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A Quantitative Approach for Timing the Pedestrian Walk Interval

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Abstract

At a typical signalized intersection, the pedestrian phase consists of a walk interval and a change/clearance interval, during which pedestrians are given the right of way. The walk interval is intended to allow pedestrians to exit the curb ramp and enter the crosswalk. The clearance interval will enable them to cross entirely to the other side of the road. Unfortunately, the literature is quite vague on how long the walk interval should be and provides values ranging from 4 to 15 seconds based on qualitative pedestrian demand ranging from Negligible to High. To provide some quantitative guidance for walk interval selection, this paper reports on a study that collected 1,500 pedestrian movement data from 12 signalized intersections with varying pedestrian demand, pedestrian storage areas, and pedestrian push-button locations. The data was used to propose a quantitative model for designers to select the appropriate walk interval. Specifically, this paper seeks to add values to the Traffic Operations Handbook walk-interval guidelines as to how many pedestrians are considered "negligible volume" and can be accommodated by the 4 second minimum time, how many pedestrians are considered "typical volume" and require 7 to 10 seconds, and how many pedestrians are considered "high volume" and require 10 to 15 seconds, or perhaps longer. In addition to examining pedestrian demand, this paper looks at the impact of storage areas and pedestrian push-button location on pedestrian start-up time and, consequently, an appropriate walk interval.

Keywords

Pedestrian Start-Up Time, Walk Interval, Pedestrian Phasing

1. Introduction

At signalized intersections, the pedestrian phase, during which the right-of-way is given to pedestrians, consists of two intervals: 1) Walk interval typically begins with the adjacent vehicular through-movement green interval and is used to allow pedestrians to move from the curb into the crosswalk; 2) Pedestrian Clearance, also referred to as flashing don't walk (FDW) or change interval: follows the walk interval and informs pedestrians should either complete their crossing if already in the intersection or refrain from entering the intersection until the next pedestrian walk interval is displayed. Finally, the pedestrian phase ends with the solid *Don't Cross*

The duration of the pedestrian phase, seen in Figure 1 (Walk interval + Clearance interval), is computed using the following equation:

$$G_p = P.W. + P.C.$$

where;

G_p is the green interval duration needed for the pedestrian crossing time.

P.W. is the walk interval duration. The MUTCD indicates that the minimum walk duration should be at least 7 seconds but states that a duration as low as 4 seconds may be used if pedestrian volumes are low. The traffic signal operations handbook suggests using the walk values listed in Figure 2 and Table 1, but does not provide corresponding quantitative values for Pedestrian volume.

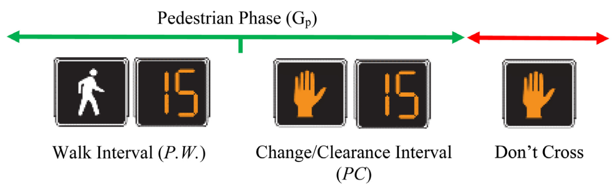


Figure 1. Pedestrian phase inervals [1].

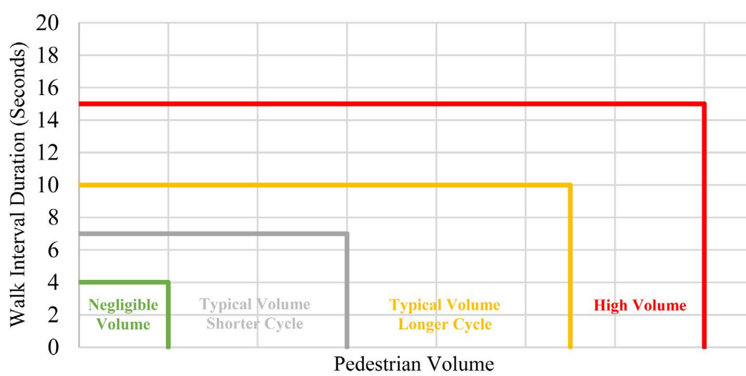


Figure 2. Pedestrian walk interval categories.

