KOA CORPORATION
PLANNING & ENGINEERING

1100 Corporate Center Drive, Suite 201
Monterey Park, CA 91754
t. (323) 260-4703
www.koacorporation.com

TECHNICAL MEMORANDUM

Date: September 23, 2015

To: Hong Wang, PE, City of Culver City Public Works

From: Walter Okitsu, P.E., KOA Corporation

Subject: Comparison of Left Turn Signal Phasing at the Duquesne Avenue and Jordan Way/Summertime Lane Intersections with Jefferson Boulevard

JB41189

KOA Corporation (KOA) has prepared this technical memorandum comparing potential traffic signal phasing modifications at two intersections in Culver City: the intersection of Duquesne Avenue and Jefferson Boulevard, and the intersection of Jordan Way/Summertime Lane and Jefferson Boulevard. Analysis is based on traffic and pedestrian counts conducted on a weekday in early 2015 during morning and evening peak periods.

For the purposes of this document, Jefferson Boulevard is considered an east-west street despite its actual cardinal orientation.

Duquesne Avenue and Jefferson Boulevard

Issue

The impetus for the grant funding at the intersection of Duquesne Avenue and Jefferson Boulevard was concern over the conflict between pedestrian activity in the east leg crosswalk and heavy southbound left turns from Duquesne Avenue. The grant funding request was for split phasing of the intersection.

Alternatives

Alternatives for analysis include the existing condition and various modifications to the Duquesne Avenue striping, traffic signal phasing, and crosswalk operation. They are:

- Existing condition
- Split phase northbound and southbound.
- Split phase northbound and southbound with the east leg crosswalk removed.
- Dual southbound left lanes.
- Dual southbound left lanes with the east leg crosswalk removed.
- Flashing yellow arrow and green arrow left turn phases northbound and southbound.

Descriptions of the alternatives are provided below.

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Existing Condition

Southbound Duquesne Avenue currently is striped with one lane exclusively for left turns and one lane serving through-and-right turn movements. The southbound left turn demand is fairly heavy, especially during the evening peak hours, ranging from 300 to 400 vehicles per hour. The southbound left turn movement is controlled by a circular green light, meaning that left turning motorists must yield to oncoming northbound traffic emerging from Culver City Park, as well as to pedestrians in the east crosswalk. Activity in the east crosswalk is about 19 pedestrians per hour in both the morning and evening peak hours. The traffic signal currently runs on a 100-second cycle so that a given green phase is displayed every 1 minute and 40 seconds, with variations based on motor vehicle detection and pedestrian pushbutton activations. The 100-second cycle is consistent with adjacent signalized intersections to maintain a synchronized network along Jefferson Boulevard.

Split phase northbound and southbound with the east leg crosswalk removed.

Split phasing would provide a sequence where southbound Duquesne Avenue traffic would receive a simultaneous green left arrow and green circular indication, with right-turning traffic yielding to pedestrians in the west crosswalk, followed by northbound traffic receiving a simultaneous green left arrow and green circular indication with right-turning traffic yielding to pedestrians in the east crosswalk. Under this alternative, a third southbound lane would be inserted on Duquesne Avenue, requiring a reduction in the width of the northbound departure lane by two feet. The three southbound lanes would be assigned to provide a left turn lane, a left-and-through lane, and a right turn lane. Due to the necessity to provide adequate pedestrian time, the signal cycle length must be increased to at least 135 seconds. The longer cycle length means that synchronization with adjacent signals would be lost.

Split phase northbound and southbound with the east leg crosswalk removed.

Another split phase alternative is similar to that described above, but with the east leg crosswalk removed. The removal of the east leg crosswalk would allow the signal to stay within the 100 second cycle length and maintain synchronization with adjacent signals. Pedestrians would be prohibited from using the east crosswalk and would be diverted to the other crosswalks.

Dual southbound left lanes.

