Reducing Speeding Opportunities on Urban Arterials Using Short Coordination Zones

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Abstract

Timing traffic signals using coordination zones of one to three signalized intersections was tested as an approach for reducing speeding opportunities on urban arterials. Short coordination zones can reduce speeding opportunities because they allow cycle length to be shorter at most intersections, with less excess arterial green time during which vehicles can pass through unconstrained; they also avoid the outcome, common to long coordination zones, of having large clusters of intersections with simultaneous green, which create an incentive to speed. In a case study of Boston's Huntington Avenue performed using microsimulation, existing coordinated control over a stretch of nine intersections was compared with control short coordination zones with one to three intersections per zone, with each zone's cycle length tailored to the needs of its intersections. Speeding opportunities per hour – defined as the number of vehicles entering an intersection on a stale green and with no vehicle ahead of them for at least 5 s – fell by 46% - 51% midday and by 24% - 33% in the AM peak, depending on the base of comparison, while vehicle delay was unchanged in the AM peak and increased by only 9% midday, and average pedestrian delay crossing the arterial fell substantially.

Practical Applications

Cities and citizens alike are concerned with improving safety and livability by controlling traffic speed on arterial roads. An approach is presented for reducing speeding on multilane arterials by using traffic signal timing to reduce speeding opportunities and incentives. Because the experiment was conducted in a simulation environment, evidence cannot be determined regarding actual speeding behavior; however, evidence is presented for how the approach reduces speeding opportunities in

comparison with conventional approaches for arterial traffic signal timing, together with delay reductions to pedestrians and little or no impact on vehicle delay.

Introduction: The Need for Speed Control

Increasingly, city governments are recognizing their responsibility to ensure traffic safety on their streets by controlling vehicle speed (Foxx and Shahum 2018), and particularly by eliminating or at least reducing opportunities to drive at a dangerously high speed. For local residential streets, several traffic calming measures are available to meet this challenge, including vertical and horizontal deflection devices (speed humps, chicanes, and so on) that make it physically impossible (or, at least, extremely uncomfortable) to pass through at high speed. However, those measures are not suitable for multilane arterials, because vertical deflection devices are too disruptive for buses, trucks, and emergency response vehicles, and on multilane roads, horizontal deflection devices cannot be effectively control speed without creating an unacceptable risk of sideswipe collisions. As a result, controlling speed on multilane arterials remains a challenge (Parham and Fitzpatrick 2000).

Arterial Speed Control Measures Apart from Traffic Signal Control

Several methods for controlling speed on multilane arterials apart from using traffic signals have been suggested; however, they all have limited applicability or effectiveness. One is road diets that narrow a road to only one through lane per direction. Where they can be implemented, road diets are effective at controlling speed because they make it impossible to pass, forcing would-be speeders to slow down for the vehicles in front of them (Saak 2007; Gates et al. 2007). However, while road diets have been successfully applied to many 4-lane arterials in U.S. cities (Neuner 2015), many arterials carry too much traffic to be reduced to a single through lane per direction.

Lowering the speed limit has been found to have a significant but small effect on extreme speeds (Rossy et al. 2012; Hu and Cuchino 2020). Traditional enforcement campaigns have been found to have no lasting effect (Hauer et al. 1982). Automated enforcement can be highly effective at eliminating high speed behavior (Retting et al. 2008; Glauz 1998); however, it remains politically unpopular in many places, and many states forbid or severely restrict its use (Automated 2021). Intelligent speed limiters – devices that make it difficult for a driver to exceed the speed limit by limiting the throttle – could be very effective if all vehicles had them. Experiments with voluntary use of intelligent speed limiters in the European Union have been successful (Lai and Carsten 2012), and beginning in 2022, all new cars sold in the EU must have intelligent speed assistance. However, in the U.S., there is currently no near-term prospect for widespread use of these devices.

Speeding Opportunities as a Measure of Safety

Ultimately, this leaves many American cities with no practical means to effectively control speed on their multilane arterials except perhaps through use of traffic signals. Traffic signals do not directly determine a driver's speed, but traffic signal timing can create opportunities for speeding if signals are timed in such a way that speeding vehicles will encounter a succession of green lights.

