Adaptive Walk Intervals

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If the vehicular phase concurrent with a pedestrian phase is running under fully actuated control or is a noncoordinated phase under coordinated-actuated control, the length of its green is not known when the phase begins; it could run anywhere between a (known) minimum and maximum green, depending on when a gap is detected. In such a case, walk intervals are generally kept to a minimum length to prevent the pedestrian phase from constraining the ending of green that can lead to situations in which the pedestrian phase has cleared yet the concurrent phase continues its green for 20 more seconds. Proposed is the concept of an adaptive walk interval whose length is based on the predicted length of the concurrent phase's green, which in turn is calculated cycle by cycle with data from recently past cycles. That way, during heavy traffic periods in which the vehicular phase usually goes well beyond its minimum, a longer-than-minimum walk interval can be provided with very little impact on signal operation or vehicular delay. Two methods, ratio estimation and stratification, are proposed and tested for predicting the green time needed by a vehicular phase; both methods use as data only traffic signal timing data from the last several cycles. Simulation tests with coordinated-actuated and fully actuated control, with and without pedestrian recall, and with and without permissive windows show that adaptive walk intervals can markedly reduce pedestrian delay with almost no impact on vehicular delay.

Concerns for equity, livability, and promoting sustainable modes of transportation have enhanced attention toward reducing pedestrian delay at signalized intersections. While practice has long focused on minimizing vehicular delay, provisions for pedestrians have traditionally focused only on meeting the minimum safety requirements, often resulting in long pedestrian delay. Those safety requirements, laid out in the *Manual on Uniform Traffic Control Devices* (*1*), as well as the *Traffic Signal Timing Manual* (*2*), consist mainly of a policy minimum length for the walk interval (W_o)—7 s is recommended for W_o although 4 s may be used in exceptional cases—and sufficient pedestrian clearance time, the crossing length divided by a low-percentile pedestrian speed, usually taken to be 3.5 ft/s.

Recent research on reducing pedestrian delay includes attention given to two-stage pedestrian crossings (*3, 4*), longer permissive intervals for actuated pedestrian phases (*5*), overlaps involving leading pedestrian intervals that can reduce cycle length requirements (*6*), and exploring the use of fully actuated versus coordinated control at different levels of vehicular and pedestrian demand (*7*). Because pedestrians tend to arrive without a coordinated pattern (except at multistage crossings), reducing pedestrian delay is mainly a matter of shortening the signal cycle or lengthening the walk interval, or both (*8*). This paper focuses on the second idea: lengthening the walk interval for a given cycle.

MAXIMUM, MINIMUM, AND ADAPTIVE WALK INTERVALS

Pretimed signals can afford the longest possible walk intervals for a given set of splits, which makes them popular in heavily pedestrianized cities like New York and San Francisco. For a given pedestrian clearance (PedClear) time and given green interval (G) and change interval (YAR) on the concurrent vehicular phase, the walk interval (W) can be maximized by simply giving it the entire split minus the needed clearance:

$$W_{\max} = G + \text{YAR} - \text{PedClear} \tag{1}$$

With coordinated-actuated control, walk intervals that run concurrently with the coordinated phase can likewise easily be maximized. The coordinated phase may begin earlier than its nominal start time in the cycle, but it always ends at its scheduled time. By choosing the controller setting "rest in walk," walk intervals concurrent with the coordinated phase will run to their maximum length (*2*) as given by Equation 1. In this case, G is the coordinated phase's green time in a particular cycle, which may be longer than its nominal green if it begins early.

However, for crossings concurrent with a vehicular phase whose ending time is not fixed, but rather is demand responsive—which includes the noncoordinated phases at intersections with coordinated-actuated control as well as all phases at intersections with fully actuated control—the walk interval must be set without knowing in advance the length of the green interval. Standard practice is to limit the walk interval to a minimum length so that the vehicular phase can respond immediately when a gap is detected, subject only to minimum green, because the phase is constrained from switching until any concurrent pedestrian phase has cleared. While pedestrian clearance may time concurrently with the vehicular change interval, PedClear is typically greater than YAR, and so the goal is to have the pedestrian phase almost cleared—that is, having only YAR seconds left until it is fully cleared—when the concurrent vehicular green reaches its minimum green ($G_{\min}$).