Table 1. Pedestrian walk interval duration [2].

Conditions	Walk Interval Duration (*P.W.*), s
High pedestrian volume areas	15
Typical pedestrian volume and longer cycle length	10
Typical pedestrian volume and shorter cycle length	7
Negligible pedestrian volume	4

P.C. is the clearance/change interval duration. The duration of this interval is computed as the crossing distance divided by the walking speed. The MUTCD recommends a value of 4.0 feet per second (ft/s) walking speed. The Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities recommended using 3.0 ft/s. Recent work completed by LaPlante and Kaeser has suggested a speed of 3.5 ft/s [1] [3].

Pedestrian speeds and the clearance interval have been extensively studied in the literature and, consequently, well defined in designers' guidebooks [1] [3] [4] [5] [6]. However, little is known about the factors influencing the pedestrian start-up time, and as a result, the walk interval guidelines, seen in **Table 1**, are qualitative rather than quantitative.

Studies investigating pedestrian dynamics (*i.e.*, walking speed and start-up time) have considered factors such as pedestrians' age and found that, on average, pedestrians above the age of 65 differ from those younger [7] [8] [9] [10]. Other studies considered gender and roadway geometrics such as street width, speed limits, curb height, the number of travel lanes, and traffic cycle length [7] [11] [12]. All of which can be assumed to influence walking speed more so than start-up time.

The walk interval (P.W.) should be designed to accommodate pedestrians' perception-reaction delay and walking time to the crosswalk. Many factors can result in delaying a pedestrian in accomplishing this task. The social force model is widely used in defining the factors influencing pedestrian dynamics (*i.e.*, avoiding obstacles and keeping a comfort zone away from other pedestrians). Such factors/forces make a pedestrian take some time to exit the curb onto the crosswalk once the walk interval is activated [13] [14].

In terms of signal timing, the collective behavior of pedestrians matters and should be accounted for in timing the walk interval. Therefore, the walk interval should provide enough time to allow all waiting pedestrians to move onto the crosswalk from the onset of the walk signal illumination.

2. Motivation and Objective

There is a gap in the literature regarding quantitative values for pedestrian demand that should be used to select pedestrian walk times. Similarly, the literature does not provide guidance on how other factors, such as pedestrian storage areas and distance to pedestrian push-buttons, influence the selection of walk times.

This paper reports on the observation of pedestrian start-up time and propose a quantitative model for designers to select the appropriate walk interval. Specifically, this paper seeks to add values to **Figure 2** as to how many pedestrians are considered "negligible volume" and can be accommodated by the 4-second minimum time, how many pedestrians are considered "typical volume" and require 7 to 10 seconds, and how many pedestrians are considered "high volume" and require 10 to 15 seconds, or perhaps longer. In addition to examining pedestrian demand, this paper looks at the impact of storage areas and pedestrian push-button location on pedestrian start-up time.

As a result of having a proper understanding of pedestrian demand and geometrics influencing start-up time and, consequently, the selected walk interval, designers will be able to provide satisfactory service that minimizes delay for pedestrians and motorists.

3. Methods

Using video footage from 12 signalized intersection cameras collected between late 2021 and early 2022 in the City of West Lafayette, Indiana, 1500 observations of pedestrian start-up time are examined. Figure 3 and Table 2 present the 12 intersections used in this study.

