TRAFFIC ASSESSMENT LEFT-TURN SIGNAL PHASING GUIDELINES

Oahu, Hawaii

DRAFT FINAL

April 4, 2017

Prepared for:

City & County of Honolulu
Department of Transportation Services
In Cooperation with the Oahu Metropolitan Planning Organization
and the United States Department of Transportation

Austin, Tsutsumi & Associates, Inc.
Civil Engineers • Surveyors
501 Sumner Street, Suite 521
Honolulu, Hawaii 96817-5031
Telephone: (808) 533-3646
Facsimile: (808) 526-1267
E-mail: atahnl@atahawaii.com
Honolulu • Wailuku, Hawaii

TRAFFIC ASSESSMENT
Left-Turn Signal Phasing Guidelines
Oahu, Hawaii

DRAFT FINAL

Prepared for

City & County of Honolulu
Department of Transportation Services
In Cooperation with the Oahu Metropolitan Planning Organization
and the United States Department of Transportation

Prepared by
Austin, Tsutsumi & Associates, Inc.

Civil Engineers • Surveyors
Honolulu • Wailuku, Hawaii

April 4, 2017

DISCLAIMER

TABLE OF CONTENTS

TABLE OF CONTENTS
Cont'd

TABLE OF CONTENTS
Cont'd

APPENDICES

AUSTIN, TSUTSUMI & ASSOCIATES, INC. CIVIL ENGINEERS • SURVEYORS
CONTINUING THE ENGINEERING PRACTICE FOUNDED BY H. A. R. AUSTIN IN 1934

TERRANCE S. ARASHIRO, P.E.
ADRIENNE W.L.H. WONG, P.E., LEED AP
DEANNA M.R. HAYASHI, P.E.
PAUL K. ARITA, P.E.
ERIK S. KANESHIRO, L.P.L.S., LEED AP
MATT K. NAKAMOTO, P.E.
GARRETT K. TOKUOKA, P.E.

TRAFFIC ASSESSMENT
FOR LEFT-TURN SIGNAL PHASING GUIDELINES
Honolulu, Oahu, Hawaii

I. FOREWORD

This document provides general guidelines of the City & County of Honolulu Department of Transportation Services relative to the selection of left-turn phasing. This document is not intended to replace or override the guidance and requirements prescribed or mandated by current reference manuals and/or guidelines. These guidelines have been adapted from other publications and should not be used as the sole means of warranting left-turn phasing. Engineering judgment should be used to determine whether left-turn phasing should be implemented.

II. INTRODUCTION

This report documents the findings of a traffic study conducted by Austin, Tsutsumi, & Associates, Inc. (ATA) to:

1. Update the existing left-turn signal phasing guidelines;
2. Evaluate effectiveness of left-turn signal phasing guidelines by applying the methodology to the following case study intersections:
    - Kapiolani Boulevard/Kamakee Street
    - Moanalua Road/Kuala Street/Waimano Home Road

- Monsarrat Avenue/Leahi Avenue
- Nuuanu Avenue/North Kuakini Street/South Kuakini Street
- Kailua Road/Hamakua Drive/Kainehe Street
- Dillingham Boulevard/Kalihi Street
- Waialae Avenue/6th Avenue

The left-turn phasing guideline application to the case study intersections is detailed in Appendix C.

III. BACKGROUND

A. Current Left-Turn Signal Phasing Guidelines

The current guidelines for left-turn signal phasing for the City and County of Honolulu are based primarily on the Traffic Engineering Handbook, 4th Ed., 1992, which evaluates left-turn volumes, left-turn delay, and accident experience. Thresholds are as follows:

1. Volumes - The product of left-turning vehicles and opposing volumes during peak hours exceeds 100,000 on a four-lane street or 50,000 on a two-lane street.
2. Delay - The left-turn delay is 2.0 vehicle-hours or more on a critical approach during a peak hour and the left-turn volume is greater than two vehicles per cycle with an average delay per left-turning vehicle of at least 35 seconds.
3. Accident Experience - Four left-turn accidents in one year or six in two years. For both approaches, six left-turn accidents in one year or ten in two years.

The existing guidelines, established in 2005, recommend providing a left-turn phase if one of the above guidelines is met. Based upon review of nationally published manuals, reports, and research studies, the current guidelines provide some generally acceptable methods used in other jurisdictions. This report intends to build on the existing guidelines to formulate a balanced approach when evaluating left-turn signal phasing, consistent with the latest Traffic Engineering Handbook, 6th Ed., 2009.

B. Left-Turn Signal Phasing Modes

The three major types of left-turn phasing were studied in this report and include the following:

1. Permissive Only Left-Turn Phasing – Provides no protected left-turn signal phase for left-turn movement. Left-turn vehicles must always yield to oncoming through traffic. Permissive phasing is typically used if left-turn volumes and/or opposing through volumes are low enough to create gaps in traffic that accommodate left-turn vehicles, provided enough sight distance is given.
2. Protected Only Left-Turn Phasing – Provides a protected left-turn signal phase for left-turn movements. Left-turn vehicles are only allowed to proceed during this left-turn signal phase. This phase is typically used where sight distance issues, geometric constraints, frequent accidents, and/or generally high left-turn and opposing through volumes exist at an intersection. Protected only left-turn phasing can typically provide a higher degree of safety than permissive left-turn phasing but could result in capacity and delay issues at an intersection, as more green time will need to be allocated to the protected left-turn phase instead of typically higher priority through movements.
3. Protected + Permissive Left-Turn Phasing – Provides a combination of a protected left-turn signal phase for the left-turn movement and a permissive phase where left-turn vehicles must yield to oncoming through traffic. This type of phasing generally provides an efficient form of left-turn treatment if left-turn volumes and/or opposing through volumes are high enough to warrant a left-turn phase. Compared to protected only left-turn phasing, protected + permissive left-turn phasing can provide numerous advantages and disadvantages. See further discussion below (3,6):

   Advantages

- Potentially increase left-turn capacity and reduce left-turn/overall intersection delay.
- Provides efficient vehicle progression through an intersection or throughout an arterial in a coordinated signal system.
- Potentially reduce or eliminate the required left-turn green phase time, providing more green time for higher priority through movements.
- Improves safety performance (compared to permissive only phase), by providing a protected left-turn phase for a portion of left-turn vehicles.

Disadvantages

- Creates condition for “yellow trap” scenario. The Traffic Signal Timing Manual defines “yellow trap” as a condition that leads the left-turning driver into the intersection when it could potentially cause conflicts even though the signal displays are correct.
- Potential for some driver confusion.
- Some drivers may not use the permissive phase even when adequate gaps in opposing traffic are available, and instead turn left only when given the protected left-turn arrow indication.

IV. GUIDELINES FOR THE IMPLEMENTATION OF A LEFT-TURN PHASE

This section will provide guidelines to determine when a left-turn phase would be appropriate to install at a traffic signal. The guidelines are based upon a literature review.

A. Literature Review

In the absence of a nationally accepted policy document for left-turn signal phasing, various manuals, reports and research studies associated with the Federal Highway Administration (FHWA), Institute of Transportation Engineers (ITE), Transportation Research Board (TRB), and local state agencies were reviewed.

To date, there are no nationally established warrants for left-turn phasing. However, many local and federal agencies have developed their own guidelines for considering left-turn phasing. This report favors those guidelines federally published by the FHWA and ITE.

The following studies were reviewed and used as a basis for guidelines. The studies are listed in order of applicability.

1. Federal Highway Administration, **Traffic Signal Timing Manual (2008)**
   - Intended to be a comprehensive guide and synthesis based upon North American practice.
   - Explicitly states that it is not "intended to serve as a standard or policy document."
   - Provides one of the most recent sets of federally published guidelines for left-turn phasing.
   - Cites the following references as the basis for its warrants:
     - The Manual of Traffic Signal Design, 2nd Edition, which was also used to form the existing City and County of Honolulu guidelines.
     - The Traffic Signal Book (1993)

- Unique amongst the publications reviewed is its provision of guidelines for left-turn phasing in the form of a flowchart.
    - The flowchart sequences and prioritizes the individual criteria to act as conditions to each other, thus providing a more comprehensive set of guidelines.
- Results of the flowchart can differentiate between the various left-turn phasing schemes: Protected-only, Permissive, and Protected + Permissive.

2. Federal Highway Administration, **Signalized Intersections: Informational Guide (2004)**
    - References other states' local guidelines.
    - Provides similar guidelines to the Traffic Signal Timing Manual, except in a list format.
3. Institute of Transportation Engineers, **Traffic Engineering Handbook, 6th Edition (2009)**
    - Existing C&C Honolulu left-turn phasing guidelines are based on the 4th edition of this publishing (identical to the 6th edition for left-turn warrants).
    - Does not provide guidelines of their own, but references the Manual of Traffic Signal Design and Signalized Intersections: Informational Guide.
4. Institute of Transportation Engineers, **Manual of Traffic Signal Design, 2nd Edition (1991)**
    - Provides a set of federally published guidelines which are used in the Traffic Signal Timing Manual.
    - Guidelines are identical to the existing C&C Honolulu left-turn phasing guidelines.
5. Miscellaneous Sources

Various sources from the TRB and state local agencies provide a list of left-turn phasing guidelines that are similar to those recommended by the Traffic Signal Timing Manual and Signalized Intersections: Informational Guide. Because the guidelines are comparable to those favored and federally published by the FHWA and ITE, the following publications were examined with less emphasis. However, the various publications in combination helped provide a consensus in determining the guidelines. The following sources were reviewed:

- Transportation Research Board, **Transportation Research Record No. 1605: Research on Traffic Control Devices (1997)**
- Transportation Research Board, **NCHRP Synthesis 225: Left-Turn Treatments at Intersections (1996)**
- ASCE Journal of Transportation Engineering, **Warrants for Protected Left-Turn Phasing (2005)**
- New York City Department of Transportation, **New York City Department of Transportation Traffic Operations (2006)**
- Arizona Department of Transportation, **ADOT Traffic Engineering Policies, Guidelines, and Procedures (2011)**
- Texas Department of Transportation, **Development of Left-Turn Operations Guidelines at Signalized Intersections (2008)**

B. Recommended Criteria for Determining Left-Turn Phasing

Information and recommendations obtained from the sources listed in Section III.A were used to formulate the following criteria and guidelines for left-turn signal phasing:

1. *Crash history* is one of the prominent factors in evaluating the need for a left-turn signal phase. The frequency of accidents involving left-turning vehicles will dictate the need for and type of left-turn phase mode for each left-turn movement. Common types of collisions for left-turn vehicles include angle collisions from opposing and crossing vehicular traffic, sideswipe and rear-end collisions from through traffic in the same

direction, and vehicular-pedestrian collisions at crosswalks (3). In rural settings, vehicles may operate at higher speeds, which may create greater accident potential due to shorter gaps in opposing through traffic. Generally, the need for left-turn phasing should be weighted more heavily on safety considerations than on traffic volumes (9). Research has shown that implementing a left-turn signal phase can provide a 12% reduction in all collisions at an intersection and 38% reduction in left-turn collisions (11).