The minimum length walk interval is given by

$$W_{\min} = \max\left(G_{\min} + \text{YAR} - \text{PedClear}, W_o\right) \tag{2}$$

$W_{\min}$ is the longest walk interval that will not constrain vehicle operations and will therefore not affect vehicular delay, subject to the *Manual on Uniform Traffic Control Devices*' policy minimum. While $W_{\min}$ often equals W_o, there are many pedestrian phases for which they are not equal. For example, if $G_{\min} = 20$ s, YAR = 5 s, and PedClear = 13 s, then $W_{\min} = 12$ s. Setting the walk interval to W_o instead of $W_{\min}$ creates additional delay for pedestrians with no benefit to vehicular traffic.

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Unfortunately, W_o is often used in such cases because of the industry focus on meeting only pedestrian minimum needs, rather than on giving them the best possible service.

Even if the concurrent walk interval is set to $W_{\min}$, the pedestrian signal can still display (solid) "Don't Walk" while the concurrent vehicular phase remains green, sometimes for a considerable time, leaving waiting pedestrians wondering why they are told to wait while the concurrent traffic phase still has a green. Figure 1 illustrates how $W_{\min}$ relates to the minimum and maximum green times for a concurrent vehicular phase with demand-responsive end-of-green. As shown in the figure, $W_{\min}$ is chosen so that pedestrian clearance (c) will end simultaneously with the change interval if the green runs for its minimum value (b). But if the green runs longer (a), there can be a long time while the vehicular signal is green yet the parallel pedestrian signal says "Don't Walk."

Short walk intervals increase pedestrian delay, which in turn increases the likelihood of noncompliance (*1*). This can become a safety problem because pedestrians crossing with the green but without a walk signal will get no advance indication of when the signal is about to change until the onset of yellow. Therefore, they may be caught in the middle of the intersection when a conflicting movement is released.

If it could be predicted that a demand-responsive phase would run longer than its minimum green, then its walk interval could be lengthened correspondingly, reducing pedestrian delay without constraining vehicular operation. This is what will be called an adaptive walk interval—one whose length varies from cycle to cycle between $W_{\min}$ and $W_{\max}$ based on a prediction of how long the concurrent vehicular phase is expected to run. Adaptive walk intervals will be short when traffic is light and the vehicular phase is expected to gap out later. At an extreme, an adaptive walk interval will have length $W_{\max}$ when the vehicular phase is expected to max out. Adaptive walk intervals represent a middle ground between the long walk intervals offered by pretimed control and the short walk intervals offered by actuated control.

The objective of this research is to develop a method for setting walk interval lengths on a cycle-by-cycle basis based on predicted lengths of the concurrent vehicular green. Because predictions are imperfect, inevitably, vehicular intervals will sometimes gap out sooner than predicted. So lengthening the walk interval beyond $W_{\min}$ will sometimes force the phases to end later than they otherwise would, increasing vehicular delay to traffic whose red interval is thus lengthened. That creates a trade-off: adaptive walk intervals should be able to lower pedestrian delay, but at the cost of some increase in vehicular delay.

The hypothesis is that substantial reductions in pedestrian delay are possible with very little increase in vehicular delay. This is based on the idea that in many situations, vehicular phases routinely run considerably longer than their minimum green, offering an opportunity to increase walk intervals with almost no impact on traffic operations.

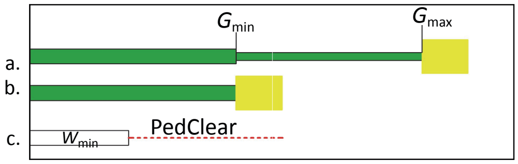

FIGURE 1 Minimum walk interval in relation to minimum and maximum green of a concurrent vehicular phase.

PEDESTRIAN DELAY AND PERMISSIVE WINDOWS

Research on pedestrian behavior has established that pedestrians tend to start walking not only during the walk interval but also for a short period at the start of "Don't Walk." The *Highway Capacity Manual* suggests 4 s as this default extra pedestrian green (*9*). Therefore, effective pedestrian green (g_{ped}) and effective pedestrian red (r_{ped}) are given by

$$g_{\text{ped}} = W + 4 \qquad r_{\text{ped}} = C - g_{\text{ped}} = C - (W + 4) \tag{3}$$

where W is length of the walk interval and C is cycle length.