Furth et al. (2018) created a new line of inquiry in this domain by defining "speeding opportunities" in a way that can be measured, and therefore evaluated and minimized. A speeding opportunity is defined as a vehicle passing through an intersection on a stale green with no vehicle ahead of it (in its lane) for at least 5 s. Speeding opportunities can be readily measured In the field – just count the number of vehicles meeting the qualification. They are a function of both signal timing and traffic flow, and can be quantified either as the number of speeding opportunities per hour or as the percentage of through vehicles that are speeding opportunities. Furth et al. (2018) found that speeding opportunities as measured with traffic microsimulation matched those measured in the field, and Halawani (2018), in a field study, found that speeding opportunities and speeding behavior are highly correlated – that is, vehicles that meet the definition of “speeding opportunity” are far more likely to speed than those that aren’t.

Is Signal Coordination a Good Means of Speed Control? Theoretical Considerations

Signal coordination has frequently been described as a method of speed control (Parham and Fitzpatrick 2000; Shinar et al. 2004). As generally understood, arterial signal coordination means that all of the signals along a stretch of an arterial have the same cycle length, and that offsets for the arterial through phases are selected in a way that allows vehicles, as much as possible, to arrive at intersections during a green interval (a “green wave”), and thus pass through with little or no delay.

One-Way Coordination and Speed Control: Not Only Offsets, but Also Cycle Lengths that Limit Excess Green

On one-way streets, signal coordination’s ability to control speed is obvious. By choosing offsets at a desired progression speed, the leading edge of the green interval becomes an effective constraint preventing the lead vehicle from exceeding the progression speed. In some cities, drivers are alerted to the progression speed by signs such as “Signals Set for 27 MPH.” Vehicles in the platoon following the lead vehicle are then constrained by the vehicles ahead of them.

However, effective speed control requires giving attention to another design parameter besides progression speed and offsets, namely, the cycle length. Every intersection, at a given period of the day, has its own needed cycle length, sometimes called the natural cycle length, which is the smallest cycle length that will serve all traffic streams with a specified degree of saturation and meet all timing constraints, including applicable pedestrian timing constraints. Needed cycle length (Urbanik, 2015) is given by

$$C_{needed} = \frac{\sum Lost_i}{1-\frac{1}{X_{target}}\sum\left(\frac{v}{s}\right)_i} \tag{1}$$

where the summations are over critical movements only, and where

C_{needed} = needed cycle length

$Lost_i$ = lost time for critical movement *i*

$(v/s)_i$ = flow ratio for critical movement i = ratio of volume (v) to saturation flow rate (s)

X_{target} = target degree of saturation

See Urbanik (2015) for a discussion of how to determine lost time and which movements are critical. For pedestrian movements that are critical, their entire needed split is considered lost time and their flow ratio is zero.

Because all the signals in a coordination zone must have the same cycle length, the intersection within the zone that needs the longest cycle – say, due to heavy cross traffic – forces the other intersections to have a longer cycle than needed, giving them extra green time, which is typically given to the arterial phase. (While excess arterial green could instead be given to the side streets, that is rarely done, and could create opportunities for speeding on the side streets.) Where there is substantial excess arterial green, vehicles joining the arterial from a side street or parking place during the latter part of the green will be able to speed until they reach the rear of the platoon, as illustrated in Figure 1. The distance a speeder can cover in this situation, $d_{unconstrained}$, is given by

$$d_{unconstrained} = \frac{g_{unsat}}{\frac{1}{v_{prog}} - \frac{1}{v_{speeder}}} \tag{2}$$

where v_{prog} = progression speed on which offsets are based

g_{unsat} = excess green time

$v_{speeder}$ = a speed considered dangerous

Figure 1 goes approximately here

For the example values given in Figure 1, $d_{unconstrained}$ = 809 m (0.5 miles), implying that if intersection spacing is 150 m (500 ft), a vehicle could speed through four or five intersections in spite of one-way coordination. By comparison, if the unsaturated green lasted only 4 s, $d_{unconstrained}$ would be only 156 m, meaning any potential speeder would catch up with the platoon within one block.