2. *Sight distance* is a factor that could influence the frequency of collisions at an intersection. Permissive left-turning vehicles require adequate sight distance to see opposing traffic, select an adequate gap in traffic, and make the left-turn at the intersection (9). If the movement does not have adequate sight distance, a protected left-turn signal phase should be considered to reduce potential conflicts. However, if the left-turn lane can be offset to provide adequate sight distance for left-turning vehicles, permissive phasing could be retained by implementing this mitigation in place of installing a protected left-turn signal phase (6).

3. *Roadway geometry and vehicle speeds* denote the number of opposing through lanes that conflict with the left-turn movement, presence and number of exclusive left-turn lanes, and typical speeds of opposing through vehicles (6,10).

4. *Intersection volumes and operation* are the final contributing factors that influence the need for a left-turn signal phase. Peak hour left-turn traffic volumes, conflicting opposing through and right-turn traffic volumes, left-turn movement delays, and vehicle cross products thresholds are accounted for in the left-turn signal phase guidelines (6,10). These guidelines reflect a comprehensive approach by looking at the operation of individual left-turn and through movements and the operation of multiple conflicting movement interactions.

C. Recommended Left-Turn Phasing Guidelines

Through the literature review, the left-turn warranting guidelines provided by the Traffic Signal Timing Manual are a generally conservative and comprehensive federally published collection. The Traffic Signal Timing Manual was the only federal publication found to: 1) arrange guidelines in a flowchart format, and 2) provide guidelines that differentiate between protected-only, permissive, and protected + permissive phasing.

Most of the flowchart and guidelines provided in the Traffic Signal Timing Manual were used in creating the guidelines for this report. However, the sight distance criteria found in the FHWA-published Signalized Intersections: Informational Guide, consistent with A Policy on Geometric Design of Highways and Streets published by American Association of State Highway and Transportation Officials (AASHTO) in 2011, was more conservative than those in the Traffic Signal Timing Manual. Thus, the flowchart was altered to reflect the sight distance criteria.

Figure 1 shows the recommended guidelines for this report. Figure 2 shows the minimum sight distance thresholds referenced in the flowchart. Figure 3 and Figure 4 provide design considerations and additional factors to be considered when selecting a left-turn phasing scheme.

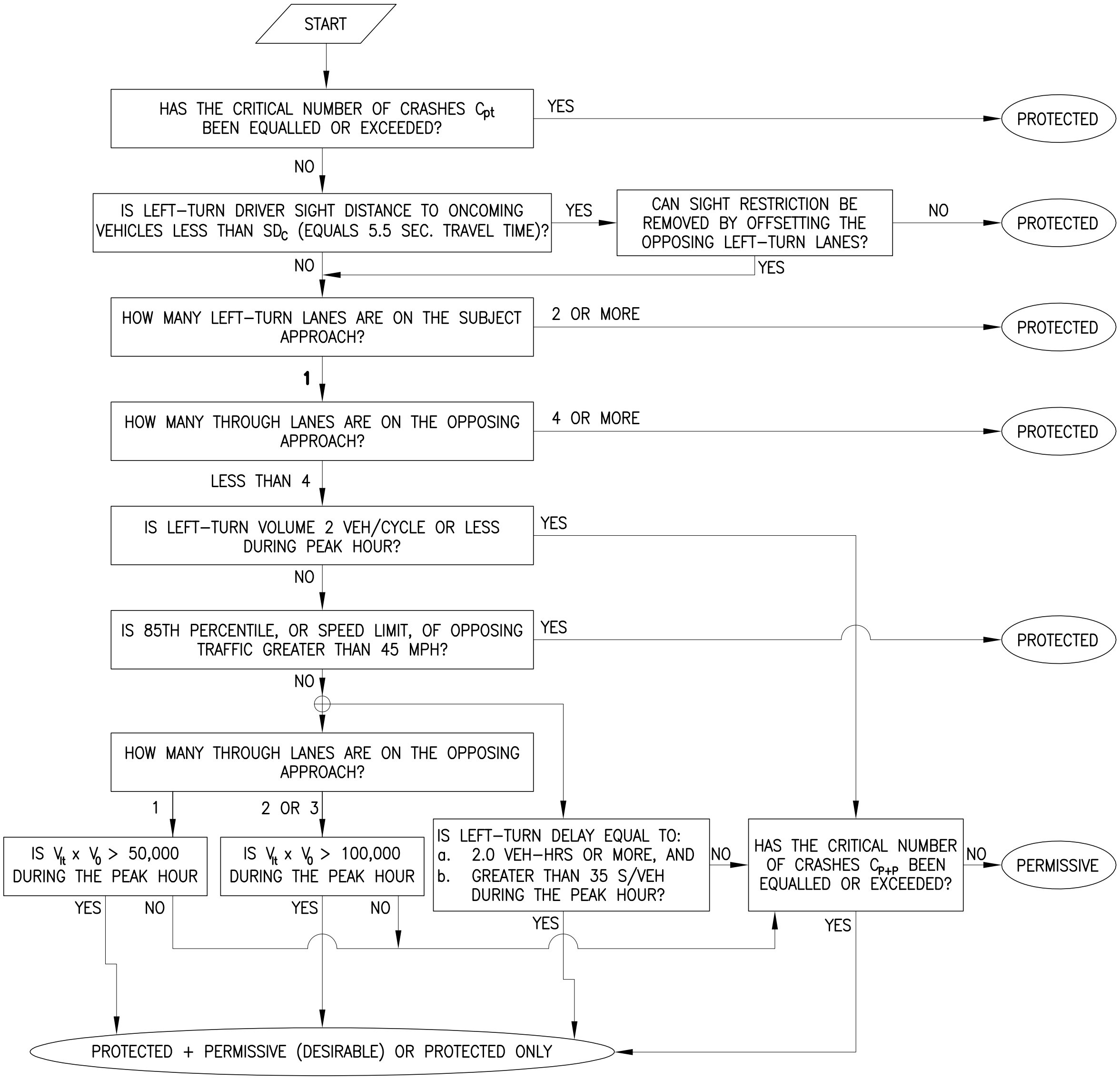
Shared left-turn lane scenario

Left-turn signal phasing is most commonly applied to left-turn movements that have an exclusive left-turn lane. However, intersections that experience safety or operational issues as a result of left-turn movements may not always be provided with an exclusive left-turn lane to facilitate the left-turn movements. Instead, left-turn vehicles may be required to share a lane with the through movement along the same approach. This can create a backlog of traffic and queuing, as left-turn vehicles potentially restrict the flow of the through movement for vehicles behind them.

According to Left-Turn Treatments at Intersections (Pline, 1996), it is *not desirable* to provide an exclusive left-turn signal phase without a separate designated left-turn lane to store the left-turning vehicles and to separate the left-turns from the through traffic (9). However, the number of accidents at an intersection must be considered in the determination of left-turn phasing and researchers agree that left-turn accidents indicate the need to consider some type of protection (11). The occurrence of vehicle collisions involving left-turning vehicles and opposing traffic at intersections with shared left-turn/through lanes may indicate a lack of adequate traffic gaps in the opposing traffic, too many left-turning vehicles for the available gaps, visibility restrictions or speed problems (9). Therefore, Pline argues that in the absence of an exclusive left-turn lane, corrective measures could include a signal phase for left-turn maneuvers (9).

No guidelines have been created for left-turn phasing for shared left-turn/through lanes. As a result, caution should be applied when using the left-turn phasing guideline flowchart for this scenario. Field observations and a traffic study could provide more insight to the number of left-turn vehicles that will benefit from a left-turn signal phase, the potential reduction of vehicular pedestrian conflicts, benefits to the straight-through vehicles that are delayed behind the left-turning vehicle, and the potentially negative impacts on delay for the opposing through vehicles (9). See Figure 3 for further discussion.

