are shown in **Figure 1**. Under the great efforts by the members of ***Interchange*** Nakamura Laboratory, video data was collected for vehicular flows and pedestrian flows on all approaches and all directional movements during the peak period on a typical weekday. Manual survey is also conducted for traffic signal timing data and coordination timing data along both directions in the period of collecting the video data. The vehicular traffic demands along the three intersections are presented in **Table 1**. For the signal coordination, the offset at intersection (1) (Horita Eki Mae) is defined as zero. The offsets for the other two intersections are reference to intersection (1).

Regarding pedestrian demand, it was assumed that there are only two pedestrian flows between the two destinations (subway station and the activity area) on the western side of the main corridor. One of the two pedestrian flows is the major flow and the other is minor flow. The major flow departs from the activity area to the subway station while the minor flow goes in the opposite direction. The major flow demand is assumed as 2500 *ped/hr* while the minor is assumed as 600 *ped/hr*.

As aforementioned, the interactions among pedestrian can be significant when calculating pedestrian delays, particularly at intersection crosswalk with condensed conflicting flows. Thus, it is very important to carefully consider such interactions in the study. Previous studies by Ishaque and Noland (2004, 2007) did not consider the pedestrian interactions in the simulation study. In this study, we applied a parallel simulation approach to utilize a vehicle-based simulator together with a pedestrian-based simulator that specifically considers the pedestrian interactions.

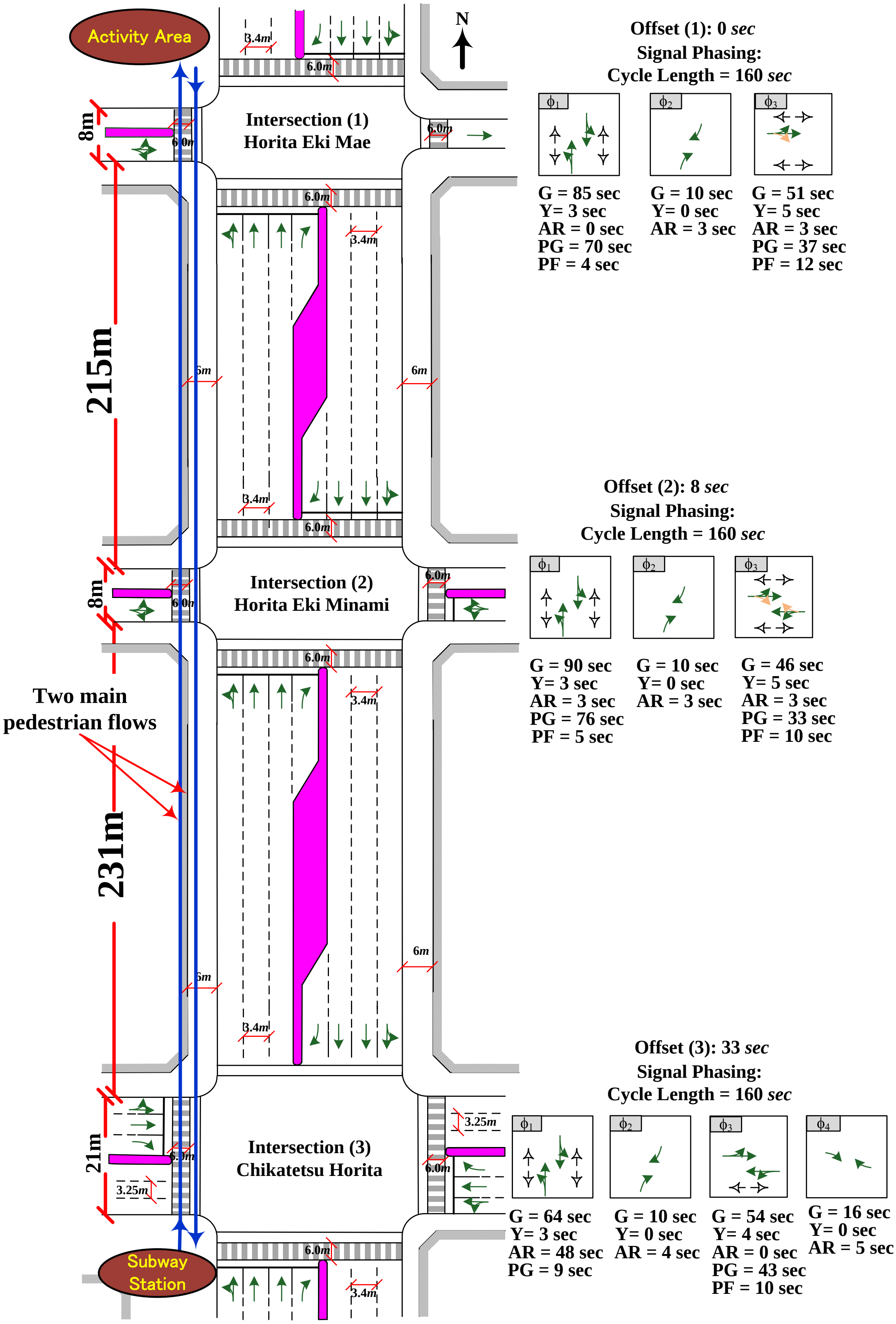


Figure 1 - Geometric characteristics and existing signal timings of the case study