Fully Actuated, Uncoordinated Signal Control Severely Limits Speeding Opportunities

In the Netherlands, Scandinavia, and elsewhere in Europe, the vast majority of signalized intersections use fully actuated control with no fixed cycle length, also called running free (Wahlstedt 2014; Linders 2012). Compared with coordinated control, fully actuated control offers multiple benefits, including speed control. With fully actuated control, there is little excess green, because in normal operation, as soon as a gap in traffic detected, green signals turn to yellow and yield control to the next phase.

Unfortunately, where intersections are closely spaced, as is often the case on urban arterials in the U.S., running free becomes infeasible because coordination is necessary to prevent queues from one intersection from spilling back to another. For adjacent signals to be uncoordinated, the distance between them should be enough to store one cycle’s worth of traffic. Depending on cycle length and traffic volume, that minimum intersection spacing is typically 180 to 270 m (600 to 900 ft).

Two-Way Arterial Coordination and Speeding Opportunities

Most urban arterials are two-way, and in the U.S., tend to follow a two-way coordination scheme with long coordination zones, aiming to provide good progression for both directions over a large number of intersections. (During peak periods, it is possible to use one-way coordination oriented toward the dominant direction of travel. However, the stops and delay that result for the opposing direction are often unacceptable; and during most of the day, including the periods of intermediate and low demand when traffic congestion presents little or no constraint on speeding, traffic flows are too balanced for using one-way coordination.) Two-way coordination invariably uses half-cycle offsets – that is, arterial offsets are either 0 or $0.5C$, where C = cycle length, with small adjustments for differing green interval lengths and for lead-lag left turn phasing (Urbanik 2015).

If intersection spacing is ideal – meaning the travel time between adjacent intersections equals $0.5C$ or a multiple thereof (C = cycle length) – two-way coordination will be the same as one-way coordination in both directions, and therefore can be an effective means of speed control if cycle lengths are kept short enough to limit excess green.

However, in most urban situations, intersection spacing is much smaller than ideal, and rather than being an effective means of speed contol, Furth et al. (2018) have shown that typical two-way arterial coordination actually creates many opportunities and incentives for speeding. One reason is that the long zones typically used require the cycle length to be set for the most demanding intersection, creating excess green at most intersections. The other is that the combination of long cycles and short intersection spacing inevitably leads to large “simultaneous offset clusters,” that is, sets of three or more sequential intersections that turn green and red (nearly) simultaneously. Where intersection spacing is shorter than ideal, two-way coordination naturally leads to this kind of intersection clustering, such that the center of one cluster is as close as possible to half a cycle distant (in travel time) from the center of the next cluster, and with clusters offset from one another by half-cycles. For a given cycle length, progression speed, and intersection spacing, the formula for cluster size *n* (that is, the number of intersections in a cluster) is

$$n = \frac{C}{2} \frac{v_{prog}}{L} \qquad (3)$$

where v_{prog} = progression speed and *L* = block length (Furth et al. 2018). For example, if *C* = 100 s, intersection spacing = 120 m (400 ft), and progression speed = 12 m/s (40 ft/s or 27 mph), travel time between intersection is only 0.1*C*, and cluster size is 5. This means that drivers looking ahead will see five successive signals that turn green at the same time. Clusters with three or more intersections create an obvious opportunity for speeding for the lead vehicle, who sees ahead of them an empty road and a set of green lights; it also creates an incentive to speed because many drivers think that the surest way to make it through all those intersections without hitting a red light is to speed.

Furth et al. (2018) proposed *short coordination zones* as a strategy for reducing speeding opportunities. With this strategy, sets of one to three sequential intersections whose needed cycle length is roughly equal are grouped together, given a common cycle length, and coordinated with a moderate progression speed. With each zone's cycle length tailored to its need, there will be little excess green, and, because cluster size is proportional to cycle length, clusters within the zone will tend to be small, often only one or two intersections. These factors help limit speeding opportunities within coordination zones, and at zone boundaries, the lack of coordination will most often force vehicles to stop.

Short zone coordination is the preferred signalization approach for the main arterials in Zurich, Switzerland (Furth 2005). Vehicles enjoy a green wave through one or two intersections and are then stopped for a short time when entering the next coordination zone. Officials in Zurich say that this approach offers good enough service that drivers don't complain, while keeping arterial roads from attracting additional through traffic that will otherwise use the ring highways. The short cycles also keep the city friendly to pedestrians.