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT	
		WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC **DESIGN SPEED** (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)*****
25	**205**
30	**245**
35	**285**
40	**325**
45	**365**
50	**405**
55	**445**
60	**490**

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

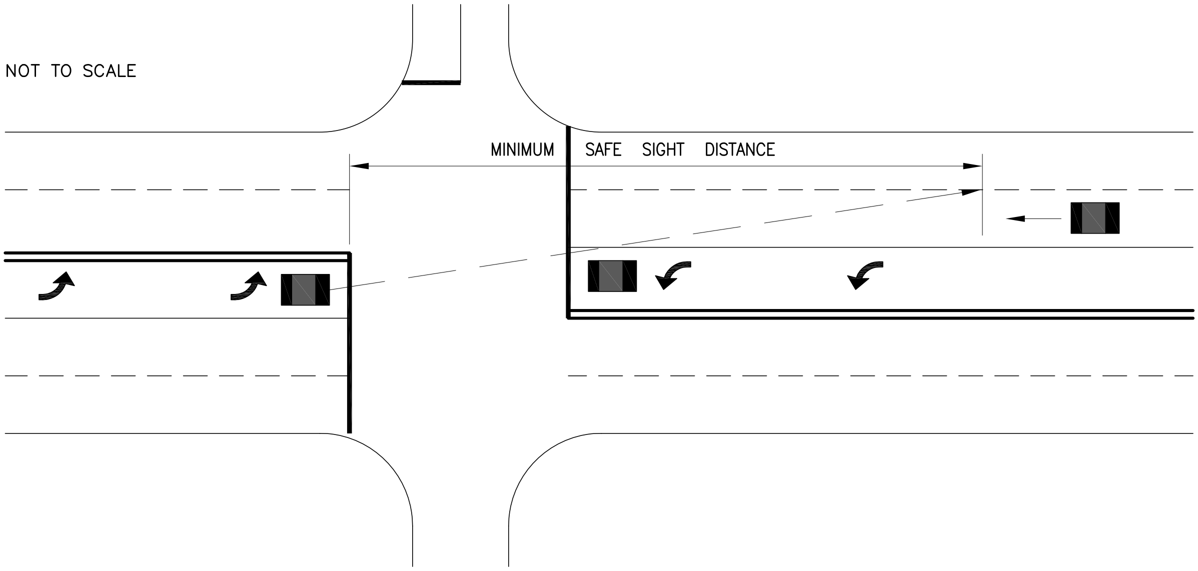


TABLE 1: MINIMUM RECOMMENDED SIGHT DISTANCE FOR PERMISSIVE ONLY OR PROTECTED–PERMISSIVE LEFT–TURN PHASING

DESIGN SPEED (MPH)	INTERSECTION SIGHT DISTANCE PASSENGER CARS DESIGN (FT.)
15	125
20	165
25	205
30	245
35	285
40	325
45	365
50	405
55	445

NOTE: INTERSECTION SIGHT DISTANCE SHOWN IS FOR A PASSENGER CAR MAKING A LEFT TURN FROM AN UNDIVIDED HIGHWAY AND WAS DEVELOPED FROM THE UNADJUSTED TIME GAP OF 5.5 SECONDS FOR PASSENGER CARS. FOR OTHER CONDITIONS AND DESIGN VEHICLES, THE TIME GAP SHOULD BE ADJUSTED AND THE SIGHT DISTANCE RECALCULATED PER (2) TABLE 9–13 AND EQUATION 9–1.

SOURCE: FIGURE 2 ADAPTED FROM (1) & (2) TABLE 9–14.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

MINIMUM SIGHT DISTANCE ALLOWABLE FOR PERMISSIVE LEFT–TURN PHASING

FIGURE
2

PAGE 3 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT–TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT–TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT–TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE–RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT–TURN ARROW.

SPECIAL CASE: SHARED LEFT–TURN/THROUGH LANE

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED–ONLY LEFT–TURN PHASING WHERE LEFT–TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT–TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE–ONLY LEFT–TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT–TURN PHASES FOR SHARED LEFT–TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT–TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT–TURN LANE:

- **IF A DEDICATED LEFT–TURN LANE CAN BE FEASIBLY CONSTRUCTED**, UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT–TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT–TURN LANE**, CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT–TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT–TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:
    - THE LEFT–TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT–TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT–TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT–TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT–TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT–TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT–TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT–TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT–TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT–TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE – 1

FIGURE
3

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED-ONLY LEFT-TURN PHASING

WHEN CONSIDERING INSTALLING PROTECTED-ONLY PHASING, DETERMINE THE IMPACT OF ROADWAY GEOMETRICS ON THE OPERATIONS OF THE INTERSECTION. MORE SPECIFICALLY:

1. PROTECTED-ONLY LEFT-TURN PHASING MAY INCREASE THE QUEUE LENGTHS FOR THE LEFT-TURN MOVEMENTS DUE TO THE MORE FINITE GREEN TIME DURING WHICH LEFT-TURNS CAN BE MADE. THEREFORE, CARE SHOULD BE TAKEN TO INCREASE THE STORAGE LENGTHS WHERE POSSIBLE AND DEEMED NECESSARY.
2. IF IMPLEMENTING PROTECTED-ONLY LEFT-TURN PHASING IS ANTICIPATED TO INCREASE QUEUE LENGTHS TO BEYOND THE AVAILABLE MEDIAN STORAGE LENGTH (AND DECELERATION LENGTH, WHERE APPLICABLE), THE POTENTIAL FOR REAR-END COLLISIONS MAY INCREASE AND SHOULD BE CONSIDERED.
3. DETERMINE IF THE STORAGE LENGTH IS ADEQUATE FOR PROPER OPERATION OF LOOP DETECTORS (OR OTHER SENSOR TYPES).
4. IF THE ENGINEER IS UNABLE TO ASSESS THESE IMPACTS, A TRAFFIC STUDY SHOULD BE PREPARED.

SPLIT PHASING

ACCORDING TO THE TRAFFIC SIGNAL TIMING MANUAL, "SPLIT PHASING MAY BE HELPFUL IF ANY OF THE FOLLOWING CONDITIONS ARE PRESENT:

1. THERE IS A NEED TO ACCOMMODATE ONE OR MORE LEFT-TURN LANES ON EACH APPROACH, BUT SUFFICIENT WIDTH IS NOT AVAILABLE TO ENSURE ADEQUATE SEPARATION IN THE MIDDLE OF THE INTERSECTION. THIS PROBLEM MAY ALSO BE CAUSED BY A LARGE INTERSECTION SKEW ANGLE.
2. THE LARGER LEFT-TURN LANE VOLUME IS EQUAL TO ITS OPPOSING THROUGH LANE VOLUME DURING MOST HOURS OF THE DAY ("LANE VOLUME" REPRESENTS THE MOVEMENT VOLUME DIVIDED BY THE NUMBER OF LANES SERVING IT.)
3. THE WIDTH OF THE ROAD IS CONSTRAINED SUCH THAT AN APPROACH LANE IS SHARED BY THE THROUGH AND LEFT-TURN MOVEMENTS YET THE LEFT-TURN VOLUME IS SUFFICIENT TO JUSTIFY A LEFT-TURN PHASE.
4. ONE OF THE TWO APPROACHES HAS HEAVY VOLUME, THE OTHER APPROACH HAS MINIMAL VOLUME, AND ACTUATED CONTROL IS USED. IN THIS SITUATION, THE PHASE ASSOCIATED WITH THE LOW-VOLUME APPROACH WOULD RARELY BE CALLED AND THE INTERSECTION WOULD FUNCTION MORE NEARLY AS A "T" INTERSECTION.
5. CRASH HISTORY INDICATES AN UNUSUALLY LARGE NUMBER OF SIDESWIPE OR HEAD-ON CRASHES IN THE MIDDLE OF THE INTERSECTION AND INVOLVING LEFT-TURNING VEHICLES."

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE - 2

FIGURE
4

V. REFERENCES

1. Alabama Department of Transportation, Traffic Signal Design Guide and Timing Manual, November 2007.

2. American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, Washington D.C. 2011.

3. Antonucci, N., Et. Al., Volume 12: A Guide for Reducing Collisions at Signalized Intersections, NCHRP Report 500. Transportation Research Board (TRB), National Research Council, Washington, DC. 2004.

4. Brehmer, C., Et. Al., Evaluation of Traffic Signal Displays for Protected/Permissive Left-Turn Control. NCHRP Report 493, TRB, National Research Council, Washington, DC. 2003.

5. Highway Capacity Manual. TRB, National Research Council, Washington D.C. 2010.

6. Kittelson & Associates, Inc., Signal Timing Manual, FHWA-HOP-08-024, Federal Highway Administration, Washington D.C., June 2008.

7. Manual on Uniform Traffic Devices for Streets and Highways, 2009 Edition. United States Department of Transportation, Federal Highway Administration, Washington D.C. 2003.

8. New York City Department of Transportation, New York City Department of Transportation Traffic Operations, 2006.

9. Pline, J. L. Left-Turn Treatments at Intersections. NCHRP Synthesis 225, TRB, National Research Council, Washington, DC. 1996.

10. Rodegerdts, L., Et. Al., Signalized Intersections: Informational Guide, FHWA-HRT-04-091, Federal Highway Administration, Washington D.C., August 2004.

11. Stamatiadis, N., Et. Al., Guidelines for Left-Turn Phasing Treatment. Transportation Research Record 1605. TRB, National Research Council, Washington D.C. 1997.

12. Tennessee Department of Transportation, Traffic Design Manual, March 2011.

13. Texas Department of Transportation, Development of Left-Turn Operations Guidelines at Signalized Intersections, March 2009.

14. Traffic Engineering Handbook 6th Edition. Institute of Transportation Engineers (ITE), Washington D.C. 2009.

APPENDICES

APPENDIX A

PAGE EXCERPTS FROM AASHTO GREEN BOOK

Table 9-14. Intersection Sight Distance—Case F, Left Turn from the Major Road

Metric				U.S. Customary			
Design Speed (km/h)	Stopping Sight Distance (m)	Intersection Sight Distance Passenger Cars Calculated (m)	Intersection Sight Distance Passenger Cars Design (m)	Design Speed (mph)	Stopping Sight Distance (ft)	Intersection Sight Distance Passenger Cars Calculated (ft)	Intersection Sight Distance Passenger Cars Design (ft)
20	20	30.6	35	15	80	121.3	125
30	35	45.9	50	20	115	161.7	165
40	50	61.2	65	25	155	202.1	205
50	65	76.5	80	30	200	242.6	245
60	85	91.7	95	35	250	283.0	285
70	105	107.0	110	40	305	323.4	325
80	130	122.3	125	45	360	363.8	365
90	160	137.6	140	50	425	404.3	405
100	185	152.9	155	55	495	444.7	445
110	220	168.2	170	60	570	485.1	490
120	250	183.5	185	65	645	525.5	530
130	285	198.8	200	70	730	566.0	570
—	—	—	—	75	820	606.4	610
—	—	—	—	80	910	646.8	650

Note: Intersection sight distance shown is for a passenger car making a left turn from an undivided highway. For other conditions and design vehicles, the time gap should be adjusted and the sight distance recalculated.