As an alternative to split phasing, Duquesne Avenue would be restriped to provide two left turn lanes and a single through-and-right lane. The two southbound left turns would be controlled by a left turn arrow signal, avoiding conflict with the east leg crosswalk movement and oncoming traffic exiting Culver City Park. As with split phasing, the insertion of a third southbound lane requires reduction of the width of the northbound receiving lane. Maintaining a 100-second signal cycle and synchronization with adjacent signals would be feasible, although just barely so. Due to pedestrian timing requirements, the lightly-travelled northbound Duquesne Avenue movement would get more green light than it needs, while the heavy southbound left turn and eastbound left turn movements would be severely constrained.

Dual southbound left lanes with the east leg crosswalk removed.

A second dual left turn lane alternative is similar to that described above, but with the east leg crosswalk removed. Under this alternative, each movement would receive green light roughly in proportion to its demand. East leg pedestrians would be diverted by signage to use the other three crosswalks.

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Flashing yellow arrow and green arrow left turn phase northbound and southbound.
This alternative proposes to install protected-permissive left turn phasing for the Duquesne Avenue approaches, similar to the signal phasing at a few other Culver City intersections like the Overland Avenue-Washington Boulevard intersection and a great many intersections in the surrounding City of Los Angeles, but with a difference: instead of displaying a green circular indication to left turning traffic, those motorists would receive a flashing yellow left arrow. During the flashing yellow left arrow indication, left-turning motorists could proceed only after yielding to pedestrians and oncoming motorists. The flashing yellow arrow indications are less restrictive than the split phasing or dual left signal phasing in that on occasions when no pedestrians are present in the east crosswalk, the left turn movements can proceed. When pedestrians are present, motorists turning left would be reminded to yield to them. Flashing yellow arrow displays have become popular wherever they have been implemented, and are becoming the standard left turn treatment in jurisdictions throughout the country. Examples in Southern California can be seen in Pasadena, Fullerton, Torrance, and Long Beach. Flashing yellow arrows are seen as a solution to the "yellow trap" problem suffered by standard protected-permissive left turn phasing during emergency vehicle preemption of the type used in Culver City. Because flashing yellow arrows cause less capacity reduction than the signal phasing proposed in the other alternatives, Duquesne Avenue lanes would not have to be restriped to provide narrower lanes, and no crosswalks would need to be removed.

Analysis Results

Analysis results using the Synchro model for the morning and evening weekday peak periods are shown in Table 1. The traffic signal's cycle length was maintained at 100 seconds with the exception of the split phase alternative, where the cycle length had to be increased to 135 seconds, resulting in loss of synchronization with surrounding intersections and increased delay for motorists and pedestrians. The Average Vehicle Delay measures the delay imposed by the traffic signal for the average vehicle entering the intersection. Also displayed is the 95th percentile southbound queue length during evening peak period, measuring the approach and time period with the most congestion. The 95th percentile queue represents the length of queue that is exceeded in 5 percent of the signal cycles. As a measure of impact to pedestrians, the increase in pedestrian delay for east leg pedestrians is shown. In the worst case for pedestrians, where the east leg crosswalk is removed, pedestrians would be forced to use the remaining three crosswalks to cross the street, increasing their travel time by the length of a signal cycle, i.e. 100 seconds.

Table 1: Traffic Analysis Results for Duquesne-Jefferson Intersection

Alternative	Cycle length (sec)	Avg Veh Delay AM / PM (secs/veh)	Southbound PM 95th% Queue (ft)	Increased ped delay, east leg (secs)
Existing	100	26.0 / 28.9	408	0
Split Phase	135	40.5 / 40.1	266	17.5
Split Phase, remove east crosswalk	100	26.7/ 29.1	210	100
Dual left lanes	100	40.5 / 35.1	213	0
Dual left lanes, remove east crosswalk	100	27.0 / 26.4	161	100
Flashing yellow arrow with PPLT	100	30.4 / 32.0	271	0

Links to the video simulations of all of the alternatives are provided in Table 2.