To our knowledge, short zone coordination has been tested as a means of speed control only once, in the landmark study that defined the concept of speeding opportunities (Furth et al., 2018). In that simulation study, compared to the existing long-zone coordination, short-zone coordination on Boston's Massachusetts Avenue reduced speeding opportunities by 37% without any increase in average vehicle delay. While those results are promising, engineers and safety advocates alike are interested in more studies testing the efficacy of this approach.

Objective and Hypothesis

The objective of this research was to test the strategy of short zone coordination in a case study of an arterial corridor that currently has long-zone coordination, determining its impact on speeding opportunities, vehicle delay, and pedestrian delay in both a peak period, when capacity tends to be critical, and a midday period, when speeding opportunities tend to be greatest because there is still a moderately high volume of traffic, but little congestion. The hypothesis is that short coordination zones will lead to substantially fewer speeding opportunities with little increase in vehicular delay and with a reduction in pedestrian delay.

Methods and Case Study Site

The method used was a case study, using Vissim microsimulation software, of the Huntington Avenue corridor in Boston *(Figure 1)* from Gainsborough Street to Brigham Circle (which, despite its name, is not a traffic circle), a stretch of 1.1 miles with 9 signalized intersections. Two periods of the day were studied: the AM peak hour, when capacity is most constraining, and midday (12-1 PM), when the number of speeding opportunities is expected to be the greatest.

At the time of the study, Huntington Avenue had two through lanes per direction, plus left turn bays where left turns are allowed. It has a median transit reservation, varying in width from 32 ft to 42 ft, where the Green Line light rail runs at grade. To cross the street, pedestrians are expected to stop and wait in this median. Peak direction volume on a representative segment (Longwood to Evans) was 1,040 veh/h in the a.m. peak, and 790 veh/h midday, volumes great enough to support the need for two lanes per direction. The corridor is bordered by six academic institutions, multifamily housing, hospitals, and a large art museum, resulting in high pedestrian activity throughout the corridor.

Intersection spacing varies from 160 to 275 m (520 to 970 ft). In the study, traffic signal timing at Brigham Circle and at Gainsborough Street was left unchanged as a boundary condition, leaving 7 intersections whose traffic signal timing was changed as part of the study. Intersections east of Gainsborough Street were included in the simulation model only to set the arrival pattern for vehicles at Gainsborough Street; they were not part of the evaluation area.

Figure 2 goes approximately here

Along the corridor, cross traffic varies considerably in intensity. It is greatest on Ruggles Street, while at the other extreme, two of the intersections, Wigglesworth and Opera, are essentially signalized midblock crossings with a closed median, with the two arterial roadways controlled independently. At both Wigglesworth and Opera, one side of the arterial has no side street, and therefore runs with two serial phases (crosswalk – arterial); on the other side of the arterial, there is a side street from which vehicles may turn right only, which runs concurrently with the pedestrian crossing at Wigglesworth, while at Opera it runs with a distinct phase. In the proposed alternative, Opera Place will have a red signal at all times with right turn allowed on red (the equivalent of a Stop sign), so that it, too, can have just two serial phases.

While only some of the pedestrian crossings in the corridor are on recall, those that are on demand have a call in virtually every cycle during the daytime, and thus were modeled as being on recall.

As illustrated in Figure 2, the case study corridor is already divided into several coordination zones. The western end of the study area has a coordination zone with just two intersections: Brigham Circle, with a very long signal cycle (140 s in the AM peak, 130 s midday) because it has five legs and a long exclusive pedestrian phase, and Wigglesworth, a midblock crossing that double cycles (C = 70 s AM peak, 65 s midday). The rest of the study area, a zone with seven intersections, uses C = 100 s for the AM peak and 90 s midday. Opera Place, the other midblock crossing, double cycles in the AM peak, while in the midday, one side of the arterial double cycles while the other does not. Control logic throughout is coordinated-actuated with fixed force-offs.

Traffic counts, obtained from the Boston Transportation Department for all but one intersection (which we counted ourselves), are from an October weekday that, depending on the intersection, was in 2014, 2017, or 2019. Inconsistencies between intersections were balanced manually based on local knowledge of midblock sources and sinks, minimizing the overall size of adjustments.