Case D—Intersections with Traffic Signal Control

At signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. Left-turning vehicles should have sufficient sight distance to select gaps in oncoming traffic and complete left turns. Apart from these sight conditions, there are generally no other approach or departure sight triangles needed for signalized intersections. Signalization may be an appropriate crash countermeasure for higher volume intersections with restricted sight distance that have experienced a pattern of sight-distance related crashes.

However, if the traffic signal is to be placed on two-way flashing operation (i.e., flashing yellow on the major-road approaches and flashing red on the minor-road approaches) under off-peak or nighttime conditions, then the appropriate departure sight triangles for Case B, both to the left and to the right, should be provided for the minor-road approaches. In addition, if right turns on a red signal are to be permitted from any approach, then the appropriate departure sight triangle to the left for Case B2 should be provided to accommodate right turns from that approach.

Case E—Intersections with All-Way Stop Control

At intersections with all-way stop control, the first stopped vehicle on one approach should be visible to the drivers of the first stopped vehicles on each of the other approaches. There are no other sight distance criteria applicable to intersections with all-way stop control and, indeed, all-way stop control may be the best option at a limited number of intersections where sight distance for other control types cannot be attained.

Case F—Left Turns from the Major Road

All locations along a major highway from which vehicles are permitted to turn left across opposing traffic, including intersections and driveways, should have sufficient sight distance to accommodate the left-turn maneuver. Left-turning drivers need sufficient sight distance to decide when to turn left across the lane(s) used by opposing traffic. Sight distance design should be based on a left turn by a stopped vehicle, since a vehicle that turns left without stopping would need less sight distance. The sight distance along the major road to accommodate left turns is the distance traversed at the design speed of the major road in the travel time for the design vehicle given in Table 9-13.

Table 9-13. Time Gap for Case F, Left Turns from the Major Road

Design Vehicle	Time Gap (t_g)(s) at Design Speed of Major Road
Passenger car	5.5
Single-unit truck	6.5
Combination truck	7.5

Note: *Adjustment for multilane highways*—For left-turning vehicles that cross more than one opposing lane, add 0.5 s for passenger cars and 0.7 s for trucks for each additional lane to be crossed.

The table also contains appropriate adjustment factors for the number of major-road lanes to be crossed by the turning vehicle. The unadjusted time gap in Table 9-13 for passenger cars was used to develop the sight distances in Table 9-14 and illustrated in Figure 9-21.

The intersection sight distance in both directions should be equal to the distance traveled at the design speed of the major road during a period of time equal to the time gap. In applying Table 9-5, it can usually be assumed that the minor-road vehicle is a passenger car. However, where substantial volumes of heavy vehicles enter the major road, such as from a ramp terminal, the use of tabulated values for single-unit or combination trucks should be considered.

Table 9-5 includes appropriate adjustments to the gap times for the number of lanes on the major road and for the approach grade of the minor road. The adjustment for the grade of the minor-road approach is needed only if the rear wheels of the design vehicle would be on an upgrade that exceeds 3 percent when the vehicle is at the stop line of the minor-road approach.

Table 9-5. Time Gap for Case B1, Left Turn from Stop

Design Vehicle	Time Gap (t_g)(s) at Design Speed of Major Road
Passenger car	7.5
Single-unit truck	9.5
Combination truck	11.5

Note: Time gaps are for a stopped vehicle to turn left onto a two-lane highway with no median and with grades of 3 percent or less. The table values should be adjusted as follows:

For multilane highways—For left turns onto two-way highways with more than two lanes, add 0.5 s for passenger cars or 0.7 s for trucks for each additional lane, from the left, in excess of one, to be crossed by the turning vehicle.

For minor road approach grades—If the approach grade is an upgrade that exceeds 3 percent, add 0.2 s for each percent grade for left turns.

The intersection sight distance along the major road (distance *b* in Figure 9-15B) is determined by:

Metric	U.S. Customary	
$ISD = 0.278\, V_{\text{major}}\, t_g$	$ISD = 1.47\, V_{\text{major}}\, t_g$	(9-1)
where:	where:	
ISD = intersection sight distance (length of the leg of sight triangle along the major road) (m)	ISD = intersection sight distance (length of the leg of sight triangle along the major road) (ft)	
V_{major} = design speed of major road (km/h)	V_{major} = design speed of major road (mph)	
t_g = time gap for minor road vehicle to enter the major road (s)	t_g = time gap for minor road vehicle to enter the major road (s)	

For example, a passenger car turning left onto a two-lane major road should be provided sight distance equivalent to a time gap of 7.5 s in major-road traffic. If the design speed of the major road is 100 km/h [60 mph], this corresponds to a sight distance of 0.278(100)(7.5) = 208.5 or 210 m [1.47(60)(7.5) = 661.5 or 665 ft], rounded for design.

A passenger car turning left onto a four-lane undivided roadway will need to cross two near lanes, rather than one. This increases the recommended gap in major-road traffic from 7.5 to 8.0 s. The corresponding value of sight distance for this example would be 223 m [706 ft]. If the minor-road approach to such an

APPENDIX B

NEW YORK CITY DEPARTMENT OF TRANSPORTATION LEFT-TURN WARRANTS

Sheet 1 of 6
7/11/06

NEW YORK CITY
DEPARTMENT OF TRANSPORTATION
TRAFFIC OPERATIONS

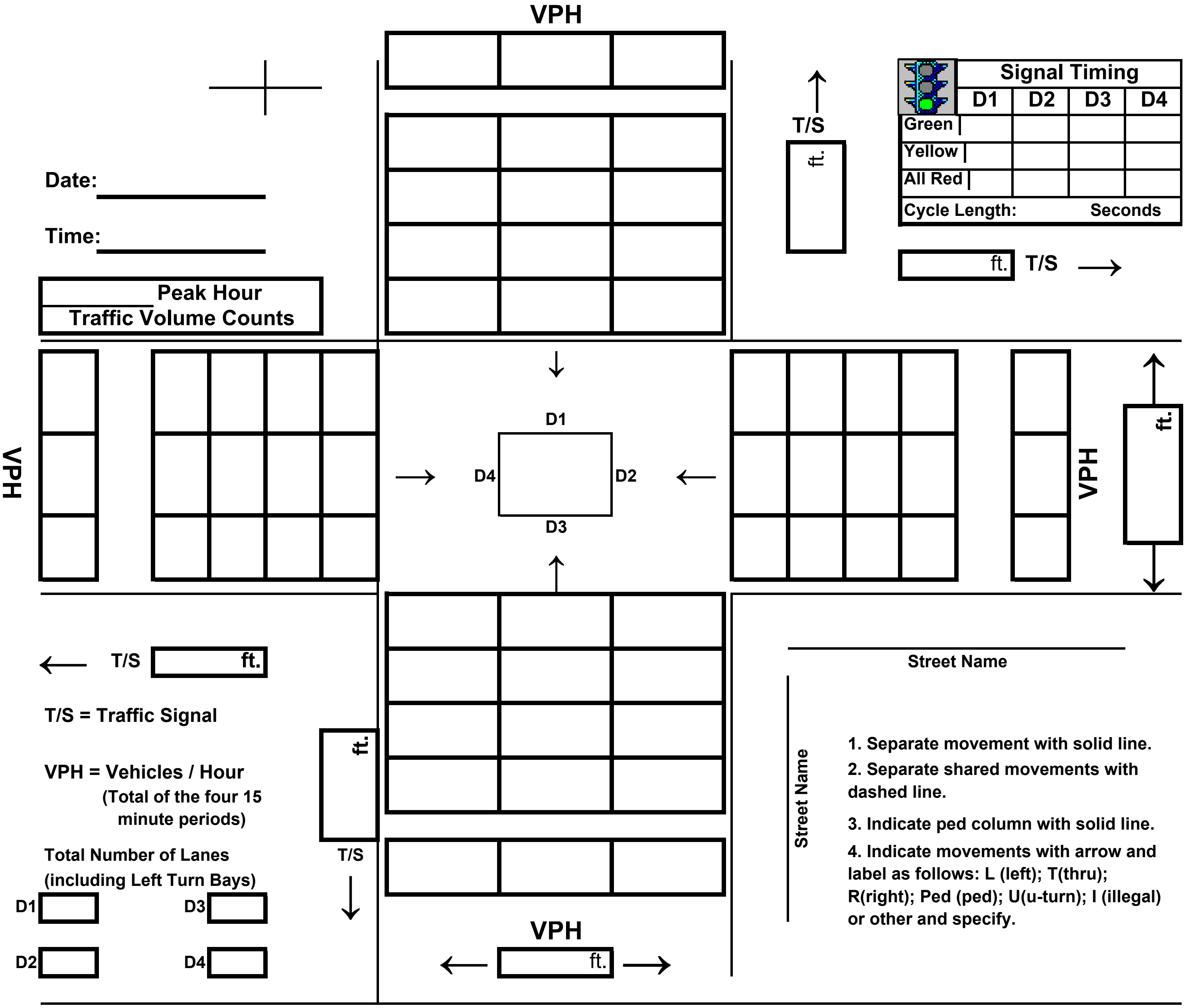
Left Turn Signal Survey Sheet

Borough: ______________________ **Log #:** __________ **Ref. #:** __________

Location: ______________________ **CB #:** __________

Requestor: ______________________ **Investigator:** ______________________

Date Completed: ______________________



Date: ______________

Time: ______________

Peak Hour Traffic Volume Counts

Signal Timing	D1	D2	D3	D4
Green				
Yellow				
All Red				
Cycle Length: Seconds				

T/S = Traffic Signal

VPH = Vehicles / Hour
(Total of the four 15 minute periods)

Total Number of Lanes (including Left Turn Bays)

D1 ☐ D3 ☐

D2 ☐ D4 ☐

1. Separate movement with solid line.
2. Separate shared movements with dashed line.
3. Indicate ped column with solid line.
4. Indicate movements with arrow and label as follows: L (left); T(thru); R(right); Ped (ped); U(u-turn); I (illegal) or other and specify.