If the pedestrian phase is on recall, average pedestrian delay (d_{ped}) can readily be calculated based on the assumption that pedestrians arrive randomly and uniformly over the cycle:

$$d_{\text{ped}} = \frac{r_{\text{ped}}}{C}\frac{r_{\text{ped}}}{2} \tag{4}$$

In Equation 4, the first fraction represents the fraction of pedestrians arriving on effective red, and the second fraction is the average wait of those who arrive on effective red. If the pedestrian phase is not on recall, Equation 4 is still a good approximation if pedestrian demand is great enough that a call for the pedestrian phase is made during almost every red interval.

However, when pedestrian demand is low enough that there is almost always a full cycle or more between pedestrian calls, pedestrians no longer have a significant chance of arriving during an active walk interval, and so pedestrian delay rises to

$$d_{\text{ped}} = \frac{C - L_{\text{window}}}{2}\frac{C - L_{\text{window}}}{C} \tag{5}$$

where L_{window} is the length of the permissive window, the part of the concurrent vehicular phase's green during which a pedestrian call will be accepted and will trigger an instantaneous walk interval (*5*). Where and when vehicular demand is so low that there is no vehicular call by the time a phase is scheduled to begin, the permissive window can begin earlier than the concurrent green, in which case a pedestrian call will trigger a phase change.

In practice, signals are often programmed with no permissive window, and so Equation 5, giving pedestrian delay when pedestrian demand is low and signals are not on recall, degenerates to the following:

$$d_{\text{ped}} = \frac{C}{2} \tag{6}$$

For intermediate levels of pedestrian demand, average pedestrian delay will lie between the extremes of Equation 4 and either Equation 5 or 6.

Where signals are demand responsive, Equations 4 to 6 are approximate, since cycle length varies from cycle to cycle, and, in the case of a full permissive window, a vehicular phase may gap out before the permissive window has expired, effectively closing the window. Therefore, with actuated control, pedestrian delay is more accurately estimated by simulation or from detector data, as in Kothuri et al. (*5*).

Kothuri et al. studied how permissive windows, which the city of Portland, Oregon, has begun to apply systematically, reduce pedestrian delay (*5*). Two options exist for permissive windows. One option, minimum permissive windows, does not constrain signal operations at all; they allow pedestrian calls that, if fulfilled, would still allow the phase to end as early as the vehicular timing would allow. The length of the minimum permissive window is

$$L_{\text{window}}^{\min} = \max\left(W_{\min} - W_o, 0\right) \qquad (7)$$

The minimum permissive window will be nonzero only where the vehicular minimum green is long enough that $W_{\min}$ exceeds W_o. Where a minimum permissive interval is applied, the walk interval is ended by a force-off at $W_{\min}$ s following the onset of vehicular green.

Another option is to use a full permissive window, which means accepting pedestrian calls up until the time at which a fresh pedestrian phase would force the vehicular phase's green to reach $G_{\max}$. The associated walk interval is usually set to W_o, or it can run until the force-off time just discussed, if that is later than W_o. Full permissive windows constrain signal timing, though not beyond the limit that would be allowed for serving vehicular demand. Using field tests that measured the difference in time between a pedestrian call and the start of walk, Kothuri et al. found that using full permissive windows significantly reduced pedestrian delay (*5*). However, their study did not look at impacts on vehicular traffic.

PROPOSED APPROACH

If knowing in advance that the coming vehicular phase would need a certain amount of green time (G') before it gapped out or maxed out, one would set the walk interval to the length given by Equation 8, which is the same as Equation 1, except that G' substitutes for $G_{\max}$:

$$W_{\text{adapt}} = \max\left(G' + \text{YAR} - \text{PedClear}, W_o\right) \qquad (8)$$

That way, it would be the longest it could without constraining signal control. Of course, one does not know in advance what the needed green will be, but it can be predicted. Letting G' then be the predicted green time needed by the concurrent vehicular movement, the adaptive walk interval length is given by Equation 8.