In the Vissim model, desired vehicle travel speed was set to 40 km/h (25 mph), the speed limit. At intersections, reduced speed zones were applied for right turns (15 km/h or 9.3 mph) and left turns (25 km/h or 15.5 mph), which effectively lowers the saturation flow rate for turning traffic. Heavy vehicle percentage was taken from the traffic count data. Signal timing was implemented using Vissim's Ring Barrier Controller (RBC) module. Results are aggregations of three independent simulation runs of 60 minutes following a 5-minute warm-up period. There was little variation between the runs.

We programmed Vissim to create output files reporting vehicle passage times and signal state changes; from them, speeding opportunities were identified and tallied at each intersection in each arterial through lane just downstream of the stop line. Vissim reports were also used for vehicle delay evaluation.

Pedestrian delay was measured using the Northeastern University Pedestrian and Bicycle Crossing Delay Calculator (Furth et al. 2019; Furth 2015), which assumes pedestrian compliance with signals, except that people arriving during the first 4 seconds of Flashing Don't Walk cross immediately, consistent with the *Highway Capacity Manual* (2016) method for evaluating pedestrian delay. With two-stage crossings, pedestrian delay can vary enormously with walking speed when signal timing is such that faster pedestrians can cross in a single pass while slower pedestrians must wait in the median and cross in two stages. Therefore, in order to avoid the distortion that would arise from using an average walking speed for all pedestrians, pedestrian delay was evaluated for five strata of pedestrians with walking speeds of 1.05, 1.2, 1.35, 1.5, and 1.65 m/s (3.5, 4.0, 4.5, 5.0, and 5.5 ft/s), and their delays were averaged using stratum weights of 19%, 18%, 21%, 26%, and 16%, respectively, consistent with the distribution of walking speed reported by Fitzpatrick et al. (2006).

Signal Control Alternatives

Pedestrian-Friendly Baseline Improvements

At most of the intersections, crossings across Huntington Ave. are configured as two-stage crossings, timed in a way that expects pedestrians to stop and wait in the middle for the next cycle to finish their crossing. However, non-compliance is rampant, as most pedestrians don't stop in the middle, but continue their crossing in the face of a flashing Don't Walk signal, sometimes reaching the far curb after conflicting traffic has been given a green. In addition, with one exception, crossings across Huntington Ave. are not on recall, even though pedestrian volume is high.

Since the City of Boston's adoption of Vision Zero in 2015, it is unlikely that this kind of pedestrian timing would be used if the signals were retimed today. Because previous research showed that pedestrian recall settings can have a significant impact on speeding opportunities (Furth et al. 2018), the study used three signal control alternatives: existing, existing-adjusted, and proposed, with the middle alternative being the existing timings adjusted for pedestrian safety and service as described in the following paragraphs. Using three signal control alternatives allows the proposed timing plan to be compared not only against the existing timing plan, but also against an alternative representing what a modern timing plan might be.

Pedestrian crossing improvements for the existing-adjusted and proposed alternatives go beyond minimum safety requirements by providing coordination between the two crossing stages, using the criterion that pedestrians walking in either direction who depart in the first stage of their crossing within the first 4 seconds of the Walk interval and walk 1.2 m/s (4.0 ft/s) or faster should encounter a Walk indication when reaching the start of their second stage as well. At all but two intersections, this coordination was achieved by making the side street split long enough so that pedestrians, walking concurrently with the side street, can cross in a single pass, reducing the split of the coordinated phase as needed. Facilitating single-pass crossings like this greatly reduces delay for compliant pedestrians – or, looked at another way, vastly increases compliance for pedestrians who already cross in a single pass.

At the two midblock crossings, pedestrian coordination was achieved in a different way – by using a very short signal cycle, about 34 s long, with a half-cycle offset between the stages, so that pedestrians beginning at either side of the street with the onset of Walk will get a Walk to cross the second roadway

17 s later, requiring at most a few seconds' wait in the median. The very short cycle means pedestrians have only a short wait to get started as well.

As in the existing plan, Walk intervals last at least 7 s, and pedestrian clearance is timed for a walking speed of 1.05 m/s (3.5 ft/s).