Engineer: ______________________ **Date:** __________

Reviewed ☐ ______________________ **Date:** __________ **Satisfied** ☐

Recommended ☐ ______________________ **Date:** __________ **Warrant #** ☐

Denied ☐ ______________________ **Date:** __________ **Not Satisfied** ☐

NEW YORK CITY
DEPARTMENT OF TRANSPORTATION
TRAFFIC OPERATIONS

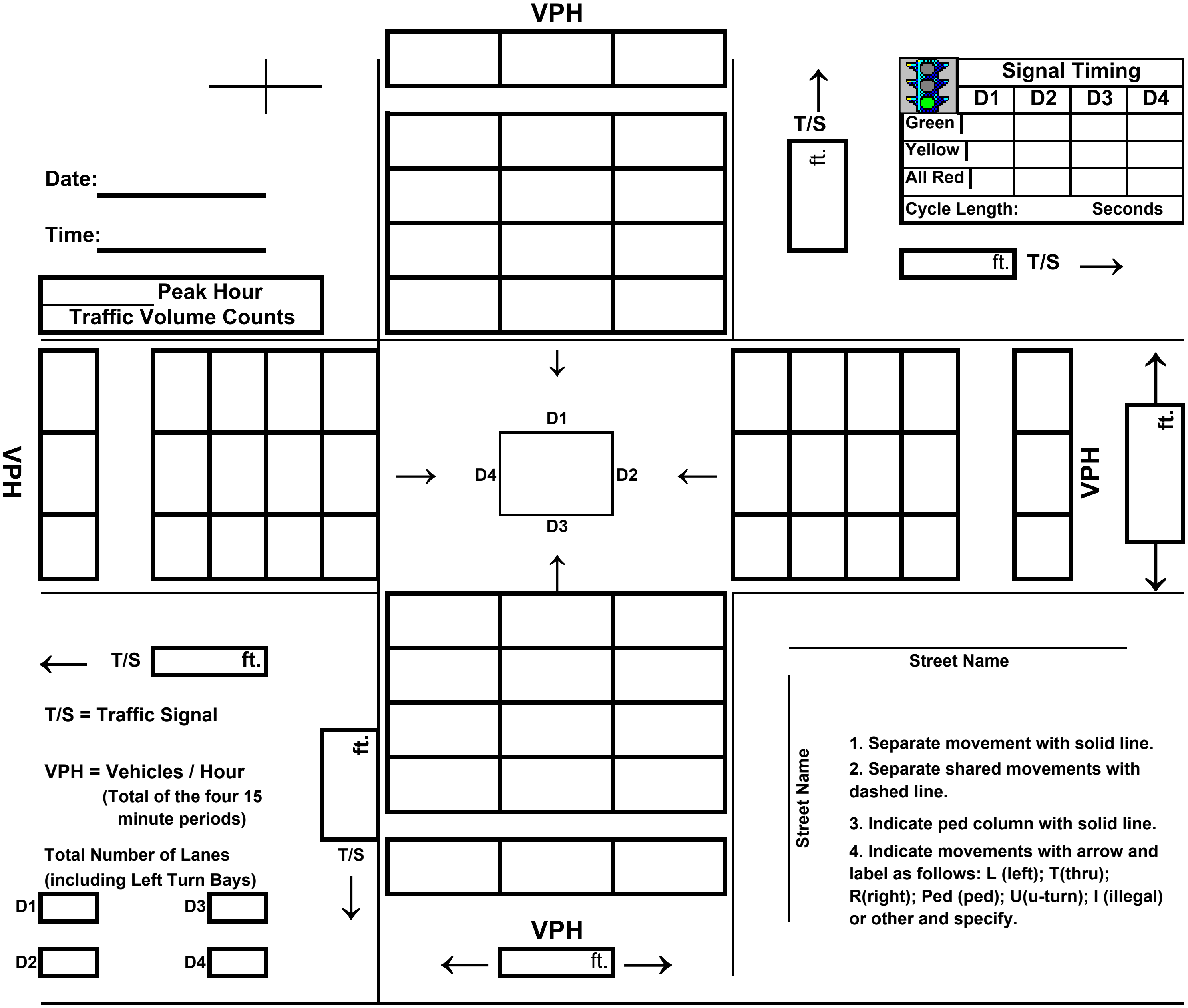
Left Turn Signal Survey Sheet

Borough: ____________________ **Log #:** __________ **Ref. #:** __________

Location: ____________________ **CB #:** __________

Requestor: ____________________ **Investigator:** ____________________

Date Completed: ____________________



	Signal Timing			
	D1	D2	D3	D4
Green				
Yellow				
All Red				
Cycle Length:			Seconds	

T/S = Traffic Signal

VPH = Vehicles / Hour
(Total of the four 15 minute periods)

Total Number of Lanes
(including Left Turn Bays)

D1 ☐ D3 ☐

D2 ☐ D4 ☐

1. Separate movement with solid line.
2. Separate shared movements with dashed line.
3. Indicate ped column with solid line.
4. Indicate movements with arrow and label as follows: L (left); T(thru); R(right); Ped (ped); U(u-turn); I (illegal) or other and specify.

Engineer: ____________________ **Date:** __________

Reviewed ☐ ____________________ **Date:** __________ **Satisfied** ☐

Recommended ☐ ____________________ **Date:** __________ **Warrant #** ☐

Denied ☐ ____________________ **Date:** __________ **Not Satisfied** ☐

NEW YORK CITY
DEPARTMENT OF TRANSPORTATION
TRAFFIC OPERATIONS

Left Turn Signal Warrant Sheet

WARRANT 1 (Accident Experience)

Satisfied ☐
Not Satisfied ☐

This Warrant is satisfied when a minimum of 5 related left turn accidents exist in the latest 12 month period in which accident records are available.

Year	Total Accidents	Left Turn Accidents

Accident sheets must be attached.

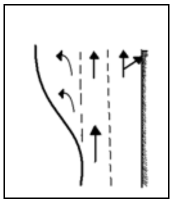
WARRANT 2 (Left Turn Capacity)

Satisfied ☐
Not Satisfied ☐

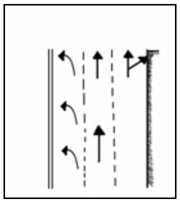
This Warrant is satisfied when for the analyzed direction the Left-Turn flow rate exceeds the left-turn capacity.
The left-turn capacity is the maximum flow rate that may be assigned to the designated phase.

- **On approaches with exclusive left-turn bays / lanes, the left-turn capacity is computed by using the following equations:**

(1A) $\boxed{C_{ELT} = (1{,}400 - V_O)\ (g/c)_{LT}}$



Exclusive Left-Turn Bay



Exclusive Left –Turn Lane

Or

(2) $\boxed{C_{ELT} = 2 \text{ vehicles per signal cycle}}$

where:

C_{ELT} = capacity of the left-turn protected / permitted phase, in vph;

V_O = opposing thru plus right-turn service flow rate*, in vph, and

$(g/c)_{LT}$ = effective green** ratio for the protected / permitted phase, in seconds.

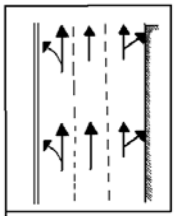
*Service flow rate is the equivalent hourly rate at which vehicles pass a roadway during a given time interval less than one hour, usually 15 minutes.

Service flow rate = (highest 15 minute count) x 4.

**Effective green time is the time during a given phase that is effectively available to the permitted movements: this is generally taken to be the green time (G) plus the change interval (Y + AR) minus the lost time (3.0 seconds) for the designated phase.

On approaches with shared left-turn and thru vehicles, the left-turn capacity is computed by using the following equations:

$$(1B)\quad \boxed{C_{SLT} = [\,(1{,}400 - V_O)\,(g/c)_{LT}\,]\,f_{SLT}}$$



Shared Lanes

Or

$$(2)\quad \boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

where:

C_{SLT} = capacity of the left-turn in the shared lane, in vph:

f_{SLT} = adjustment factor for left-turn vehicles

The adjustment factor basically accounts for the fact that the left-turn movements cannot be made at the same saturation flow rates as thru movements. They consume more of the available green time, and consequently, more of the intersection's available capacity.

The adjustment factor is computed as the ratio of the left-turn flow rate (which is converted to an approximate equivalent flow of thru vehicles) to the thru vehicles that share the same lane.

The following TABLE 1 may be used to convert the left-turn vehicles to equivalent thru vehicles.

TABLE 1

TOTAL OPPOSING FLOW RATE (V_O)	CONVERSION FACTOR (f_{pce})	TOTAL OPPOSING FLOW RATE (V_O)	CONVERSION FACTOR (f_{pce})
0 – 200	1.50	1001 – 1050	5.00
201 - 500	2.00	1051 – 1075	5.50
501 – 700	2.50	1076 – 1100	6.00
701 – 800	3.00	1101 – 1125	6.50
801 – 900	3.50	1126 – 1145	7.00
901 – 950	4.00	> 1146*	
951 - 1000	4.50		

*Use exclusive Left-Turn lane procedure.