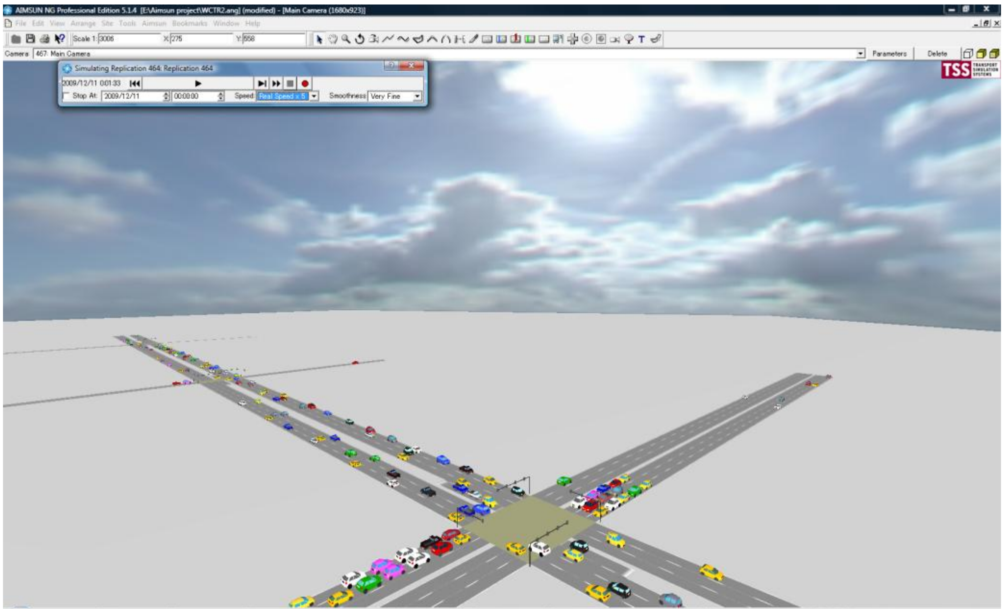


Figure 2 - Average number of stops for main corridor under various offset combinations

Vehicular Traffic Simulation

In order to estimate the average vehicular delay for the corridor under various offset combinations, AIMSUN, a popular microscopic simulation program, is utilized. The existing traffic conditions and signal timing characteristics are reproduced in the AIMSUN environment, as presented in **Figure 2**. The need to use micro-simulation for this research arises from the fact that analytical methods make use of some mathematical formulations that suffer from deficiencies in representing realistic traffic or in analysing large networks (Mahmassani et al. 1994). Therefore, AIMSUN micro-simulation, which is one of the popular programs, is used in this study.

Pedestrian Traffic Simulation

Pedestrian to pedestrian interaction and platoon dispersion are very critical issues that should be considered to provide efficient coordination for pedestrian flows. Therefore, NOMAD, a microscopic simulation model for pedestrian flow, is utilized for this study.

NOMAD is a microscopic pedestrian simulation model for the assessment of pedestrian walking infrastructure (Hoogendoorn and Bovy, 2003; Hoogendoorn and Bovy, 2004; Hoogendoorn et al., 2007). NOMAD is activity based, implying that the actions of the pedestrians are largely determined by the different activities pedestrians are performing while being in the walking facility. Given an activity pattern (an ordered set of activities; e.g. buying a train ticket and subsequently getting to the train platform) and given the (multiple) areas where these activities can be performed (ticket offices, train platforms), NOMAD determines the most likely areas where activities are performed, and the most likely routes between them. NOMAD allows for completely free route choice. That is, pedestrians do not walk along linear, predetermined paths. Rather, the routes are continuous paths in continuous space.

While walking, pedestrians aim to adhere to the shortest route. However, due to encounters with other pedestrians, they will generally not be able to do so. This holds equally for the interaction with obstacles and walls.

The modelling of the pedestrian interaction process is based on known empirical facts (Daamen et al., 2003) and theory on pedestrian behaviour. The calibration of the model parameters is done using a microscopic approach, where model results have been compared to observed microscopic pedestrian behaviour (Hoogendoorn and Daamen, 2006).

NOMAD produces many types of microscopic and macroscopic output. One important ability of NOMAD is its animation functionality, i.e. it produces high-quality animation files that can be viewed on any computer, which is very suited for presentation purposes. Moreover, it is possible to define virtual detector loops measuring pedestrian passage times, speeds, headways, etc.

In this contribution, NOMAD has been used to model traffic signals at a sequence of intersections. The walkable area consists of sidewalks and crosswalks, while the obstacles are formed by the buildings, but also by the street itself. At each side of a crosswalk, a waiting area is defined. When pedestrians walk from their origin to their destination, they will have to pass three different waiting areas, each located just in front of an intersection. The walking areas are connected to the traffic signals. When the traffic signal is green, the pedestrians finish their activity and start walking to their next activity. The route to their next activity first passes the crosswalk, so the pedestrians cross and then continue towards the next intersection. Once the traffic signal turns to amber, the waiting area is blocked. Pedestrians who arrive have to wait until the traffic light turns green again. Since the waiting area is modelled as a small area, waiting pedestrians will be grouped around this waiting area, just as in reality.

Before running the simulation, average pedestrian speed and speed standard deviation are calibrated for Japanese conditions (Alhajyaseen and Nakamura, 2009b). Average pedestrian speed is assumed as 1.34 *m/sec* while the standard deviation of the speed is assumed as 0.26 *m/sec*. Furthermore, the minimum and maximum pedestrian radii are assumed as 0.2 *m* and 0.23 *m*, respectively.

Design of Case Scenarios

In this study, we designed three scenarios to evaluate the network performance for pedestrian flows and vehicular flows, respectively. *Scenario (1)* is the existing scenario, which is under the observed timings from the field, as shown in **Figure 1**. *Scenario (2)* is under the optimal signal coordination for vehicular flows. *Scenario (3)* is designed to maximize the bandwidth for major pedestrian flows. In this study, all the three scenarios share the same cycle length and green splits, as illustrated in **Figure 1**. In this study, trip delay and number of stops are chosen to be the measures of effectiveness for the evaluation of signal coordination. The trip delay and number of stops are calculated for all vehicles and pedestrians moving along the main corridor (main flow). Turning vehicles from the cross roads to the main corridor are also considered. It is noted that the trip delay is the difference between the trip travel time and the free flow trip travel time. Thus, the trip delay includes not only the delay around intersection but also on the links between intersections. In other words, the pedestrian trip delay also covers the delay due to pedestrians' interactions on sidewalk.

For each simulation scenario, three simulation runs for both AIMSUN and NOMAND with various random seeds were conducted. In AIMSUN, each simulation run started with a fifteen-minute warm-up period and then a one-hour simulation time. While for NOMAD, each simulation run started with a ten-minute warm-up period following by a forty-five-minute simulation time.