Because of uncertainty in the prediction, a downward-biased estimate of needed green time was chosen, such that the actual needed green is lower than the prediction only about 30% to 35% of the time. Using a mean or 50th percentile prediction in Equation 8 would force the phase to run longer than it otherwise would about half the time. In contrast, a 30th percentile green time represents a rather short green time, and any green periods forced to run longer will be during cycles with a lot of slack time. So they will not affect capacity and should have little impact on delay. Using a low estimate is also appropriate for testing the hypothesis that substantial delay reduction for pedestrians can be achieved with little effect on vehicular traffic.

A main element of this problem is predicting the needed green. This prediction must be made at the moment the concurrent vehicular phase is about to begin. This is a common problem in adaptive signal control. It can be done using additional detectors that count cars, to estimate queue lengths, as in Cesme and Furth (*10*). For this problem, the constraint that no additional detectors should be required is accepted; rather, predictions should be based only on information from traffic signal timing.

COORDINATED-ACTUATED CONTROL: SITE 1

Two intersections were used to develop and test adaptive walk interval logic. One uses coordinated-actuated control; the other was modeled with fully actuated control.

The junction of Columbus Avenue–Heath Street–Centre Street in Boston, which has coordinated-actuated control, was analyzed for the p.m. peak hour (4:45 to 5:45 p.m.). Columbus Avenue, the coordinated arterial, runs north–south and has a six-lane cross section. It is coordinated with two nearby intersections to the south and one to the north. Heath and Centre Streets are the east side and west side legs of the junction, respectively, and each has one lane per direction. They share a single phase in the signal cycle with a concurrent pedestrian phase. Neither has a nearby traffic signal affecting its arrivals.

The pedestrian phase considered is the one concurrent with the Centre–Heath phase, which has a nominal split of 56 s in a cycle of 120 s, and being the noncoordinated phase, it is subject to gap-out. (The other crossing, concurrent with Columbus Avenue's through movements, does not need adaptive walk intervals because its concurrent phase ends at a preset time.) $G_{\min} = 8$ s. The current walk interval, consistent with Equation 2, has length $W_{\min} = W_o = 7$ s. The crossing length, 72 ft, requires a pedestrian clearance of 21 s.

The latest count found 14 pedestrians using that pedestrian phase during the p.m. peak hour. However, being in a densely populated neighborhood and close to a Metro station, that small volume could be because pedestrians are avoiding this crossing owing to the long wait time, currently 54 s using Equation 4 (*Highway Capacity Manual* formula) and 60 s using the more appropriate low-demand formula, Equation 6. In cycles in which the vehicular phase runs to its maximum—and vehicular demand during the p.m. peak is such that Centre–Heath maxes out in 43% of the cycles—the walk interval could have length $W_{\max} = 35$ s without affecting signal operations. Because of the long wait and the apparent inconsistency of a "Don't Walk" showing while the concurrent vehicular phase remains green, often for more than 20 s, pedestrian compliance is low, and that is a safety concern considering the six-lane cross section.

PREDICTING LENGTH OF VEHICULAR PHASE

One method that could be used to predict the green time needed by the Centre–Heath phase is to measure the needed green times from the last several cycles and to use an average, possibly weighted. Such an estimate will reflect the general level of traffic, which tends to rise and fall in a pattern as the peak comes and goes. Needed green is measured as the time until gap-out or, if there is no gap-out, max-out. Green time that occurs after gap-out waiting for a walk interval to clear is excluded.

However, an additional and valuable piece of information is available when a green interval is about to begin, which is precisely the moment at which an adaptive walk interval length must be determined: the length of the red period that just ended. For a given level of demand, a long red period will usually lead to a greater need for green. As is well-known from traffic theory, for a given red period (R), the time until the queue clears under uniform, deterministic arrivals and deterministic departures is given by

$$G_{\text{needed}} = R\frac{v}{s-v} = R\theta \tag{9}$$

where

v = approach volume,
s = saturation flow rate, and
$\theta = v/(s-v)$.