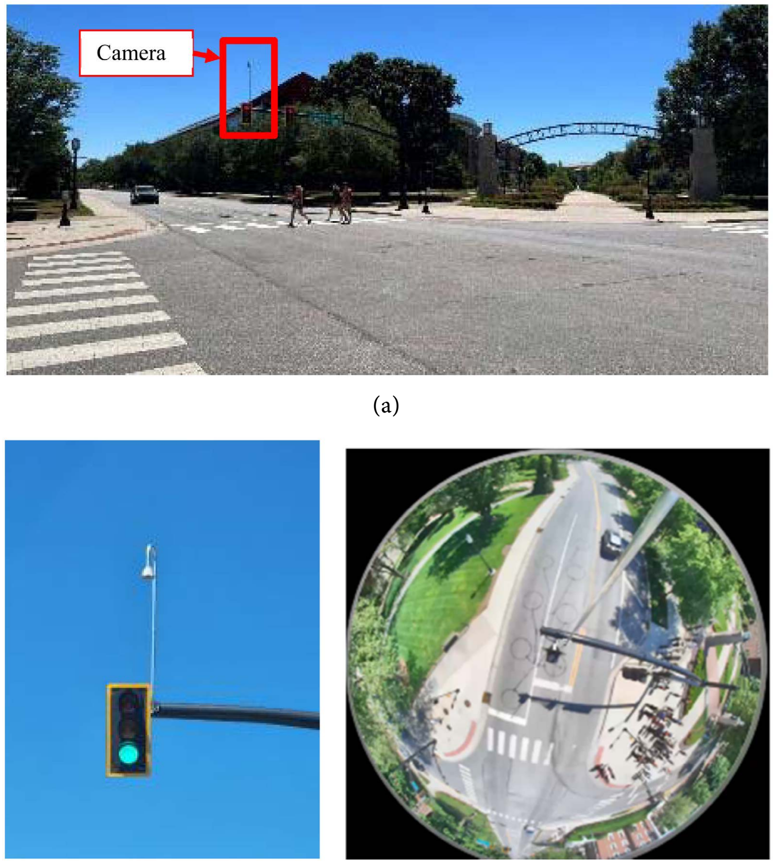
Data were extracted from videos recorded using 12 cameras mounted on the traffic light mast arms. Installed cameras recorded continuously since the day of installation. Video imagery provides a 360 view of all intersection approaches and curb ramps, as seen in Figure 4.

During each cycle, videos were analyzed in terms of start-up time. Start-up time is the duration needed for a waiting pedestrian, or a group of pedestrians, to clear the curb into the crosswalk once the Walk Interval is activated. Figure 5 illustrates the visual observation process used in this study to record pedestrians' start-up times.

In addition, each intersection observation was analyzed in terms of the total number of pedestrians waiting per quadrant, the available storage area for pedestrians per quadrant (curb ramp area), and the distance from the pedestrian push-button to the crosswalk. Figure 6 below presents examples of the collected explanatory variables.

After that, a set of statistical regression models was built to explain the variability in pedestrian start-up time (y) given pedestrian demand in terms of the number of pedestrians per cycle per quadrant (X_1), available storage area (X_2), and distance from the pedestrian push-button to the crosswalk (X_3).

Figure 3. Intersections map.



(a) (b) (c)