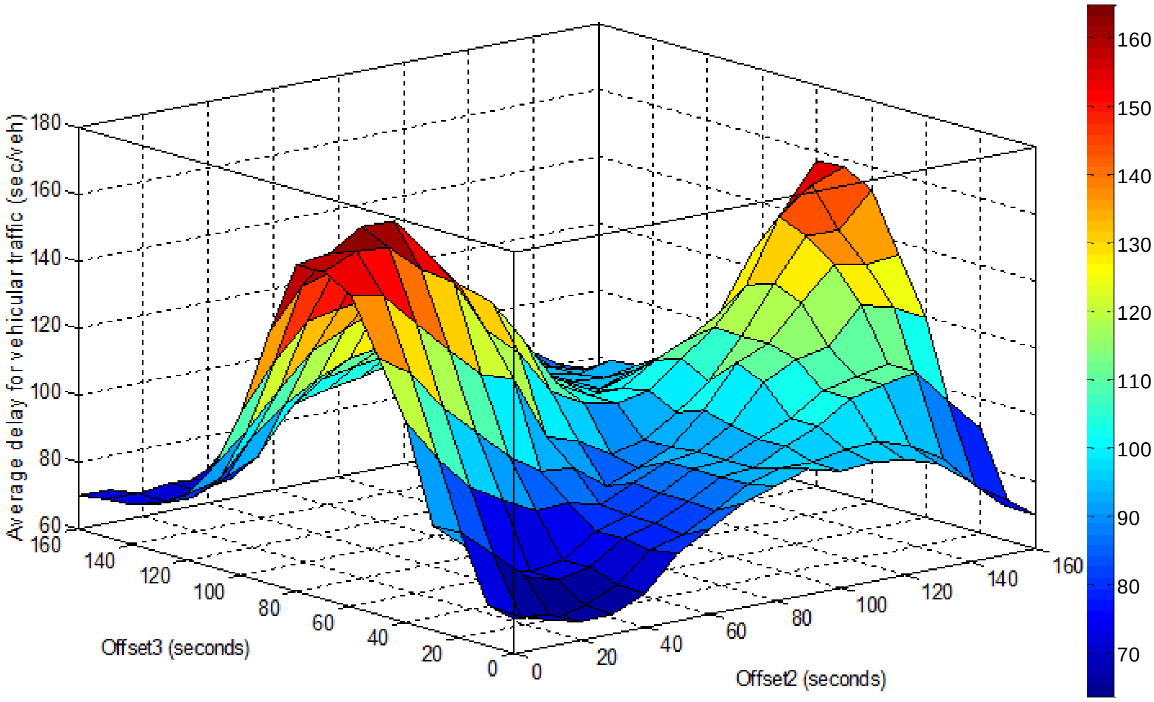
For *Scenario (2),* we used a simple searching method to look for the optimal vehicular coordination from all the feasible offset combinations. We applied 10 seconds as the interval and tried all the feasible offset combinations in AIMSUN. According to the colour contour plots and 3-D plots in **Figure 3** and **Figure 4**, the number of stops and the traffic delay for the main corridor reach their minimum values simultaneously when offset(2) is 10 *sec* and offset(3) is 20 *sec*. Under this optimum scenario with offsets (0, 10, 20), the average number of stop is 1.25 per trip along the main corridor while the average delay is 63.5 *sec* per trip. Meanwhile, the ideal band widths for southbound and northbound directions under free flow speed are 31 seconds and 95 seconds, respectively. It is noted that the existing timing with offsets (0, 8, 33) is very close to the optimal offsets (0, 10, 20). According to AIMSUN, the average delay along main corridor is 66.3 *sec* per trip, which is only 4% higher than the optimum coordination.

For *Scenario (3)*, we tried to maximize the ideal green bandwidth for pedestrian flows. Because the southbound pedestrian demand is dominant, the "optimal" timing only considers the major pedestrian flow walking southbound. The green band starts from the beginning of green at intersection (1). The offset difference between two adjacent intersections is the free flow travel time for an average pedestrian. The "optimal" offset combination for the major southbound pedestrian flow is (0, 142, 148).