By rearranging, the ratio $v/(s-v)$ becomes

$$\theta = \frac{G_{\text{needed}}}{R} \tag{10}$$

Because of random issues that affect real traffic flow, the ratio of G_{needed} to R in a single cycle will be an unreliable estimate of θ; however, an estimate made from several recent observations will offer a more robust estimate. There was use of a ratio estimator estimated from a paired sample from the last five cycles to estimate θ and its coefficient of variation (CV) (*11*). A cycle consists of a red interval and the following green interval. Using G as shorthand for G_{needed}, the ratio estimator and the estimate of its squared CV are

$$\hat{\theta} = \frac{\bar{G}}{\bar{R}} \tag{11}$$

$$\text{CV}_{\theta}^2 = \text{CV}_G^2 + \text{CV}_R^2 - 2r_{GR}\text{CV}_G\text{CV}_R \tag{12}$$

where r_{GR} is the correlation coefficient between G and R, which, like CV_G and CV_R, can be estimated from the paired sample.

As stated earlier, the predicted needed green should not be the mean, but rather a low percentile such as 30th or 35th. Because ratio estimators have an approximately normal distribution and because −0.5 is the 30th percentile value of the standard normal distribution, the proposed predicted value of needed green for the concurrent phase, as a function of the length of its red period that just ended, is

$$G' = R\hat{\theta}\left(1 - 0.5\text{CV}_{\theta}\right) \tag{13}$$

The adaptive walk interval length W_{adapt} is then calculated with Equation 8.

EXPERIMENTAL DESIGN

The corridor was modeled in Vissim, including the subject intersection and the three other intersections along Columbus Avenue mentioned earlier, using p.m. peak (4:45 to 5:45 p.m.) traffic volumes and signal timings. The simulation was run for a period of 7 h after a 15-min warm-up period. Because none of the approaches in the network is oversaturated and queues therefore rarely spill over from cycle to cycle, a single long run is essentially equivalent to multiple short runs. Seven control alternatives were tested, shown in Table 1. The first is the current control scheme.

TABLE 1 Control Alternatives

Alternative	Pedestrian Call Type	Walk Interval Length
No Per _Min.	No recall, no permissive window	W_{min}
No Per _Adapt	No recall, no permissive window	W_{adapt}
Full Per _Min.	No recall, full permissive window	W_{min}
Full Per _Adapt	No recall, full permissive window	W_{adapt}
Recall _Min.	Ped recall	W_{min}
Recall _Adapt	Ped recall	W_{adapt}
Max_Recall	Pretimed, ped recall	W_{max}

Three levels of pedestrian demand were modeled as well:

- Low: 0.5 peds/cycle served by pedestrian phase,
- Medium: 2 peds/cycle served by pedestrian phase, and
- High: 5 peds/cycle served by pedestrian phase.

With low pedestrian demand, there is little chance that a pedestrian will arrive on green unless the walk phase is on recall, and so permissive windows become important. With high pedestrian demand, there is a substantial chance that a pedestrian will arriving during a walk interval, and that chance is far greater in options offering a longer walk interval (W_{adapt} or W_{max}). At the same time, permissive windows matter little because there will almost always be a registered pedestrian call when the signal turns green.

RESULTS FOR SITE 1

Under current control, average pedestrian delay to pedestrians crossing Columbus Avenue, measured using Vissim, is 62, 55, and 54 s respectively, for the low-, medium-, and high-demand cases. Pedestrian delay on the treated crossing is shown in Figure 2 as a change from the current control alternative. Of course, max recall yields the greatest improvement. However, the three alternatives with adaptive walk intervals yield substantial delay reductions for all levels of demand. For example, with medium demand, the delay reduction is 10 s from just adding the adaptive walk interval; adding permissive windows or recall as well makes that reduction rise to 14 s.

Permissive windows make a substantial impact only under low demand. At high levels of demand, almost no delay reduction occurs with either adding a full permissive window or putting the pedestrian phase on recall. Rather, the big gains when pedestrian demand is higher come with longer walk intervals, which are offered by adaptive and max recall options.