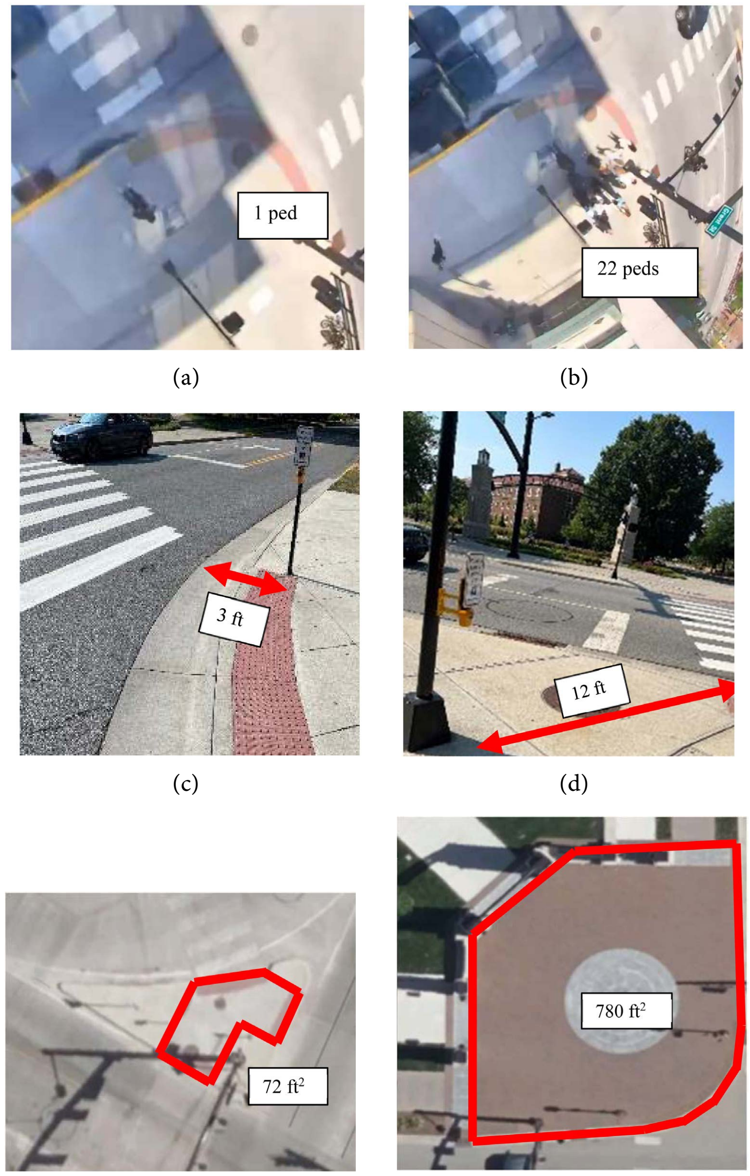
Figure 4. Camera installed at w. stadium Ave and university St. (#11). (a) Intersection view with camera location noted; (b) Close-up view of camera mounting location; (c) Camera view.

Table 2. Intersections locations.

	Intersection	Location	
		Long	*Lat*
1	Roebuck Drive and State Street	40.4212	−86.9019
2	State Street and South River Road	40.4218	−86.9042
3	State Street and Chauncey Avenue	40.4233	−86.9069
4	Northwestern Avenue and State Street	40.4240	−86.9082
5	State Street and Andrew Place	40.4240	−86.9092
6	South Grant Street and State Street	40.4239	−86.9103
7	State Street and University Street	40.4242	−86.9168
8	State Street and S. Martin Jischke Drive	40.4242	−86.9217
9	State Street and Airport Road	40.4241	−86.9302
10	South Chauncey Avenue and West Wood Street	40.4219	−86.9076
11	University Street and 3rd Street	40.4272,	−86.9166
12	West Stadium Avenue and University Street	40.4313	−86.9168

(a) (b) (c)

Figure 5. Pedestrian start-up time observation process. (a) Pedestrians waiting for the walk interval; (b) Pedestrian walk interval active (t = 0, start the timer); (c) Last waiting pedestrian clears (t = 12.5 s, stop the timer).



(a) (b) (c) (d) (e) (f)

Figure 6. Start-up time factors. (a) Low ped volume; (b) High ped volume; (c) Close ped push-button; (d) Far ped push-button; (e) Small storage area [15]; (f) Large storage area [15].

4. Summary of Data

Intersections with heavy pedestrian traffic constitute the majority of the 1500 observations. Figure 7(a) presents the distribution of start-up time observations per intersection. From the data collected, the average pedestrian start-up time was 4.05 seconds with a standard deviation of 2.17 seconds. The average pedestrian volume was 4.03, with a standard deviation of 3.58. Figure 7(b) and Figure 7(c) present the observed frequencies of pedestrian start-up time and pedestrian volume.