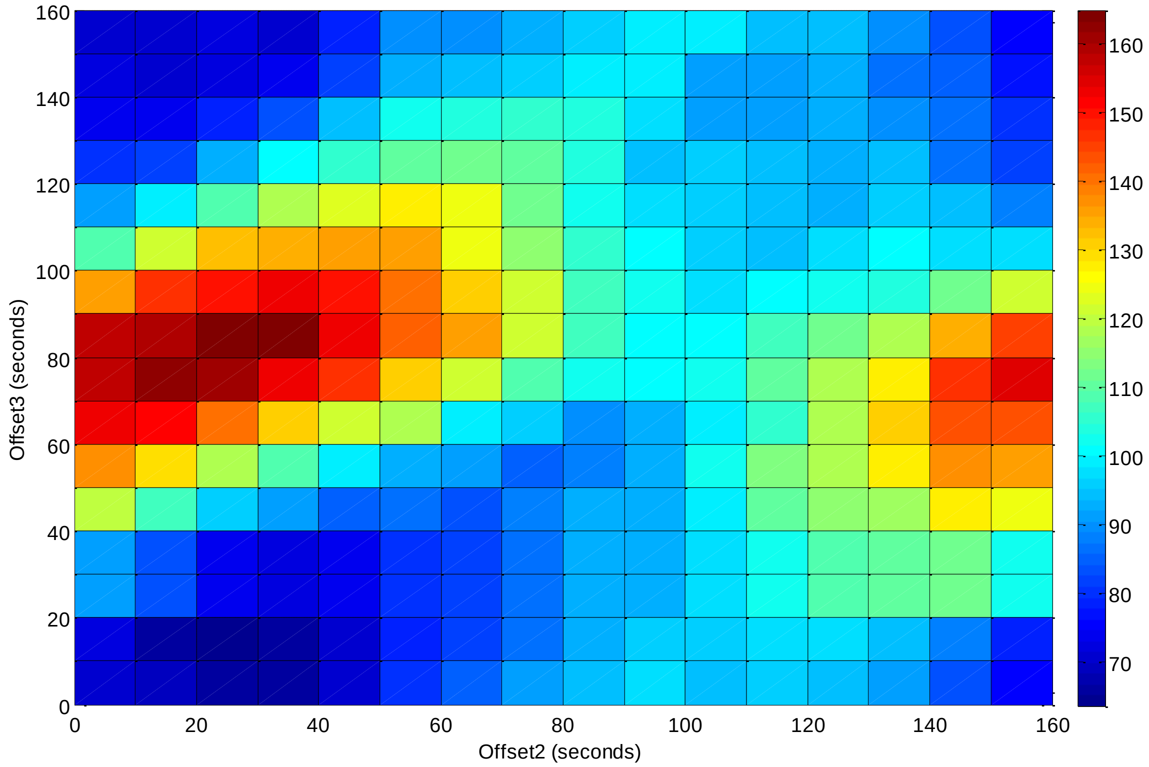
RESULTS ANALYSIS

From **Figure 3**, average vehicle delay along the main corridor under the optimum offsets for vehicular flow (0, 10, 20) is 63.5 *sec* while it is 76.4 *sec* under the optimum offsets for the major pedestrian flow (0, 142, 148). Moreover, the average number of stops under the optimum offsets for vehicular and major pedestrian flows is 1.25 per trip and 1.51 per trip, respectively.

Figure 5 illustrates the total delay distribution of the major pedestrian flow for the whole corridor. **Figure 5a)** and **Figure 5b)** present the delay distribution for *Scenario (1)* and *Scenario (2)*. Due to the minor difference on offsets between the two scenarios, the shapes



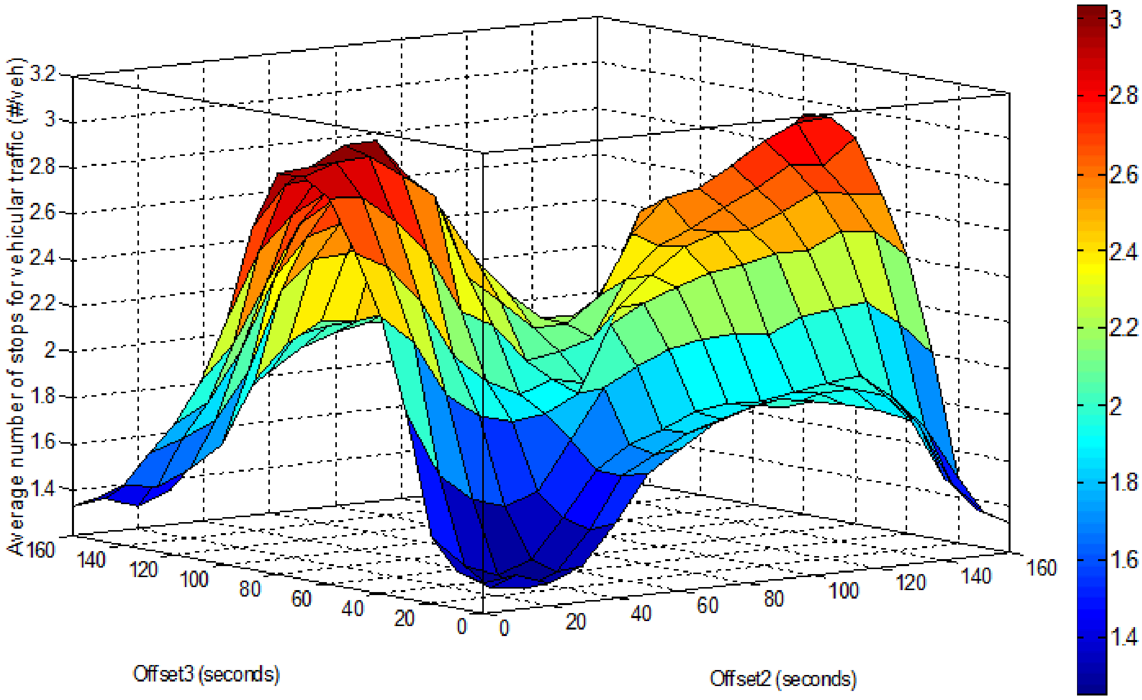
a) 3-D Distribution of average vehicular delay



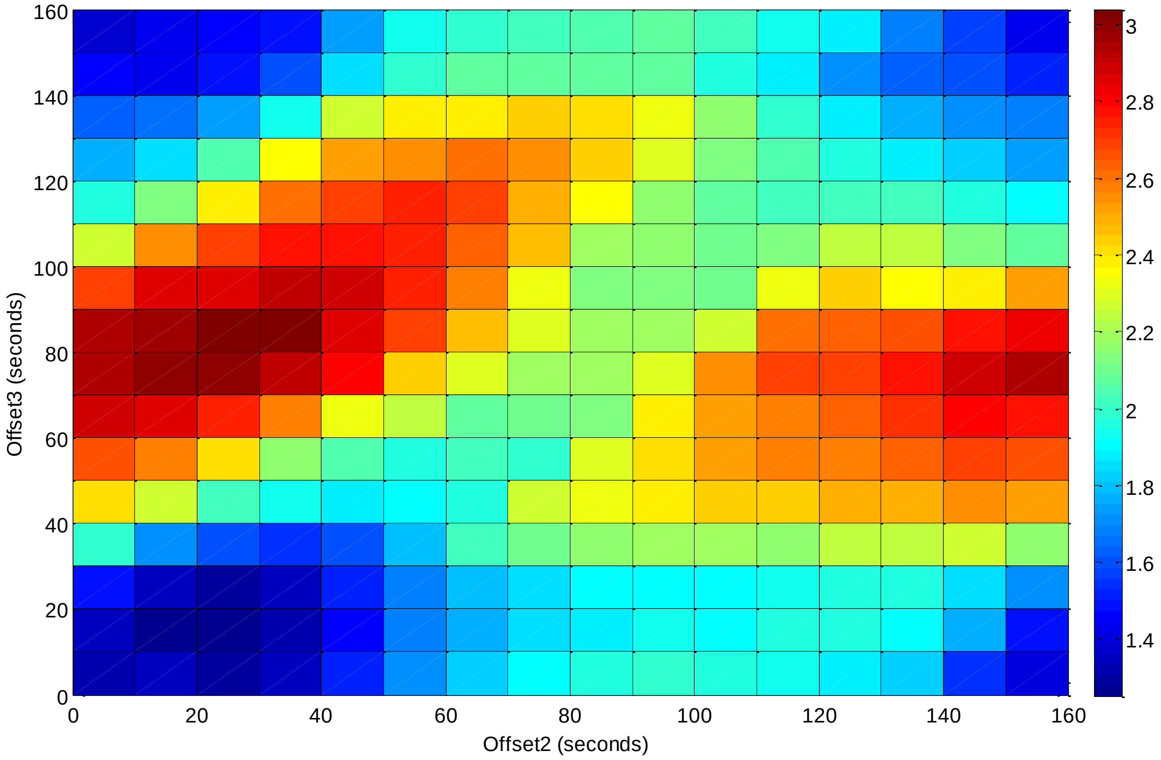
b) Colour contour plot for the average vehicle delay