Delineating Short Coordination Zones

Needed cycle lengths were calculated for all intersections, based on meeting pedestrian timing requirements and vehicle capacity needs with a degree of saturation of 0.9, using equation 1. Intersections were then grouped into coordination zones based on three considerations: (1) the intersections in a zone should have a similar needed cycle length (or, for midblock crossing intersections that can double-cycle, a similar multiple of needed cycle length); (2) zones should be short, preferably with no more than 3 intersections; and (3) segments at the zone boundaries should be at least 600 ft long, a distance that we determined would be needed to store one cycle's queue in the peak hour based on the given traffic volumes and anticipated cycle lengths.

Results for the a.m. peak are shown in Figure 3, which shows each intersection's existing cycle length, needed cycle length, and proposed cycle length. Needed cycle lengths range from 24 s (a midblock crossing, with pedestrians crossing only two lanes) to 92 s. Existing and proposed coordination zones can be seen in Figure 3, but they are perhaps better visualized on maps, as shown in Figures 2 and 4. While the existing plan has two coordination zones with cycle lengths of 140 and 100 s, the proposed plan has five coordination zones with cycle lengths, from west to east, of 140 s, 76 s, 104 s, 68 s, and 100 s. (Recall that the first and last intersection in the study area were constrained, as a boundary condition, to have the same signal timing plan as existing.) At one of the midblock crossings (Opera), there are two cycles of 34 s for every master cycle of 68 s, while at the (Wigglesworth) uses quadruple cycling, with four cycles of 35 s for each master cycle of 140 s. Splits at those midblock crossings are roughly 17-18 s for vehicles, 17 s for pedestrians.

Figure 3 goes approximately here

Figure 4 goes approximately here

The Ruggles intersection, whose needed cycle length is the greatest (apart from one of the boundary intersections), is proposed to be in a zone by itself. As such, it can run free, with fully actuated control, albeit with the pedestrian phases on recall. The cycle length shown in Figure 3, 104 s, is the maximum cycle length (i.e., if all phases max out); on average, it will have a cycle of around 90 s.

A similar analysis for the midday resulted in the same set of five coordination zones. Midday cycle lengths, from west to east, are proposed to be 132 s, 72 s, [Ruggles will again run free], 66 s, and 90 s. The midblock crossings will operate with a cycle length of 33 s, quadruple cycling at Wigglesworth and double cycling at Opera, as in the AM peak.

Proposed Offsets and Progression Speed

Within coordination zones, two-way progression calls for offsets to be either zero or half a cycle. Where intersection spacing is very short, zero offset is the obvious choice, and where travel time between intersections is close to $C/2$, a half-cycle offset is likewise an obvious choice. Where travel time between intersections is close to $C/4$, an offset of 0 or $C/2$ will yield the same width progression band; however, because simultaneous offsets create more speeding opportunities, half-cycle offsets were chosen for such cases. At the two midblock crossings, to allow the two sides of Huntington Avenue to be offset from one another by half a cycle (for pedestrian progression, as explained earlier), offsets were zero for one direction and half a cycle (about 17 s) for the other. Small offset adjustments were sometimes made to account for asymmetric left turn phases and varying arterial greens.

Results

Speeding Opportunities

For each intersection and arterial direction, speeding opportunities per hour are a count of the number of thru vehicles on the arterial meeting the speeding opportunity criteria (arrive on a stale green at least 5 s behind the preceding vehicle). For the seven intersections for which a new signal timing was proposed, measurements were made in both directions; for the boundary intersections, measurements were made only for the westbound direction at Brigham Circle, and for the eastbound direction at Gainsborough Street. Thus, in each direction, measurements were made for eight intersection approaches.

Summing over the corridor and the two directions, corridor-wide speeding opportunities per hour are as shown in Figure 5 for the three signal timing alteratives. First, it is interesting to look at the absolute and relative speeding opportunity rates in the current signal timing plan. In absolute numbers, there are 1,615 speeding opportunities per hour in the a.m. peak and 1,893, in the midday. Because the sum of arterial thru volume on the approaches subject to measurement is 8,134 in the a.m. peak and 6,779 in the midday, this means that with the current timing plan, the percentage of arterial thru traffic that has a speeding opportunity – that is, they can pass through an intersection without being constrained either by a red signal or a vehicle in front of them – is 20% in the a.m. peak and 28%

midday. The absence of congestion in the midday substantially increases the chance of having a speeding opportunity.