Change in delay to vehicles is less than 1 s in every alternative, and that is effectively undetectable. Surprisingly, even the most aggressive pedestrian treatment, max recall for pedestrians—which is essentially equivalent to making the Centre–Heath phase pretimed—yields a small net decrease in vehicular delay. That treatment increases delay to Columbus Avenue traffic by only 2 s because arterial traffic is platooned by other nearby signals, and the time taken from the arterial comes from outside its through band; at the same time, it reduces delay to the cross street by 7 to 9 s. This result does not seem generalizable, however.

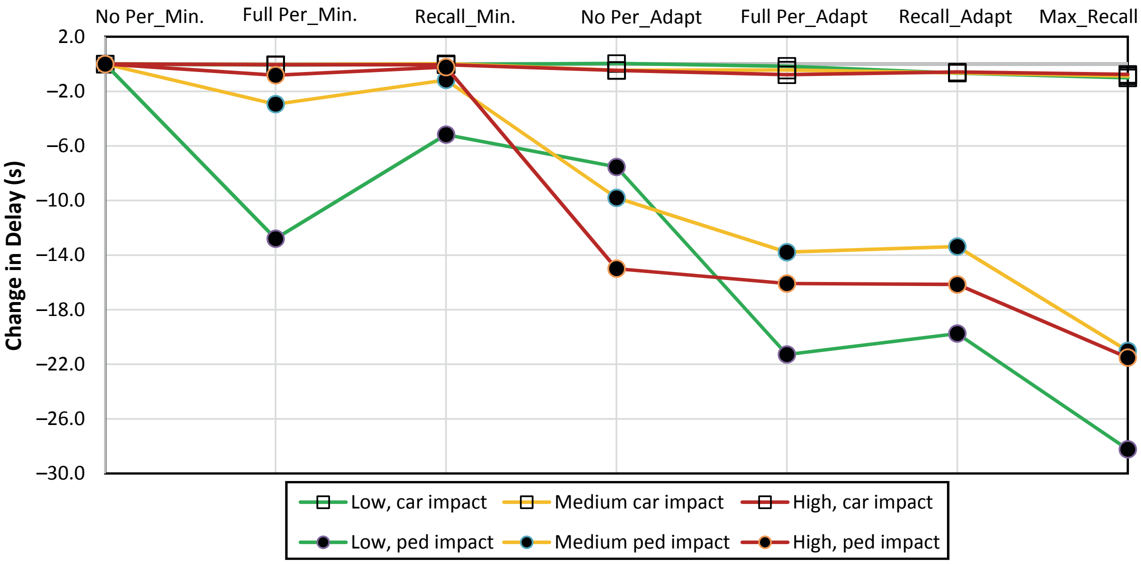

FIGURE 2 Change in delay to all vehicles and to pedestrians using an east–west crossing relative to the base alternative under low-, medium-, and high-pedestrian demand for seven control alternatives at Site 1.

The adaptive walk alternatives lengthen the east–west green time by 1 to 2 s at the expense of the arterial phase, indicating that the proposed adaptive control is successful in avoiding placing a substantial constraint on signal operations. In contrast, the maximum recall option shifts 7 to 8 s from the arterial phase to the cross street.

For pedestrians on other crosswalks, change in delay is within 1 s for every alternative except for max recall, which increases delay on the heavily used north–south crosswalks by almost 10 s. This trade-off is a reason to favor adaptive walk intervals over max recall.

FULLY ACTUATED CONTROL: SITE 2

The second test site is the junction of Longwood Avenue (east–west) and Saint Paul Street (north–south) in Brookline, Massachusetts. It has heavy pedestrian traffic going to and from a very large employment area, the Longwood Medical Area, about ½ mi to the east, as well as several nearby colleges and rapid transit stops. The site was studied during the p.m. peak hour, when it sees about 375 pedestrian crossings per hour, of which 285 are along the east–west street. Both streets have one through lane per direction; in addition the southbound approach has a left-turn lane. The critical sum is 800 vehicles per hour.