Figure 3 - Average vehicular delay for main corridor under various offset combinations

of the delay distributions for major pedestrian flows are very similar. Both of them have two peaks for close or over 40 pedestrians with delays around 35 *sec* and 80 *sec*. The average pedestrian delays for *Scenario (1)* and *Scenario (2)* are 78.6 *sec* and 77.7 *sec*, respectively.



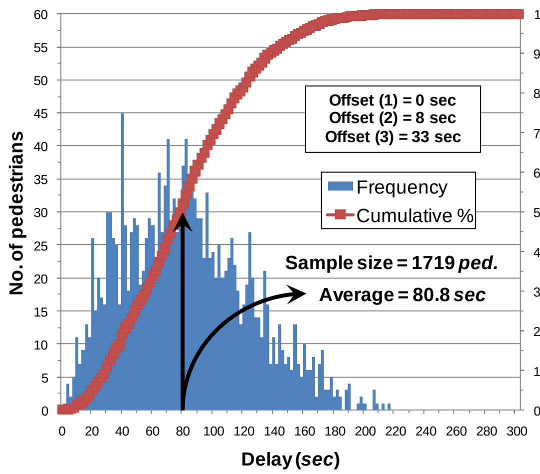
a) 3-D Distribution of average number of stops



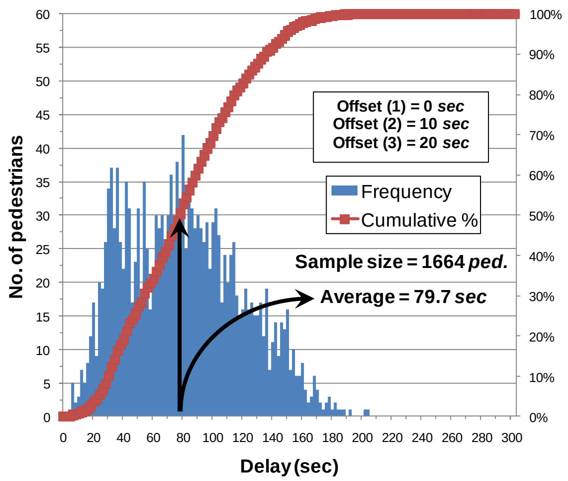
b) Colour contour plot for the average number of stops

Figure 4 - Average number of stops for main corridor under various offset combinations

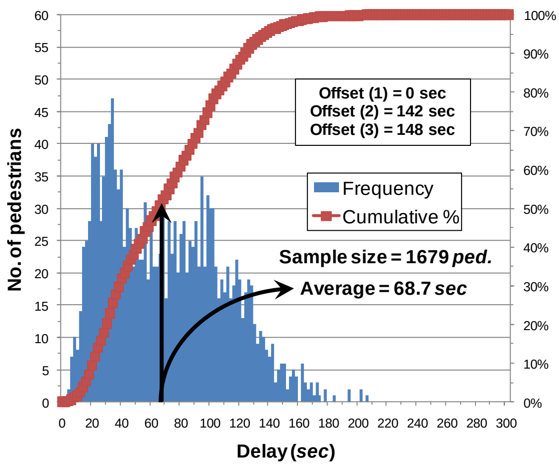
It is noted that the sample sizes for total amount of pedestrians are different due to the various random seeds.



a) Pedestrian delay distribution under existing offsets



b) Pedestrian delay distribution under optimum offsets for vehicular flow

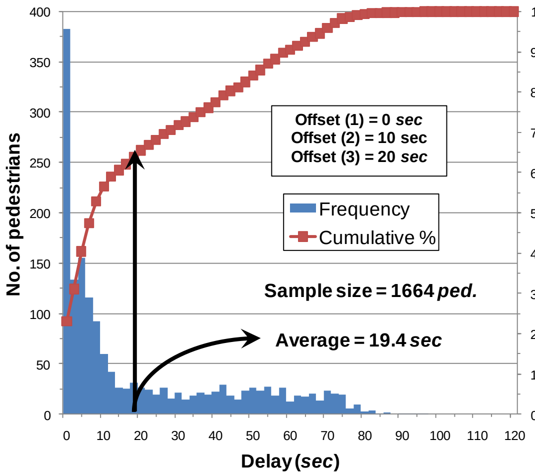


c) Pedestrian delay distribution under optimum offsets for major pedestrian flow

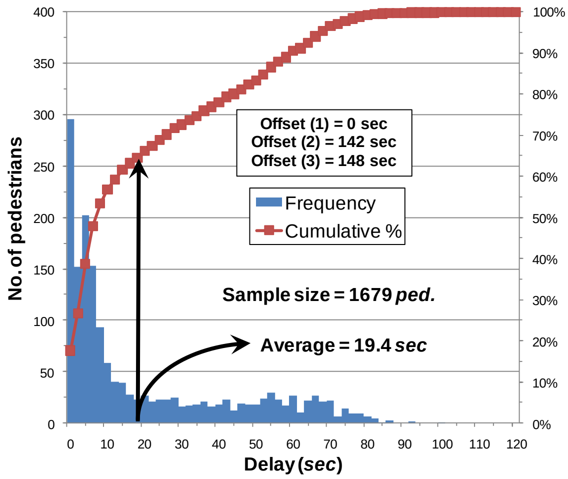
Figure 5 - Total delay distribution of the major pedestrian flow for the whole corridor

Figure 5c) shows the pedestrian delay distribution for *Scenario (3)*. The shape of the distribution for *Scenario (3)* has one unique peak for over 45 pedestrians with delay around 35 seconds. It is quite different from the other two scenarios, as shown in **Figure 5a)** and **Figure 5b)**. The design of pedestrian coordination successfully helped some pedestrians with delays longer than 80 *sec*. Such improvement also reflects on the reduction of average pedestrian delay to 66.9 *sec*.