Comments:____

COMPUTATIONS

EXCLUSIVE LEFT-TURN LANE

Opposing Thru Plus Right Turn Service Flow Rate

V_O = (highest 15 minute count) x 4

$V_O = \boxed{}$ x 4 = $\boxed{}$ vph

Left Turn Service Flow Rate (Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

$V_{LT} = \boxed{}$ x 4 = $\boxed{}$ vph

Left Turn Capacity

$$\boxed{C_{ELT} = (1{,}400 - V_O)\,(g/c)_{LT}}$$

where:

$g = [\,G + Y + AR - 3.0\,] \times f_q{}^{*} = \boxed{} \times \boxed{} = \boxed{}$ seconds

* Adjustment factor used to calculate the portion of the green phase that is <u>not</u> blocked by an opposing queue of vehicles. The fq factor is given for each case in TABLE 2.

c = cycle length = $\boxed{}$ seconds

thus, $(g/c)_{LT} = \boxed{}$

TABLE 2

OPPOSING THRU LANES	f_q
1	.85
2	.90
$\geq$ 3	.95

and

$C_{ELT} = (1400 - \boxed{}\,)\,(\,\boxed{}\,)_{LT} = \boxed{}$ vph

or

$$\boxed{C_{ELT} = 2 \text{ vehicles per signal cycle}}$$

$C_{ELT} = 2 \times (3600 \div C) = \boxed{}$ vph

V_{LT}= vph	>	or	<	$C_{ELT}{}^{**}$ = vph

**Select the highest left turn capacity

- If V_{LT} (Left turn service flow rate) is greater than (>) the C_{ELT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.
- If V_{LT} is less then (<) the C_{ELT} the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

COMPUTATIONS
SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

$V_O = \boxed{}$ x 4 = $\boxed{}$ vph

Using TABLE 1, $f_{PCE} = \boxed{}$

$V_{TV} = \boxed{}$ x 4 = $\boxed{}$ vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

$V_{LT} = \boxed{}$ x 4 = $\boxed{}$ vph

$V_{PCE} = V_{LT} \times f_{PCE} = \boxed{} \times \boxed{} = \boxed{}$ vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE}) = \boxed{} \div (\boxed{} + \boxed{}) = \boxed{}$

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
2	.90
≥ 3	.95

Left Turn Capacity

$$\boxed{C_{SLT} = [(1,400 - V_O) (g/c)_{LT}] \; f_{SLT}}$$

where:

$g = [G + Y + AR - 3.0] \times f_q = \boxed{} \times \boxed{} = \boxed{}$ seconds

c = cycle length = $\boxed{}$ seconds

thus, $(g/c)_{LT} = \boxed{}$

and $C_{SLT} = [(1400 - \boxed{}) (\boxed{})_{LT}] \times \boxed{} = \boxed{}$ vph

or

$$\boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

$C_{SLT} = 2 \times (3600 \div C) = \boxed{}$ vph

$\boxed{V_{LT} = \text{vph}}$ $\boxed{>}$ or $\boxed{<}$ $\boxed{C_{SLT}{}^{*} = \text{vph}}$

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.
-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

APPENDIX C

CASE STUDIES

1. CASE STUDY: KAPIOLANI BOULEVARD AND KAMAKEE STREET

Existing Conditions

At the intersection of Kapiolani Boulevard and Kamakee Street the westbound left-turn from Kapiolani Boulevard to Kamakee Street operates as permissive phasing with a shared left-turn through lane. During the AM peak hour, Kapiolani Boulevard operates with a contraflow lane, resulting in four lanes traveling westbound towards Downtown and two lanes traveling eastbound. During the PM peak hour, contra-flow lanes are set up on the east side of the intersection and the westbound left-turn movement from Kapiolani Boulevard to Kamakee Street is prohibited. See Exhibit C1-1 and Exhibit 1-2 for the existing intersection layout during AM and PM peak hours, respectively.

Traffic Observations & Analysis

The flow of traffic along Kapiolani Boulevard is relatively consistent between the AM and PM peak hours of traffic. There was observed to be sufficient gaps in the eastbound through traffic for westbound left-turning vehicles to complete the movement during the AM peak hour. However, queues of 3-4 vehicles or more often develop as a result of platooned arrivals. Traffic counts indicate that approximately 300 westbound vehicles turn left during the AM peak hour and approximately 6 vehicles turn left illegally during the PM peak hour. This movement operates adequately at LOS C during the AM peak hour of traffic.

See Table C1-1 for a summary of the LOS analysis results.

Conclusions

See Table C1-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

Westbound Approach

The existing permissive left-turn phasing for the westbound approach is acceptable. Although the westbound approach currently does not include a dedicated left-turn lane and installing one would be infeasible, the left-turn movement operates adequately and crash history thresholds are not met; therefore, the existing permissive phasing appears to be appropriate.

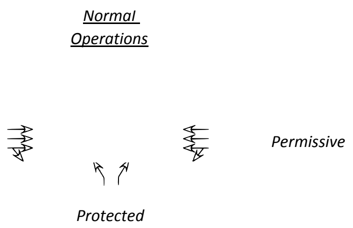
Table C1-1: Level of Service Summary Table

Intersection	Existing Conditions					
	AM			PM		
	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
1. Kapiolani Boulevard/Kamakee Street						
NB LT	37.7	0.18	D	42.3	0.43	D
NB RT	38.1	0.19	D	73.0	0.91	E
EB TH	9.6	0.35	A	10.6	0.49	B
EB TH/RT	9.5	0.35	A	11.3	0.49	B
WB TH	12.1	0.64	B	10.2	0.48	B
WB LT/TH	30.7	0.76	C	-	-	-
Overall	14.5	-	B	18.6	-	B

Table C1-2: Left-Turn Warrant Guidelines
Kapiolani Boulevard & Kamakee Street
Westbound (Kapiolani Boulevard)

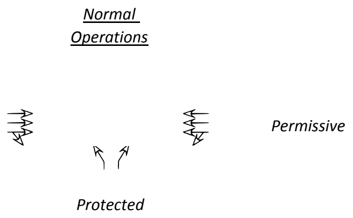
No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Kapiolani Boulevard.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	No.	
b)	**<u>If answer to 2a is "No":</u> Should a left-turn lane be installed?**	No. *Option not feasible due to the eastbound and westbound contraflow conditions during the AM and PM peaks.*	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A. *In lieu of left-turn lane.*	
3b.	**If <u>No</u> Exclusive Left-Turn Lane Exists (If answer to 2a <u>AND</u> 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**		
	Crash History	No. *7 westbound left-turn related crashes in 4 years.*	Maintain existing permissive phasing.
	Operational	No. *Left-turn movement operates adequately at LOS C(B) during AM(PM) peak hours.*	
ii)	**<u>If answer to 3bi is "Yes" for Operational:</u> NYDOT shared left-turn lane warrant satisfied?**	N/A.	
4.	**Recommendation & Discussion**		
	Maintain existing permissive phasing.		

Existing Lane Diagram/Left-Turn Phasing

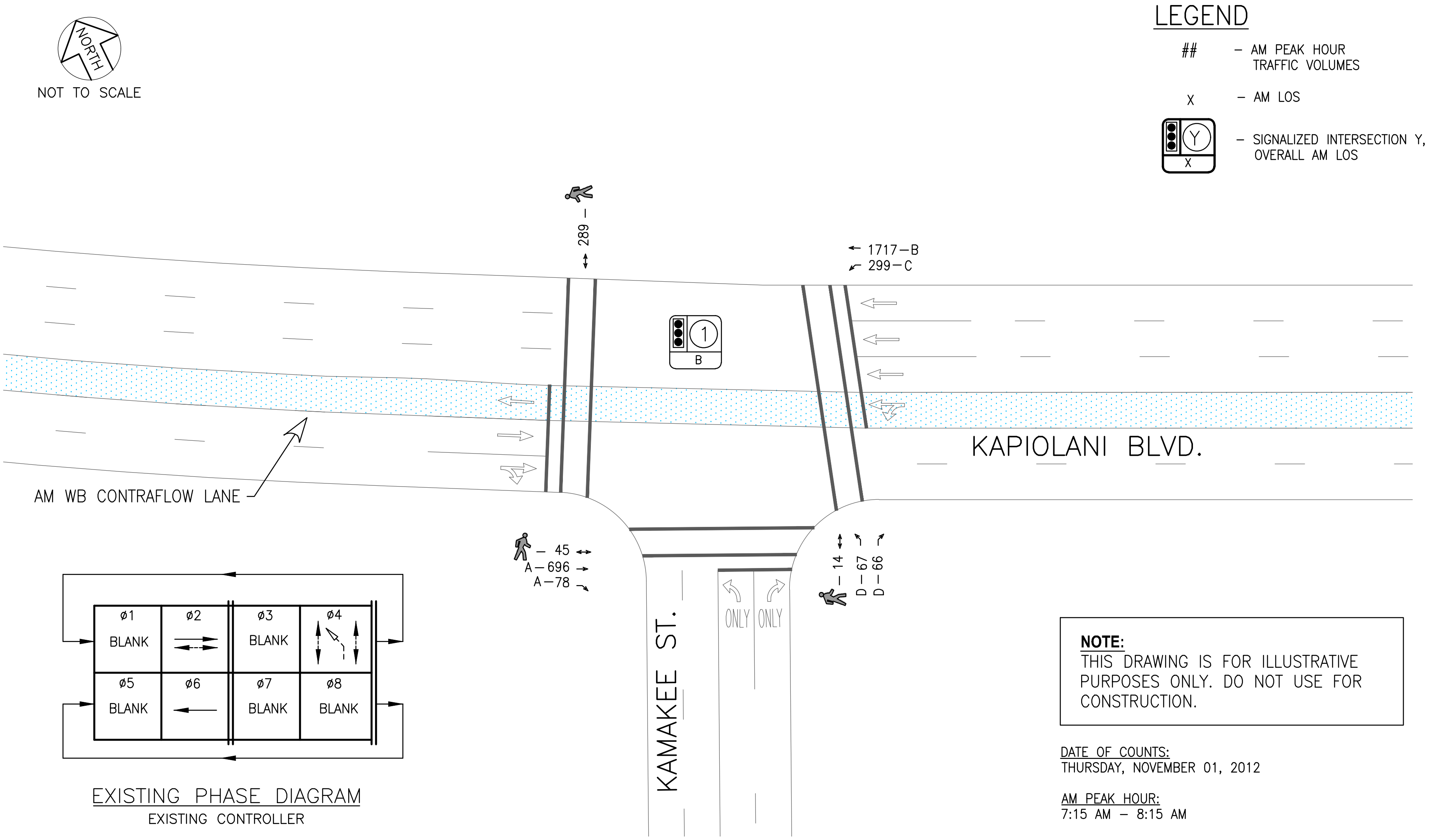


Note: AM contraflow includes 3 westbound through lanes and 1 shared left-turn/through lane. PM contraflow includes 3 eastbound through lanes and 1 shared through/right-turn lane with westbound left-turns banned.