This intersection currently operates with two-phase, pretimed control on a 90-s cycle with 20-s walk intervals, yielding an average pedestrian delay of 24 s. The 90-s cycle allows there to be coordination for Saint Paul Street, which intersects with Beacon Street, a major arterial that has arterial coordination on a 90-s cycle, 800 ft to the north. However, the long cycle imposes a lot of delay on pedestrians, and that seems out of place at a junction of two narrow streets with only two phases. Casual observation shows that pedestrian noncompliance is high. There is no compelling reason to force the signal to coordinate with the Beacon–Saint Paul intersection, because of the following:

1. Intersection spacing enables good progression in only one direction.
2. Substantial turning flows onto and off of Saint Paul Street limit the benefit of progression even for the coordinated movement.
3. Spacing between these intersections is long enough to store queues without causing spillback or starvation.

Applying fully actuated control at this intersection will allow much shorter cycles, and with them, considerably less pedestrian delay. And because this research tests a method that applies where signals are actuated, it was modeled as having fully actuated operation. There remain two simple phases, with minimum green set at 10 s, which will result in snappy signal operation when demand is light. The same set of control alternatives and demand levels used at the other test site were applied here as well. Pedestrian phase treatments, whether adaptive walk, recall, or permissive windows, were applied to all crosswalks. Modeling was done in Vissim, and they included the Beacon–Saint Paul junction that sends a platoon to the subject intersection every 90 s. No nearby signalized intersections are present in the other directions.

PREDICTING VEHICULAR PHASE LENGTH

The eastbound, westbound, and northbound approaches have no nearby upstream traffic signals, and so their phase length prediction was done as described earlier, using the length of the just-ended red period along with an estimate of the ratio of needed green to red made from records of the last five cycles.

For the southbound approach, however, the needed green time varies not so much with the length of the red period as with whether a platoon released from the coordinated intersection at Beacon Street is served. Because Beacon Street operates with a 90 s-cycle while the subject intersection is fully actuated (and, it turns out, tends to cycle every 50 s or so), platoons from Beacon Street can arrive at any time in the cycle, or not at all. Therefore, cycles at the subject intersection were divided into three strata, with cycles beginning at the start of southbound red:

- Early platoon. Cycles in which the head of the platoon arrives between the start of red and the end of minimum green. Cycles in this group tended to need a long green phase. Platoon arrival is defined as the start of green at the upstream intersection for the phase discharging the platoon plus a fixed travel time of 18 s; therefore, no detector information is needed to determine platoon arrival time.

- No platoon. Cycles in which the head of a platoon does not arrive. Cycles in this group tend to need a short green phase.
- Late platoon. Cycles in which the head of the platoon arrives after minimum green has expired. This is the smallest stratum. Cycles in this group exhibit highly variable green times because sometimes the platoon stays together well enough to hold the green until all of it has passed. But at other times, platoon dispersion leads to gap-out after only a leading part of the platoon has been served.

Data from past cycles were collected and stratified into those three groups, with data from the last seven cycles in each stratum retained in memory. When a green period for Saint Paul Street is about to start, it is known with near certainty what stratum that cycle belongs to. If a cycle was in either the early platoon or no platoon stratum, G' was set equal to the third smallest of the last seven green periods for its stratum. That roughly represents a 33rd percentile value, since two cycles had shorter needed greens and four had longer. For the stratum late platoon, predictions were made with data from the stratum early platoon because the late platoon stratum had a smaller sample size and was more unpredictable.

On the basis of those predictions of needed green, the adaptive walk interval was calculated with Equation 8.

RESULTS FOR SITE 2

Average pedestrian delay and average vehicular delay are shown in Figure 3 as a change against a base. The base is fully actuated control with no recall, and no permissive window, and 7 s-walk intervals, for which pedestrian delay was 18, 19, and 21 s for the low-, medium-, and high-demand scenarios, respectively. Average vehicular delay for the same scenarios was 24, 22, and 22 s.

As at Site 1, permissive windows were found to be very effective for low demand, but it becomes almost inconsequential with high demand. Adding adaptive walk phases without permissive windows or recall reduces pedestrian delay by 2.3 to 3.5 s, depending on pedestrian demand, or 12% to 17%. With recall, a setting that seems reasonable for a pedestrian-intensive location like this, switching from minimum to adaptive walk intervals reduces average pedestrian delay by 2.7 to 4 s, depending on whether pedestrian demand is light or heavy.