At intersection level, **Figure 6a)** presents the delay distributions for the major pedestrian flow at intersection (1) under *Scenario (2)*. **Figure 6b)** illustrates the distribution for *Scenario (3)*. There is no change on average pedestrian delay. It is because the southbound pedestrian trip starts from intersection (1). In NOMAD, the arrivals for southbound pedestrians at intersection (1) follow a Poisson distribution and have no correlation with the offset settings. Thus, the pedestrian delay at intersection (1) should not be impacted by the change of timings.

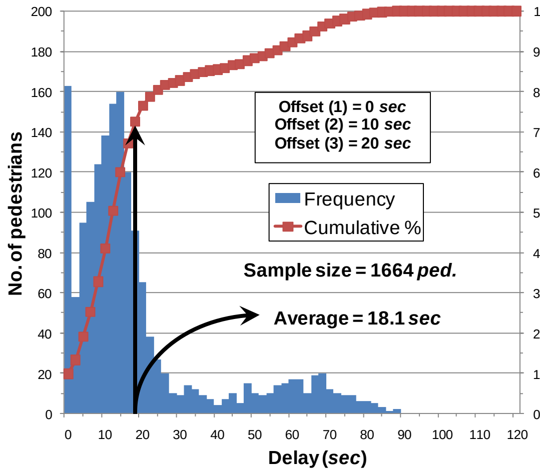


a) Pedestrian delay distribution under optimum offsets for vehicular flow

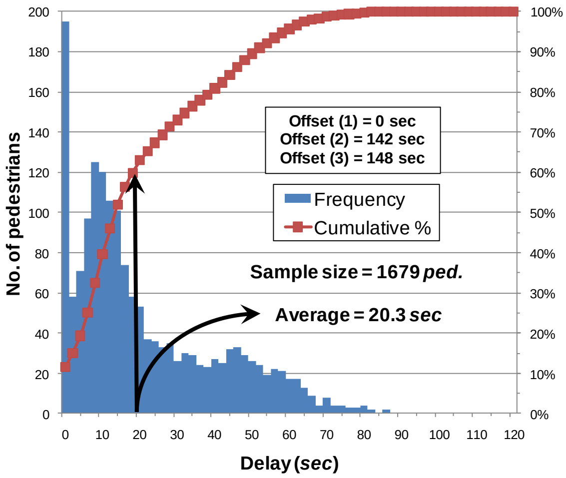


b) Pedestrian delay distribution under optimum offsets for major pedestrian flow

Figure 6 - Delay distribution of the major pedestrian flow at intersection (1)



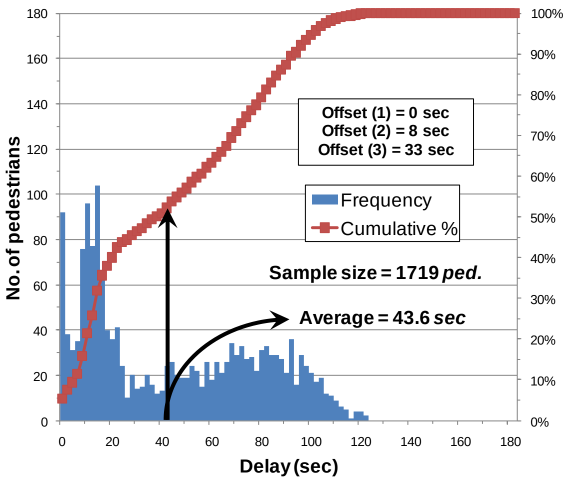
a) Pedestrian delay distribution under optimum offsets for vehicular flow



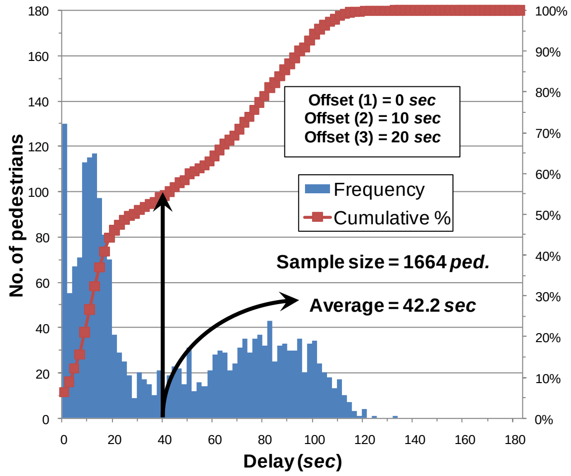
b) Pedestrian delay distribution under optimum offsets for major pedestrian flow

Figure 7 - Delay distribution of the major pedestrian flow at intersection (2)

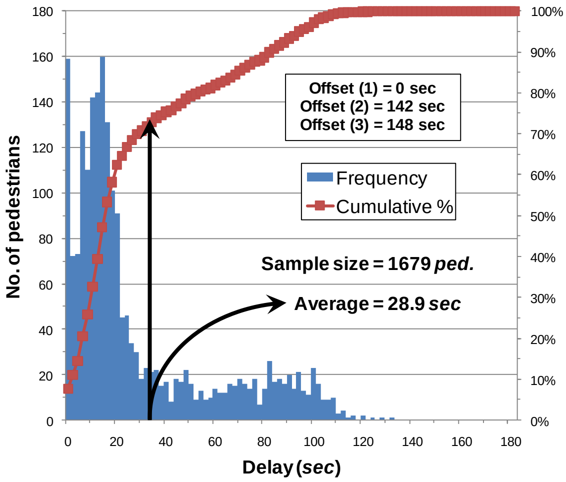
Figure 7a) and **Figure 7b)** show the delay distribution of major pedestrian flow at intersection (2). The shape of the distribution for *Scenario (3)* in **Figure 7b)** is different from that of *Scenario (2)* on **Figure 7a)**. The designed green band successfully help some pedestrians reduce the delay to zero as the number of pedestrians with zero delay in *Scenario (3)* is more than that in *Scenario (2)* by 35 pedestrian. Also in *Scenario (2)*, the amounts of pedestrian with delays around 10 *sec* and 70 *sec* decreased but those with delay around 40 *sec* increased. The average delay is slightly increased under the optimal timing for pedestrian although the change is statistically insignificant. It is partially because intersection (2) is not the critical intersection or bottleneck of the three-signal-corridor. The majority of the trip delay is contributed by intersection (3). Moreover, the average delay at intersection (2) is similar with that for intersection (1), which actually has no impact from signal coordination. It means the average pedestrian delay at intersection (2) is not largely contributed by signal coordination either, but from other factors such as interactions among pedestrians.