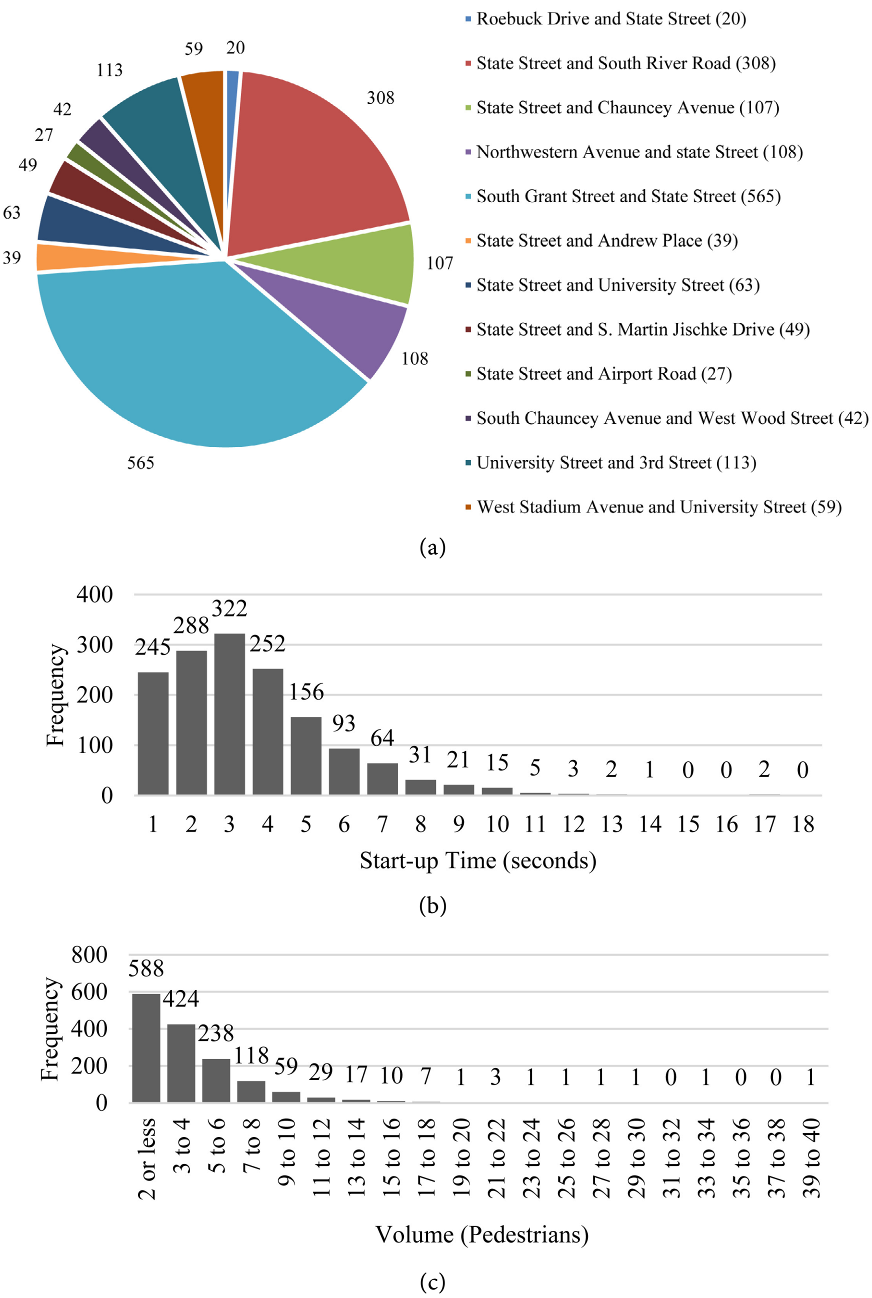


Figure 7. Data observations. (a) Observations per intersection; (b) Start-up time frequency; (c) Ped volume frequency.