For vehicular traffic, most control alternatives increase delay by less than 1 s, and none by more than 2 s, with one exception. That exception is max recall, which for a case like this means providing pretimed control. For that alternative, traffic delay rose by 8 to 10 s, depending on demand, because it forces the cycle to 70 s, while average cycle length hovered in the range of 48 to 56 s for the other alternatives.

It is especially instructive to compare pedestrian recall with adaptive phases against pedestrian recall with maximum pedestrian phases. With adaptive phases, one gains 66% to 72% of the pedestrian delay reduction (depending on pedestrian demand), but at only 2% to 20% of the delay increase imposed on vehicular traffic. That trade-off confirms that adaptive walk phase logic manages to secure substantial benefit for pedestrians with little impact on vehicular traffic.

CONCLUSIONS

Adaptive walk interval logic can substantially reduce pedestrian delay with little or no impact to vehicular traffic at pedestrian crossings that run concurrently with traffic-responsive vehicular phases, as confirmed by tests involving both coordinated-actuated and fully actuated control. Calculations use only information that can be detected by traffic signal control equipment without a need for additional detector. While the control logic for determining adaptive walk intervals must be special-purpose programmed, no change is needed to the operation of the local controllers once they are given an updated walk interval length.

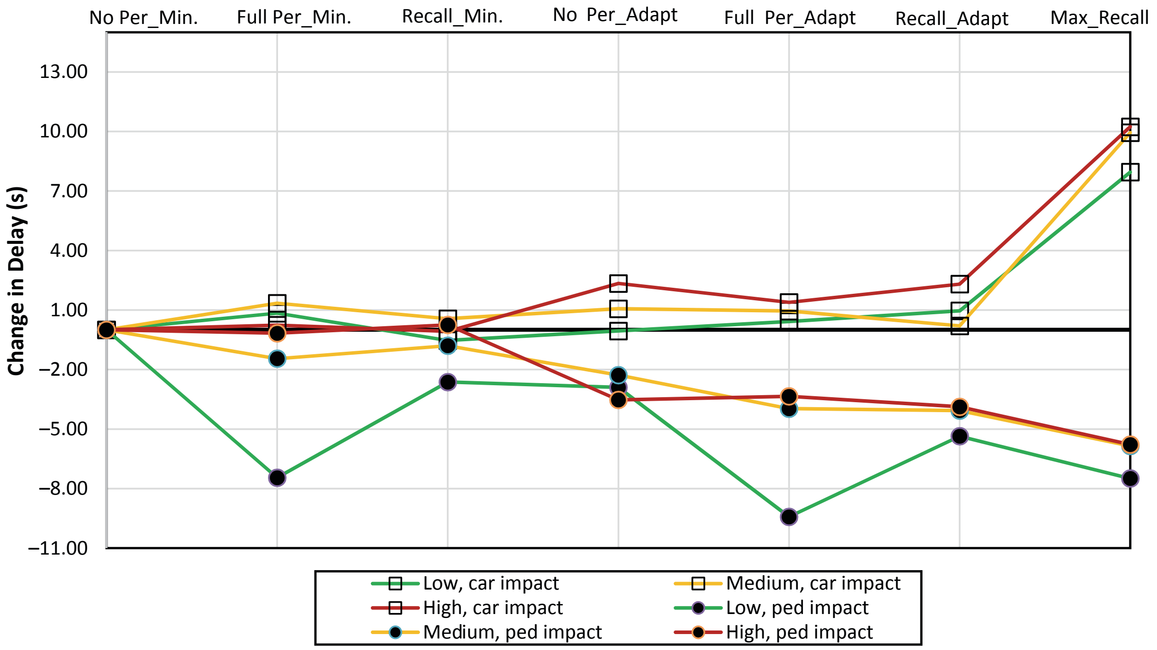

FIGURE 3 Change in delay to cars and pedestrians relative to the base alternative under low-, medium-, and high-pedestrian demand for seven control alternatives at Site 2.

Full permissive intervals also help reduce pedestrian delay with nearly no impact to vehicular traffic, but substantial gains appear only where pedestrian demand is below two pedestrians per cycle.

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