Recommended Lane Diagram/Left-Turn Phasing



Note: AM contraflow includes 3 westbound through lanes and 1 shared left-turn/through lane. PM contraflow includes 3 eastbound through lanes and 1 shared through/right-turn lane with westbound left-turns banned.



EXISTING PHASE DIAGRAM
EXISTING CONTROLLER

NOTE:
THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. DO NOT USE FOR CONSTRUCTION.

DATE OF COUNTS:
THURSDAY, NOVEMBER 01, 2012

AM PEAK HOUR:
7:15 AM – 8:15 AM

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

EXISTING AM PEAK HOUR LANE CONFIGURATION, VOLUME AND LOS

EXHIBIT
C1-1

LEGEND

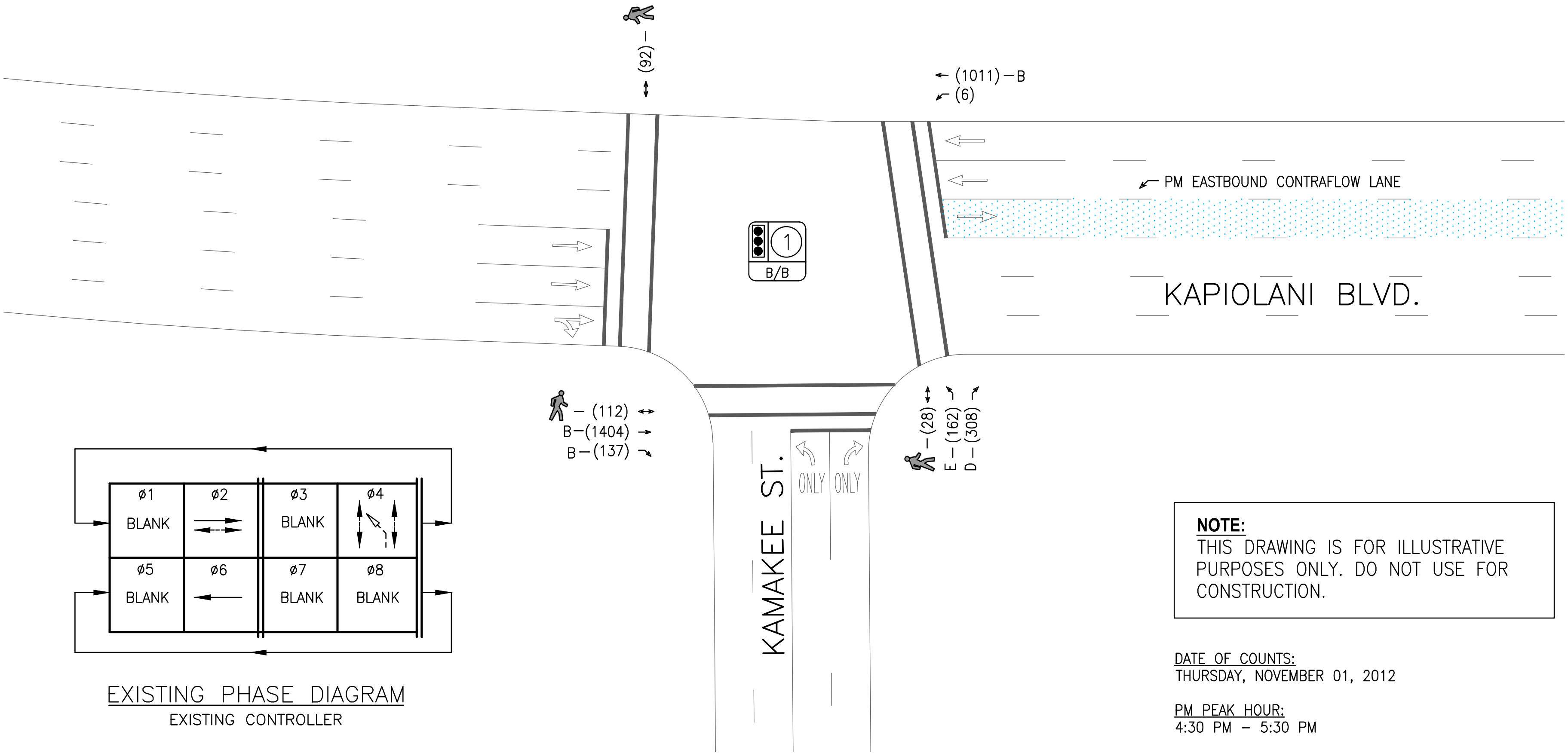
(##) – (PM) PEAK HOUR OF TRAFFIC VOLUMES

(X) – (PM) LOS

Y / X – SIGNALIZED INTERSECTION Y, OVERALL PM LOS

NORTH

NOT TO SCALE



ø1 BLANK	ø2	ø3 BLANK	ø4
ø5 BLANK	ø6	ø7 BLANK	ø8 BLANK

EXISTING PHASE DIAGRAM

EXISTING CONTROLLER

NOTE:
THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. DO NOT USE FOR CONSTRUCTION.