Second, it is interesting to see how the alternative timing plans reduce speeding opportunities. The existing-adjusted plan, which leaves the current coordination scheme in place but applies higher standards for pedestrian crossings, reduces the absolute number of speeding opportunities modestly, by 12% in the a.m. peak and by 9% in the midday. The proposed plan, with short coordination zones, achieves far greater absolute reductions – a 33.5% reduction in the a.m. peak, and a 51% reduction midday. With the proposed plan, the percentage of arterial thru passages that have a speeding opportunity falls to only 13% in the a.m. peak and 14% midday.

Figure 5 goes approximately here

For further insight, speeding opportunities by intersection and by direction for the three alternatives are shown in Figure 6 for the midday. Comparing the proposed plan to the existing plan, one can see decreases in speeding opportunities at nearly every approach. The overall decreases eastbound and westbound are roughly equal. In the existing plan, Evans Way eastbound has the most speeding opportunities; the proposed plan lowers this measure from 234 to 127 per hour. At Forsyth Street, which has an especially heavy pedestrian crossing volume because it lies in the middle of a university campus, speeding opportunities per hour fall from 165 to 85 in one arterial direction, and from 103 to only 10 per hour in the other.

Figure 6 goes approximately here

Vehicle Delay

While reductions in speeding opportunities were expected, since they were the objective of the proposed timing plan, the big question for this research was how vehicle delay would be affected. Average network delay, which is average delay per vehicle that enters the network (and thus considers vehicles on the side streets as well as the arterial and, for vehicles traveling along the arterial, incorporates delay at multiple intersections), is shown in Figure 7. The changes are small. In the a.m. peak, the proposed plan has essentially the same average delay as the existing plan; in the midday, there is an increase of 5.6 s per vehicle, or about 9%.

A closer look at vehicle delay results shows that delay increases for through arterial traffic (because their progression is worse) while it decreases for side street traffic and for arterial left turns (because of the shorter cycle length). On segments that are coordination breaks, the queues that form do not spill back to an upstream intersection or otherwise cause secondary delays.

Figure 7 goes approximately here

Pedestrian Delay

Figures 8 and 9 show average pedestrian delay for all Huntington Avenue crossings for the two periods of the day. (Crossings parallel to Huntington Avenue have little delay in every alternative and therefore were not evaluated.) Compared to the existing plan, the existing-adjusted plan shows the expected strong reductions in pedestrian delay, reflecting the added pedestrian coordination that makes it possible for most people to cross in a single pass. In the AM peak, taking a simple average over all crossings, adjustments to the existing plan lower average delay per person from 91 to 49 seconds, a reduction of 42 s. In the midday, the reduction is still greater, 46 s.

The proposed short-coordination-zone plan offers still further and substantial reductions in average pedestrian delay. Using a simple average over all intersection, the additional reduction is 21 s per person in the AM peak and 16 s in the midday. Because the benefits of pedestrian coordination are captured by the base-adjusted timings, the additional reductions arise mainly due to shorter cycle lengths.

Comparing the proposed plan to the existing plan, the difference is dramatic. Average pedestrian delay for crossing Huntington Avenue (simple average over all intersections) falls from 91 s to 28 s in the AM peak, and from 89 s to 26 s in the midday.

Figure 8 goes approximately here

Figure 9 goes approximately here

Discussion

The study's hypothesis – that short coordination zones will lead to substantially fewer speeding opportunities with little increase in vehicular delay and with a reduction in pedestrian delay – was confirmed. Speeding opportunities fell substantially; there was no change in vehicle delay in the AM peak and only a 9% increase in the midday; and pedestrian delay fell substantially. Impacts are greatest when comparing against the existing timing, but are almost as large when compared against the existing-adjusted timing, which represents a modern timing plan with pedestrian improvements.

As expected, short coordination zones allow signal cycles to be substantially shorter. Instead of requiring a 100 s cycle across seven intersections, only one intersection in the short-zone plan has a cycle length of around 100 s, while the others enjoy cycle lengths of 68 s and 76 s.