a) Pedestrian delay distribution under existing offsets



b) Pedestrian delay distribution under optimum offsets for vehicular flow

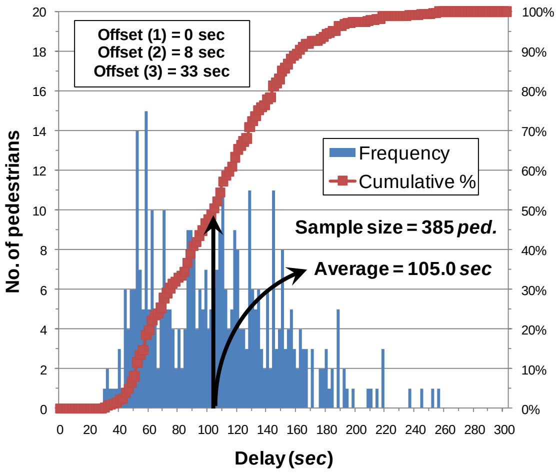


c) Pedestrian delay distribution under optimum offsets for major pedestrian flow

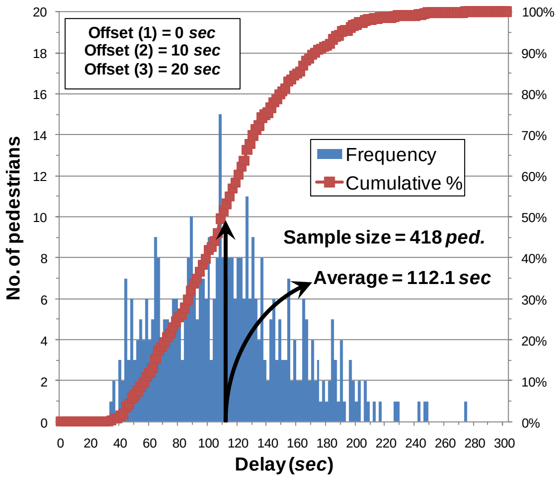
Figure 8 - Delay distribution of the major pedestrian flow at intersection (3)

At the intersection level, the change of average pedestrian delay is most significant at intersection (3). **Figure 8** demonstrates the same delay distribution for intersection (3). **Figure 8a)** and **Figure 8b)** for Scenario (1) and (2) show similar shape of the distribution, which roughly has three peaks with delay around 0 *sec*, 10 *sec*, and 85 *sec*. However, for *Scenario (3)*, **Figure 8(c)** shows two high peaks at 0 *sec* and 10 *sec*. The specifically designed coordination for pedestrian successfully added more pedestrians with zero delay and also removed the peak with delay around 85 *sec*. Many pedestrians, who used to suffer from delays longer than 40 *sec* in Scenario (1) and (2), now only experience zero delay or about 10 *sec* delay.

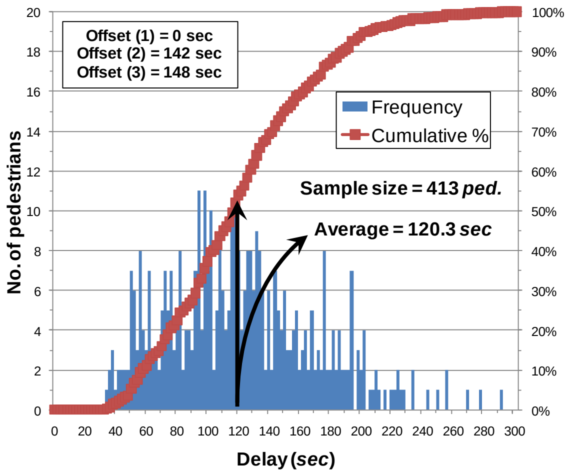
Figure 9 presents the delay for the minor pedestrian flow, which is northbound pedestrian flow in the case study. The minor pedestrian flow experienced much longer delay than the major pedestrian flow. This is expected since the minor flow faces much more interactions with the opposing major flow at crosswalks and sidewalks. It leads to a significant reduction