Results

The guidelines in place for determining the duration of the pedestrian walk interval, presented in Table 1, categorize the time needed into three categories: 1) "negligible volume" and require 4 seconds, 2) "typical volume" and require 7 to 10 seconds, and 3) "high volume" and require 10 to 15 seconds. Figure 8 and Table 3 below present the descriptive statistics of the study's observations within these categories.

The relation between pedestrian start-up time and the explanatory variables was near linear, so linear regression was used to explain the variability in the response variable y: start-up time. Three models were built, and a report of the findings is listed in Table 4.

5. Discussion and Recommendations

Since this data was collected on and near a college campus, the authors propose using the 50th percentile values in the pedestrian volume categories listed in Table 5 and seen in Figure 9 as a quantitative guideline for selecting an appropriate pedestrian walk interval duration. However, the 25th percentile values could provide more conservative values in locations where the pedestrians might have slower start up time.

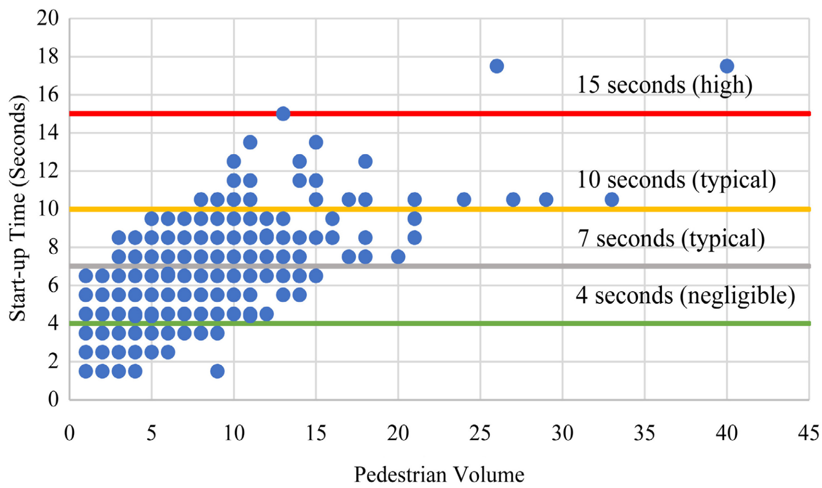


Figure 8. Start-up time to Ped volume relation.

Table 3. Pedestrian walk ınterval start-up time observation statistics.

Start-up Time	Pedestrian Volume								
	Obs.	Avg	Min	Max	Std.	Percentile			
						25th	50th	75th	90th
1 - 4 s	1107	2.75	1	12	1.88	1	2	4	5
4 - 7 s	313	6.41	1	20	2.87	4	6	8	10
7 - 10 s	67	11.99	3	33	5.91	8	11	15	19.2
10 - 15 s	13	15.92	10	40	8.45	11	14	15	24.4

Table 4. Summary of statistical models.

Model 1: Startup Time = β_1 (Ped Volume)

Explanatory Variable Coefficient		*Explanatory Variable Significance*			*Goodness-of-Fit*	
	Coefficient		t-stat	p-value	Adj. R2	0.817
β_1	0.7709	X_1 (peds)	82.12	0.0000	Std. Err.	1.962
					Obs.	1500

Regression Statistics

	df	SS	MS	F
Regression	1	25979.6336	25979.6336	6744.0812
Residual	1499	5774.4664	3.8522	
Total	1500	31754.1		

Model 2:
Startup Time = β_1 (Ped Volume) + β_2 (Storage Area) + β_3 (Push Button Offset)

Explanatory Variable Coefficient		*Explanatory Variable Significance*			*Goodness-of-Fit*	
	Coefficient		t-stat	p-value	Adj. R^2	0.896
β_1	0.5460	X_1 (peds)	55.82	0.0000	Std. Err.	1.477
β_2	0.1933	X_2 (ft^2)	24.95	3.4E−115	Obs.	1500
β_3	−3.4E−06	X_3 (ft)	−0.03	0.9739		