Table 2: SimTraffic Videos for the Duquesne-Jefferson Intersection

Alternative	Morning Peak Hour	Evening Peak Hour
Existing	http://bit.ly/1NZZBlg	http://bit.ly/1L06IPa
Split Phase	http://bit.ly/1K6hXAz	http://bit.ly/1IXjQOZ
Split Phase, remove east crosswalk	http://bit.ly/1UA7xUZ	http://bit.ly/1g8iwly
Dual left lanes	http://bit.ly/1UA7ys9	http://bit.ly/1hVnjrR
Dual left lanes, remove east crosswalk	http://bit.ly/1OwDZAw	http://bit.ly/1ENBIRv
Flashing yellow arrow with PPLT	http://bit.ly/1KD5QBy	http://bit.ly/1K6iliC

Discussion

In terms of motor vehicle operation, the least vehicle delay would be achieved by removing the east leg crosswalk across Jefferson Boulevard and inserting a third southbound lane on Duquesne Avenue. The signal phasing could either be a split phase or a protected left for dual southbound lanes: the overall vehicle delay would be approximately the same. The southbound queue length is likely to be shorter with the dual left turn lanes compared to split phasing (161 feet vs. 210 feet), but either operation would significantly reduce queue length primarily because the additional lane could store more cars. However, the removal of the east crosswalk has the largest impact to pedestrian access. Pedestrians wishing to traverse between the northeast and southeast corners would be guaranteed a delay of 100 seconds, because they must use three crosswalks and would therefore require one additional 100-second signal cycle to accomplish the same movement. This additional delay poses the risk of pedestrians running across the east leg in violation of the "No Pedestrian" signs and in conflict with two lanes of left turning traffic, a risk that may increase with pedestrians hoping to catch an eastbound Line 4 Culver CityBus.

If removal of the east leg crosswalk is deemed undesirable, split phasing becomes infeasible because the cycle length must be increased to 135 seconds to accommodate sequential pedestrian phases for the east and west leg crosswalks. Synchronization with the rest of the city's signal network would be lost. It is still possible to provide the dual left turn lane operation while retaining the east leg crosswalk. However, the traffic operation would degrade. The biggest impact would be to morning eastbound left turn traffic from Jefferson Boulevard onto northbound Duquesne Avenue, because the length of the left turn green arrow would be shortened to accommodate the new southbound left arrow.

Another impact arises from the insertion of a third southbound lane, necessitating the reduction of the northbound receiving lane width. Under current conditions, large vehicles making the right turn from eastbound Jefferson Boulevard onto Duquesne Avenue have difficulty negotiating the tight turn and occasionally damage the traffic signals on the northeast corner. The possibility of signal damage is likely to increase with the narrower northbound lane. This impact occurs for both the split phase and the dual left turn alternatives, regardless of whether the east leg crosswalk is removed.

The flashing yellow arrow alternative results in far less congestion than with dual left lanes if all crosswalks are retained, and is not much worse than existing conditions. Queue lengths on Duquesne Avenue would be better than the existing condition, even though the lane striping would not change. Pedestrian delay would not increase.

Although the pedestrian movements would not be fully protected from left turning motor vehicle movements, they would be better protected than with the existing condition in that motorists would receive an exclusive green arrow followed by a permissive flashing yellow arrow. The contrast in signal displays would serve notice to motorists that they should be cautious during the flashing yellow arrow. Even if motorists become confused by the unusual flashing yellow arrow, which should be expected when first installed, they would hesitate on the conservative side, i.e. they would pause before turning left rather than proceeding as if unconstrained. The intersection of Duquesne Avenue and Jefferson Boulevard appears to be an excellent location for Culver City's first flashing yellow arrow phasing.

A foam board display sheet describing the alternatives is provided in the appendix at the end of this document.

Jordan Way, Summertime Lane, and Jefferson Boulevard

Issues

Complaints have arisen from residents in the Lakeside Village community about opposing left turn traffic from Jordan Lane failing to yield to exiting Summertime Lane traffic at the signalized intersection on Jefferson Boulevard. This has led to the grant application request for split phasing of the signal phases.