a) Pedestrian delay distribution under existing offsets



b) Pedestrian delay distribution under optimum offsets for vehicular flow



c) Pedestrian delay distribution under optimum offsets for major pedestrian flow

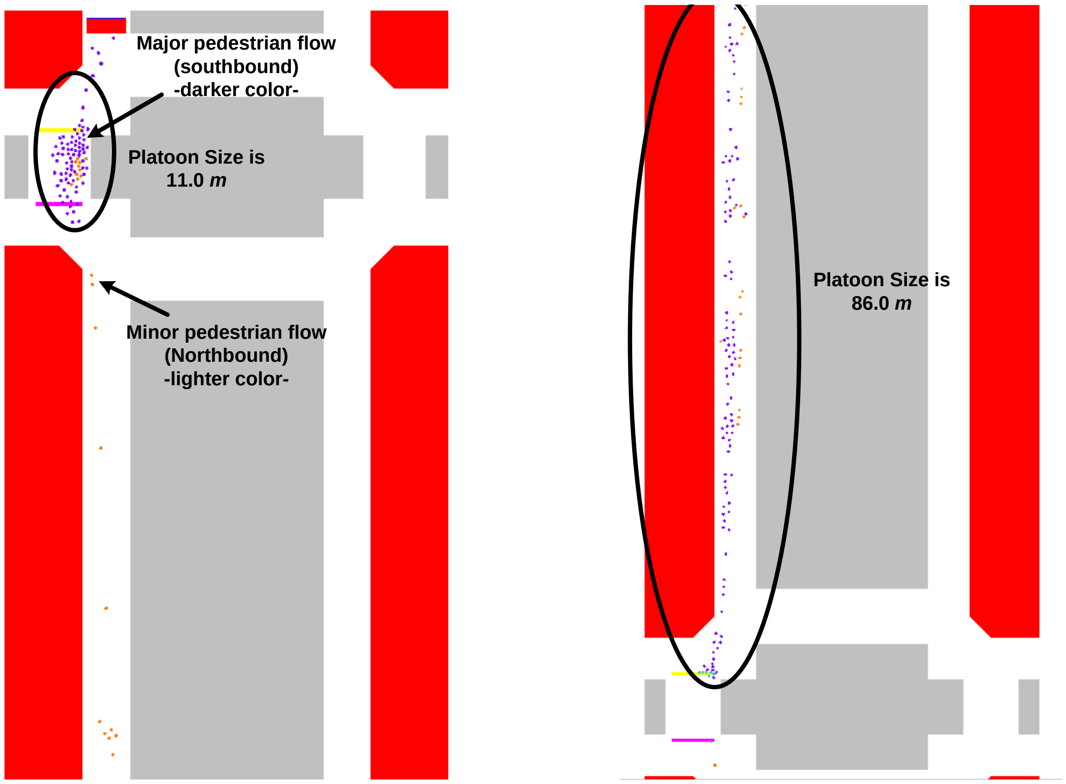
Figure 9 - Delay distribution of the minor pedestrian flow for the whole corridor

in the walking speed and significantly higher delays compared to the major flow (Alhajyaseen and Nakamura, 2009b).

DISCUSSION

According to the results analysis, adjusting signal coordination can reduce the average delay for major pedestrian flow up to 15%. However, the maximum possible reductions in the average vehicular delay and average number of stops are observed as 38.5% and 41.1%. Therefore, the benefit margins of coordination for the vehicular flow are more significant when comparing with that for pedestrian flows. This can be referred to the characteristics of the pedestrian platoon dispersion.

The speed difference, platoon formation and the interaction between pedestrians are essential factors in defining the shape of the pedestrian platoon and further in determining the efficiency of the signal coordination. Figure 10 shows the platoon dispersion in NOMAD.



a) Pedestrian platoon shape intersection (1)

b) Pedestrian platoon shape at intersection (2)

Figure 10 - Platoon formation and dispersion in NOMAD

In Figure 10(a), a pedestrian platoon at intersection (1) with a length of 11.2 meters is moving southbound. The same platoon reaches intersection (2) with a length of 86.0 meters. According to the most popular platoon dispersion model for vehicles by Robertson (1969), the vehicular platoon dispersion are mainly due to the external friction of a platoon but not from the internal interactions among vehicles. Thus, the platoon dispersion factor is given for three types of conditions in relation to such external frictions. Pedestrian platoon dispersion is quite different from that for vehicular platoon because pedestrians choose their speed more freely than vehicles that follow with each other on dedicated lanes. In other words, pedestrians are much less constrained by a pedestrian platoon than vehicles to its platoon. Therefore, pedestrian platoon dispersion should refer mainly to the desired speed difference in a pedestrian platoon.

Given NOMAND is a fully calibrated microscopic simulation model for pedestrian study. We tried to observe the platoon dispersion from NOMAD. Some platoon dispersion data, e.g. platoon size before and after dispersion as shown in **Figure 10**, has been collected. It is assumed that the distribution of pedestrians' desire speed is linear when a platoon just formatted after passing a crosswalk. The fastest pedestrian leads the platoon while the slowest is at the end. Since in reality, the fastest pedestrians and slowest pedestrians become very far from the center of the dispersed platoon. Therefore, it is assume that 80% of the original platoon would form the dispersed platoon. Since in NOMAD, pedestrians' desire speeds follow normal distribution, the maximum and the minimum speeds ($\mu \pm 1.28\sigma$) are 1.69 *m/sec* and 1.03 *m/sec*, respectively. The observed average size of the platoon at intersection

(1) is 11.2 *m*. By using the difference in speed between the fastest pedestrian and the slowest one, the size of the platoon at intersection (2) would be 99.8 *m* assuming there are no interactions among pedestrians. The estimated dispersion (88.6 *m*) is very close to the observed average dispersion (74.8 *m*) in NOMAD. The difference is mainly due to the ignorance of the interactions and attractions among pedestrians, which are dependent on platoon density. Furthermore, the 80% used in this estimation above is arbitrary selected and should be calibrated by field data.

Given the large dispersion, a pedestrian platoon might become a uniform arrival flow that covers a complete signal cycle at the downstream intersection. For this case, any signal coordination would not be helpful to significantly reduce the overall intersection delay. It means that the efficiency of signal coordination for pedestrian flows is not guaranteed but might depend on a few factors. The first factor is the composition of the pedestrian demand, which defines the distribution of pedestrians' desired walking speeds. The second factor is the link length between intersections. The third factor is the density of pedestrian flow that corresponds to the level of interactions among pedestrians. These three factors will decide the level of platoon dispersion. The last factor is the signal timing parameters, e.g. cycle length.

CONCLUSION AND FUTURE WORKS

Through this study, the signal coordination has been evaluated for both pedestrian and vehicular flows. A Japanese numerical cases study is analysed. AIMSUN microscopic simulation program is utilized to estimate average vehicular delay and number of stops while NOMAD (pedestrian micro simulation program) is used to estimate pedestrian delay under various signal coordination settings.

It is concluded that pedestrian delay can be reduced significantly by coordinating pedestrian flows. It was also found in the case study that the coordination for the major pedestrian flow led to a 15% reduction in the average delay. However, this reduction is much lower than what can be achieved for the vehicular traffic under the optimized signal offset. It is because that the efficiency of signal coordination for pedestrian flows is dependent on several factors, such as variations of pedestrians' desired speed, density of pedestrian flow, link lengths between intersections and signal cycle length.

The design of signal coordination for pedestrian flows is much more complicated than that for vehicular flows. Thus, we should carefully consider all the aforementioned factors in the signal operation. The characteristics of pedestrian platoon dispersion should be studied and modelled by empirical data.

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