While frequently breaking coordination might be expected to substantially increase vehicle delay, this was found not to be the case. One reason for this is that shorter cycle times lower delay for the minor street and arterial left turns. Another is that in corridors with short intersection spacing, even the best two-way coordination will force drivers to stop frequently except when traffic volumes are low.

For the AM peak, the finding that large reductions in speeding opportunities and pedestrian delay can be achieved with no increase in vehicle delay in the AM peak makes the strategy a clear winner. For the midday, however, there is a tradeoff; the “cost” of cutting speeding opportunities in half and reducing pedestrian delay by 70 percent is increasing vehicle delay by 9 percent. Many cities, we believe, would consider the safety and livability benefits of the short-zone solution well worth the added vehicle delay.

Using short coordination zones may have drawbacks that have not been addressed in this study. Breaking coordination will lead to increased stops, which may lead to increased rear-end crashes and/or red light running. This is something that would have to be studied in field tests. However, considering the prominent relationship of speed to road safety, those negative effects may be far outweighed by the safety benefits of reducing speeding. It should also be pointed out that breaking coordination along an arterial is a routine aspect of traffic control that motorists cope with, with no apparent safety concerns. (As mentioned earlier, the study corridor itself already has numerous coordination zones.)

Conclusion

While coordinating traffic signals contains an element of speed control, signal coordination on two-way arterials with long coordination zones, as typically practiced in U.S. cities, creates many opportunities for speeding. By comparison, using short coordination zones, with one to three intersections and low cycle lengths tailored to the zone, creates substantially fewer speeding opportunities. A case study of a four-lane arterial in Boston found that, compared to conventional arterial coordination with a long coordination zone and a long signal cycle, short coordination zones, together with short cycles, low progression speed offsets within coordination zones, and pedestrian recall reduced speeding opportunities by about 50% midday, when speeding opportunities are most rampant, and by about 30% in the AM peak, when speeding opportunities are partially suppressed by congestion. Pedestrians also benefit from the strategy, as average pedestrian delay for crossing the arterial fell by 16-20 s compared to an adjusted, pedestrian-friendly version of the existing plan, and by more than 50 s compared to the existing plan in which the two crossing stages needed to cross the arterial are not coordinated. Vehicle delay was unchanged in the AM peak, and rose by only 9% midday.

A comparison of AM peak and midday performance indicates that unlike long zone coordination, for which speeding opportunities are substantially greater in the lower demand period, short zone coordination helps control speed even when traffic volumes are moderately low. This is an important finding at a time when people are trying to understand why traffic deaths in the U.S. increased 2020 in spite of there being less traffic on the road due to pandemic-related shut-downs.

This study also modeled two paradigms for pedestrian coordination at two-stage crossings. One involves lengthening Walk intervals, and sometimes the cross street split, to enable single pass crossings concurrent with the cross street; the other is to use very short cycles (about 34 s), with the two sides of the arterial offset by half a cycle, so that the Walk signal for a person's second crossing stage comes up about 17 s after they began the first stage, resulting in nearly no delay at the median.

This research also pioneered a refinement in the method for evaluating pedestrian delay at multistage crossings by using multiple strata of pedestrians with different walking speeds. While walking speed variability has no impact on average delay at one-stage crossings, it can make a big difference at two-stage crossings where faster pedestrians can cross in a single pass while slower pedestrians have to stop in the median and wait for another cycle to make the second stage of their crossing.

Data Availability Statement

Some of all data, models, or code used during the study were provided by a third party. Direct requests for these materials may be made to the provider as indicated in the Acknowledgements.

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List of Figure Captions

Figure 1. Speeding opportunity through multiple intersections created by long cycles with excess green in spite of one-way coordination with offsets following the desired progression speed.

Figure 2. Study corridor, signalized intersections, and existing coordination zones. Map data © Google 2021

Figure 3. Cycle lengths by intersection, a.m. peak period: Existing, needed, and proposed

Figure 4. Proposed coordination zones. Map data © Google 2021

Figure 5. Speeding opportunities per hour corridor-wide

Figure 6. Speeding opportunities per hour by intersection approach, midday

Figure 7. Average network delay (delay per vehicle for all vehicles entering the network)

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