Alternatives

Alternatives for analysis include the existing condition and various modifications to the Summertime Lane striping, traffic signal phasing, and crosswalk operation. They are:

- Existing condition
- Split phase northbound and southbound.
- Split phase northbound and southbound with the east leg crosswalk removed.
- Flashing yellow arrow southbound.

Descriptions of the alternatives are provided below.

Existing Condition

Southbound Jordan Way's narrow width allows room for only a single southbound lane to serve left, through, and right movements. The northbound Summertime Lane approach is wider, currently striped with one lane for left-and-through movements and another exclusively for right turns. These northbound lane assignments may be the reason Jordan Way left turning traffic fails to yield to oncoming traffic. Motorists turning left from Jordan Way would be expected to yield to cars in the rightmost northbound lane, but may be surprised to see oncoming through traffic come from the leftmost northbound lane. The southbound left turn demand is heavy during the evening peak hours at 211 vehicles per hour, compared to 47 proceeding straight through and 59 turning right. The southbound left turn movement is controlled by a circular green light, meaning that left turning traffic must yield to oncoming northbound movement emerging from Summertime Lane as well as to pedestrians in the east crosswalk. Activity in the east crosswalk is about 7 pedestrians per hour in both the morning and evening peak hours. The traffic signal currently runs on a 100-second cycle so that a given green phase is displayed every 1 minute and 40 seconds, with variations based on motor vehicle detection and pedestrian pushbutton activations.

The 100-second cycle is consistent with adjacent signalized intersections to provide a synchronized network along Jefferson Boulevard.

Split phase northbound and southbound.
Split phasing would provide a sequence where southbound Jordan Way traffic would receive a simultaneous green left arrow and green circular indication, with right-turning traffic yielding to pedestrians in the west crosswalk, followed by northbound traffic receiving a simultaneous green left arrow and green circular indication with right-turning traffic yielding to pedestrians in the east crosswalk. Under this alternative, the northbound Summertime Lane lanes would be reassigned so that the leftmost lane would handle only left turning traffic and the rightmost lane would handle through and right turn moves. Although pedestrian crossing time requirements would result in a long duration for both the northbound and southbound signal phase, the existing 100-signal cycle length and, consequently, synchronization with nearby signals could be maintained. However, the available green time displayed to east-west traffic would be significantly reduced causing congestion on Jefferson Boulevard.

Split phase northbound and southbound with the east leg crosswalk removed.
Another split phase alternative is similar to that described above, but with the east leg crosswalk removed. The removal of the east leg crosswalk would allow more green time to be displayed to Jefferson Boulevard. Pedestrians would be prohibited from using the east crosswalk and would be diverted to the other crosswalks.

Flashing yellow arrow northbound and southbound
Under this alternative, the northbound approach lanes would be reassigned similar to the split phase alternatives, with an exclusive left turn lane and a through-and-right lane. The only traffic signal alternation, other than reassignment of detectors on Summertime Lane, would be the display of a flashing yellow left arrow at the same time as a green circular indication to southbound Jordan Way. All other signal indications would remain unchanged. All crosswalks would be maintained. Functionally and legally, the left turning motorists should behave no differently than with the green circular indication they receive now. In practice, however, the left turning motorists would be alerted by the flashing yellow indications to yield to oncoming traffic and to pedestrians in the east leg crosswalk. First encounters with the flashing yellow arrow might lead to confusion, but any hesitation would be on the conservative side: left turners would pause before entering the intersection. Shifting northbound straight through Summertime Lane traffic to the rightmost lane should further improve the likelihood that Jordan Way left-turners would yield to oncoming traffic.