Regression Statistics

	df	SS	MS	F
Regression	3	28488.2356	9496.0785	4352.7923
Residual	1497	3265.8643	2.1816	
Total	1500	31754.1		

Model 3: Startup Time = β_1 (Ped Volume) + β_2 (Push Button Offset)

Explanatory Variable Coefficient		*Explanatory Variable Significance*			*Goodness-of-Fit*	
	Coefficient		t-stat	p-value	Adj. R^2	0.8964
β_1	0.5460	X_1 (peds)	56.37	0.0000	Std. Err.	1.4765
β_2	0.1931	X_2 (ft)	33.92	1.2E−187	Obs.	1500

Regression Statistics

	df	SS	MS	F
Regression	2	28488.2332	14244.1166	6533.5448
Residual	1498	3265.8667	2.1801	
Total	1500	31754.1		

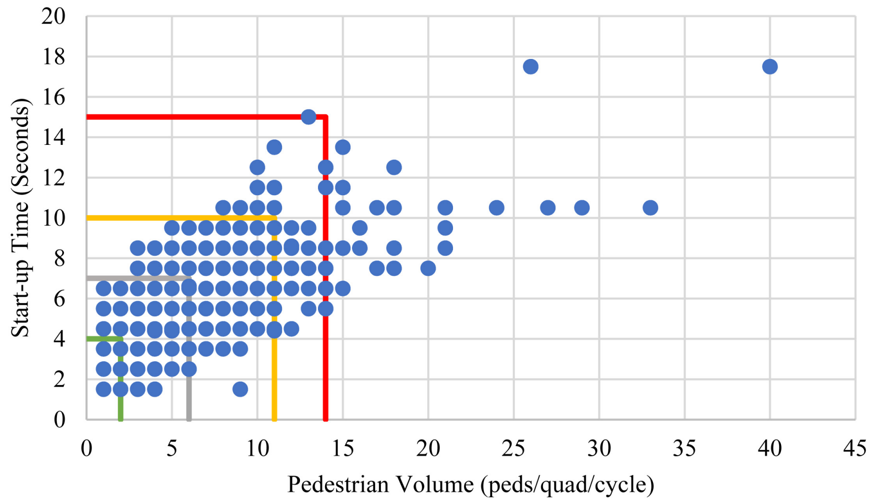


Figure 9. Recommended pedestrian walk interval duration using 50th percentile.

Table 5. Walk interval duration per pedestrian volume.

Start-up Time	Pedestrian Volume (peds/quad/cycle)			
	Percentile			
	25th	*50th*	75th	90th
1 - 4 s	1	*2*	4	5
4 - 7 s	4	*6*	8	10
7 - 10 s	8	*11*	15	19.2
10 - 15 s	11	*14*	15	24.4

The relationship between start-up time and the collected explanatory variables was near-linear, so linear regression models were used to predict start-up time. The statistical models built indicate the significant influence of the variables: 1) pedestrian volume and 2) offset from the push-button to the crosswalk on the pedestrian start-up time. The built model explains start-up time with a relatively high accuracy of 0.8964 R2.

6. Conclusions

This paper presented a quantitative analysis of the pedestrian walk interval duration given pedestrian volume conducted on 12 signalized intersections across the City of West Lafayette, Indiana, for ten months. In addition, data on the storage area and offset from the pedestrian push button to the crosswalk was used to explain the variability in pedestrian start-up time. The built statistical model can aid designers in identifying proper walk interval timing on an intersection-by-intersection basis. In addition, designers now have quantitative data for new construction to support prioritizing close-to-crosswalk push-button locations to help minimize pedestrian start-up time.

Future research should consider examining the impact of different types of pedestrian phasing (*i.e.*, exclusive service and standard concurrent service) on pedestrian start-up time. In addition, seasonality can be included in the analysis (*i.e.*, summer, fall, winter, and spring) as pedestrian behavior can be expected to change with inclement weather.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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