Analysis Results

Analysis results from the Synchro model for the morning and evening weekday peak periods are shown in Table 3. The traffic signal's cycle length was maintained at 100 seconds. The Average Vehicle Delay measures the delay imposed by the traffic signal for the average vehicle entering the intersection. The 95th percentile southbound queue length during the evening peak period measures congestion on Jordan Way capturing 95 queue lengths out of a hundred cycles. The increase in pedestrian delay for east leg pedestrians shows the worst case being the prohibition of pedestrians on the east leg, forcing them to use the remaining three crosswalks and increasing their travel time by the length of a signal cycle, i.e. 100 seconds.

Table 3: Traffic Analysis Results for Jordan/Summertime and Jefferson Intersection

Alternative	Cycle length (sec)	Avg Veh Delay AM / PM (secs/veh)	Southbound PM 95th% Queue (ft)	Increased ped delay, east leg (secs)
Existing	100	11.7 / 18.9	411	0
Split Phase	100	51.3 / 78.7	341	0
Split Phase, remove east crosswalk	100	20.8 / 23.0	348	100
Flashing yellow arrow, no green arrow	100	11.4 / 18.1	404	0

Video simulations of all of the alternatives can be accessed as from the links in Table 4:

Table 4: SimTraffic Videos for the Jordan/Summertime-Jefferson Intersection

Alternative	Morning Peak Hour	Evening Peak Hour
Existing	http://bit.ly/1K7xLr8	http://bit.ly/1LiNEHO
Split Phase	http://bit.ly/1LWmgC5	http://bit.ly/1ivENeT
Split Phase, remove east crosswalk	http://bit.ly/1K6hbDK	http://bit.ly/1K6hbDK
Flashing yellow arrow with PPLT	http://bit.ly/1UFtKeY	http://bit.ly/1g8mFWI

Discussion

In terms of traffic operation, the installation of split phasing while keeping all crosswalks intact results in the worst delay, by far. Jefferson Boulevard would be severely congested, which would escalate into congestion at the adjacent intersection at Overland Avenue. The southbound queue on Jordan Way is shown as improving under split phasing, but that could change if motorists divert from Overland Avenue and use Virginia Avenue and Jordan Way, instead.

Split phasing in combination with removal of the east crosswalk would still result in increased traffic congestion on Jefferson Boulevard, although not as much as if the east crosswalk remained. Queue lengths on Jordan Way would be reduced, provided that no motorists would be attracted to use Virginia Avenue and Jordan Way instead of making a southbound left turn from Overland Avenue. Pedestrian delay would be far greater, however, with some pedestrians needing to use three crosswalks to reach their desired location.

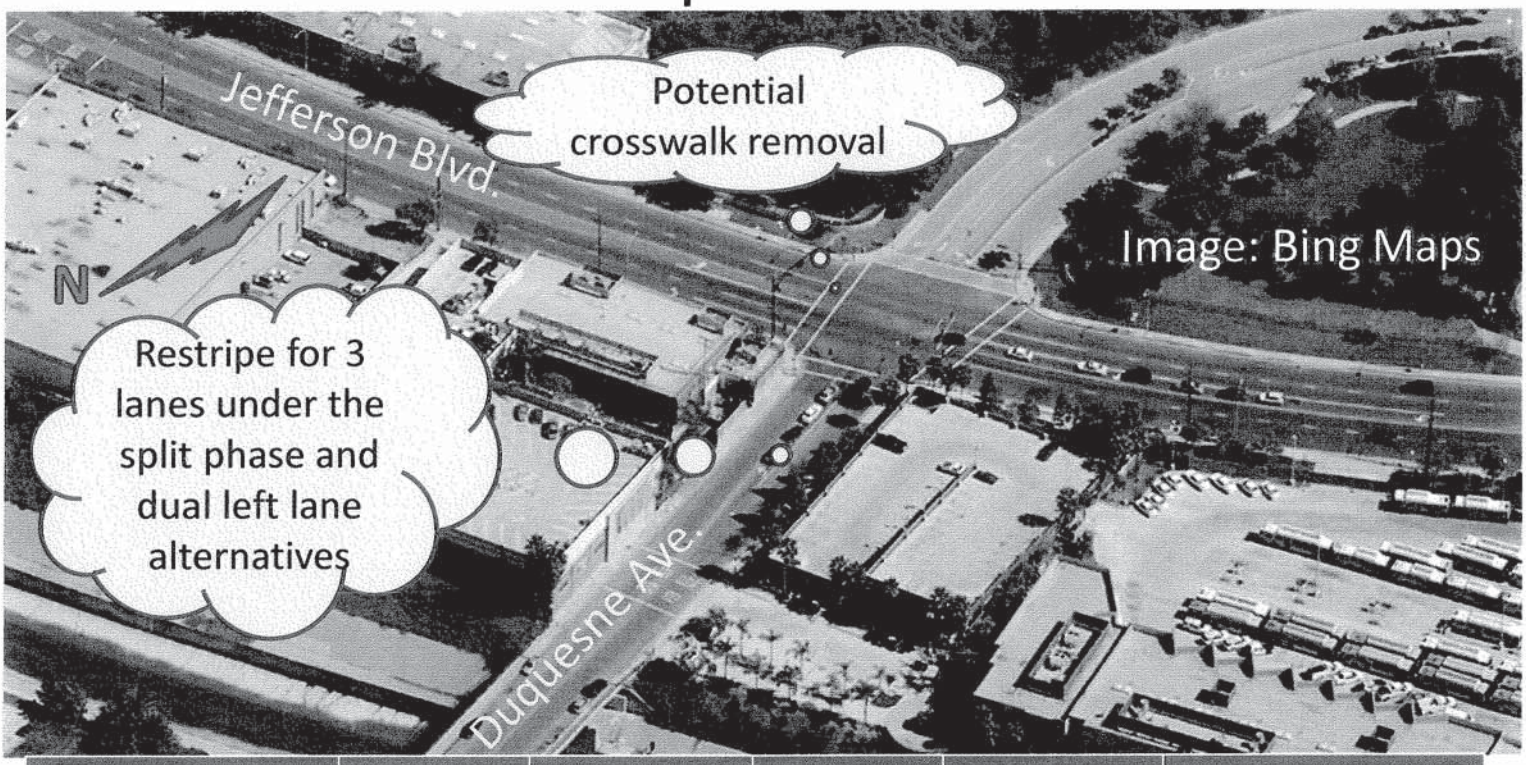
The flashing yellow arrow provides the best overall operation, performing even better than the existing condition. The slight benefit is most likely due to the reassignment of lanes on the Summertime Lane approach, where northbound through traffic is shifted to the rightmost lane.

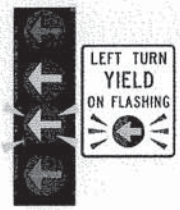
A foam board display sheet describing the alternatives is provided in the appendix at the end of this document.

Appendix: Public Presentation Displays

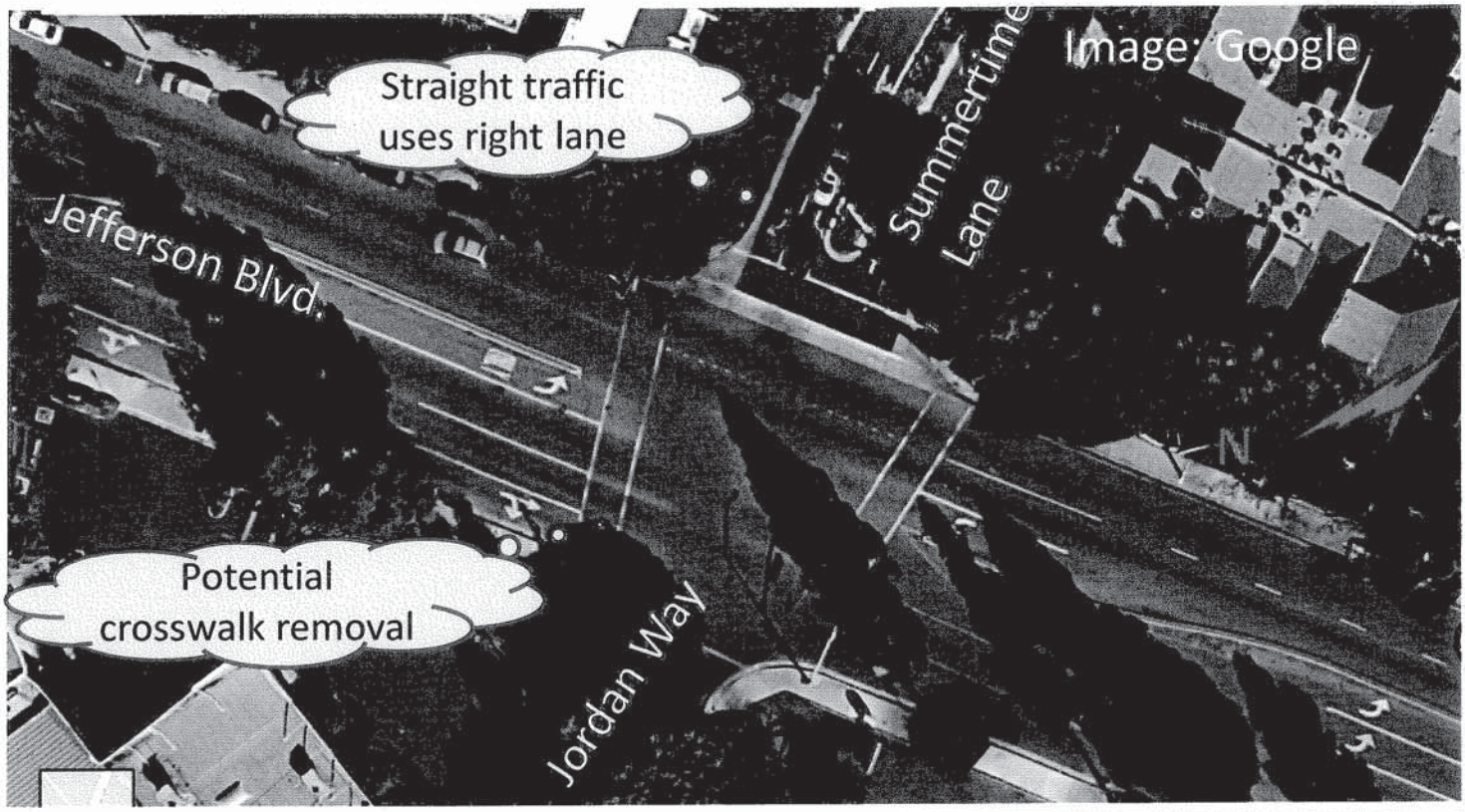
1. Duquesne Avenue at Jefferson Boulevard
2. Jordan Way-Summertime Lane at Jefferson Boulevard

Jefferson Blvd at Duquesne



Alternative	Avg Veh Delay AM (secs/veh)	Southbound PM Queue (ft)	Remove crosswalk?	Striping change	Signal display, southbound left turn
Existing	26.0 (best)	408 (worst)	No		
Split phase, remove east crosswalk	26.7	210	Yes	Adds a 3rd southbound lane	
Dual left lanes	40.5 (worst)	213	No	Adds a 3rd southbound lane	
Dual left lanes, remove east crosswalk	27.0	161 (best)	Yes	Adds a 3rd southbound lane	
Flashing yellow arrow with protected-permissive left turn	30.4	271	No	Same as existing	

Jefferson Blvd at Jordan Way



Alternative	Avg Veh Delay PM (secs/veh)	Southbound PM Queue (ft)	Remove crosswalk?	Striping change	Signal display, southbound left turn
Existing	18.9	411 (worst)	No		
Split Phase	78.7 (worst)	341 (best)	No	Summertime through traffic uses right lane	
Split phase, remove east crosswalk	23.0	348	Yes	Summertime through traffic uses right lane	
Flashing yellow arrow, no green arrow	18.1 (best)	404	No	Summertime through traffic uses right lane