DATE OF COUNTS:
THURSDAY, NOVEMBER 01, 2012

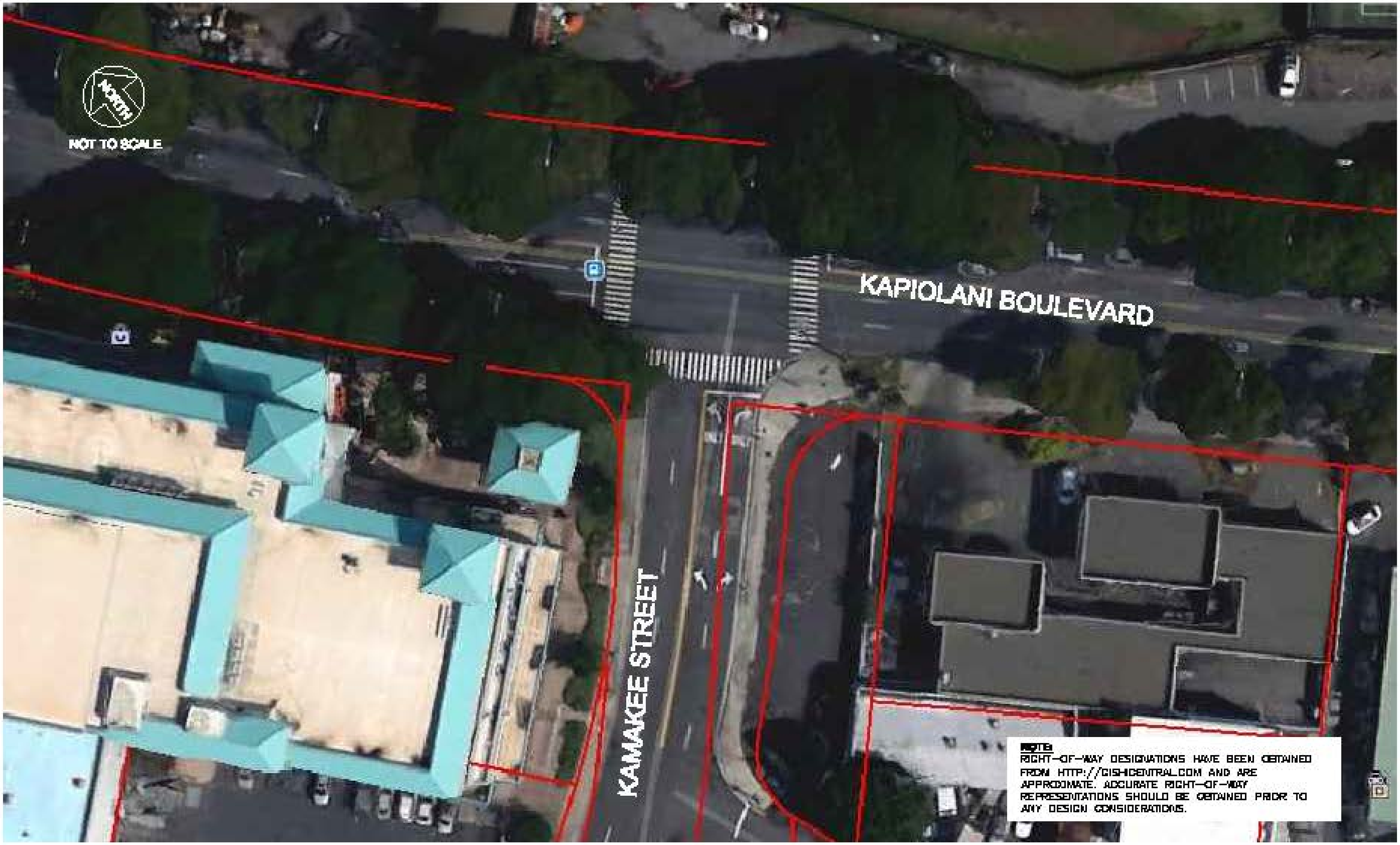
PM PEAK HOUR:
4:30 PM – 5:30 PM

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

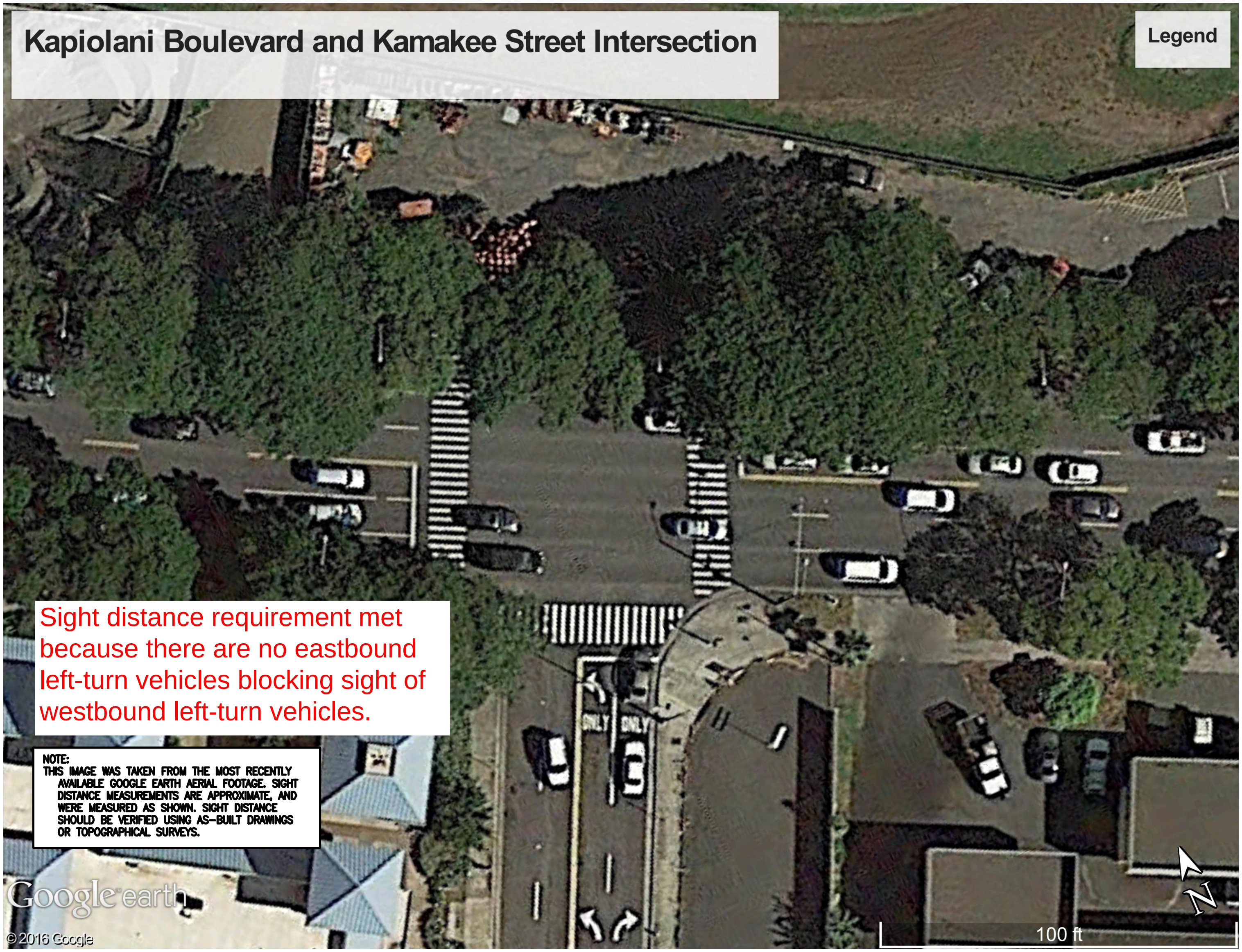
EXISTING PM PEAK HOUR LANE CONFIGURATION, VOLUME AND LOS

EXHIBIT
C1–2



NOTE:
RIGHT-OF-WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT-OF-WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR LEFT-TURN SIGNAL PHASING GUIDELINES	AUSTIN, TSUTSUMI & ASSOCIATES, INC. ENGINEERS, SURVEYORS • HONOLULU, HAWAII	EXHIBIT
	G.I.S. APPROXIMATE RIGHT-OF-WAY BOUNDARIES	C1-3



Kapiolani Boulevard and Kamakee Street Intersection

Sight distance requirement met because there are no eastbound left-turn vehicles blocking sight of westbound left-turn vehicles.

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

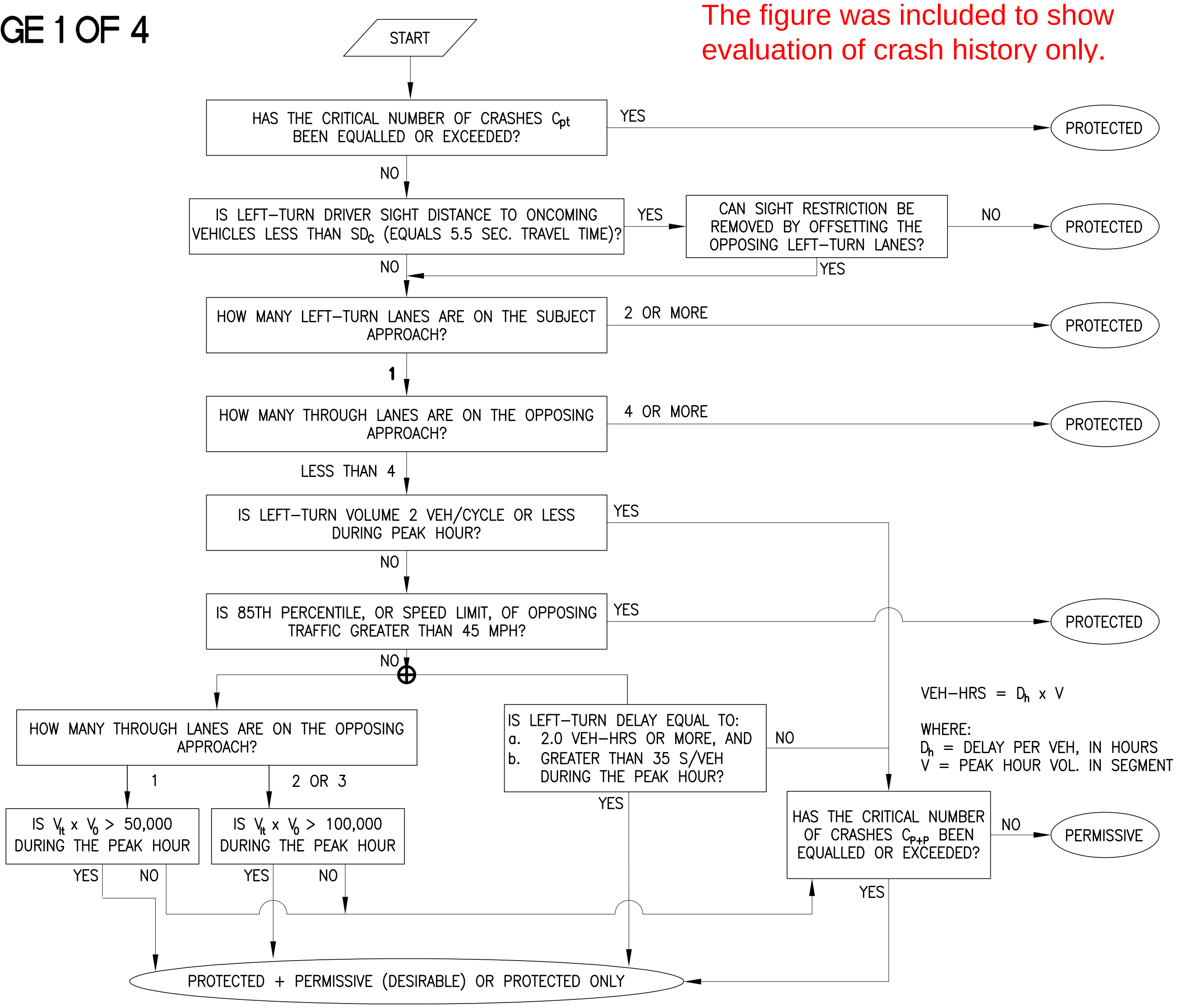
SIGHT DISTANCE ANALYSIS

EXHIBIT
C1-4

Kapiolani Boulevard/Kamakee Street Intersection

PAGE 1 OF 4

The figure was included to show evaluation of crash history only.



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	2
ONE	2	11	6	4
ONE	3	14	7	6
BOTH	1	11	6	
BOTH	2	18	9	
BOTH	3	26	13	

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

PAGE 3 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT–TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT–TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT–TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE–RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT–TURN ARROW.

SPECIAL CASE: SHARED LEFT–TURN/THROUGH LANE (Westbound Approach)

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED–ONLY LEFT–TURN PHASING WHERE LEFT–TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT–TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE–ONLY LEFT–TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT–TURN PHASES FOR SHARED LEFT–TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT–TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT–TURN LANE:

- **IF A DEDICATED LEFT–TURN LANE CAN BE FEASIBLY CONSTRUCTED,** UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT–TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT–TURN LANE,** CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT–TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT–TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:

    See Fig 1
    Does not meet
    - THE LEFT–TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT–TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT–TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT–TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT–TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT–TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT–TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.

    WB: Operations
    Acceptable
    - WHERE THE OPPOSING LANES (TO THE LEFT–TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT–TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT–TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE – 1

FIGURE
3

PAGE 4 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED-ONLY LEFT-TURN PHASING

WHEN CONSIDERING INSTALLING PROTECTED-ONLY PHASING, DETERMINE THE IMPACT OF ROADWAY GEOMETRICS ON THE OPERATIONS OF THE INTERSECTION. MORE SPECIFICALLY:

1. PROTECTED-ONLY LEFT-TURN PHASING MAY INCREASE THE QUEUE LENGTHS FOR THE LEFT-TURN MOVEMENTS DUE TO THE MORE FINITE GREEN TIME DURING WHICH LEFT-TURNS CAN BE MADE. THEREFORE, CARE SHOULD BE TAKEN TO INCREASE THE STORAGE LENGTHS WHERE POSSIBLE AND DEEMED NECESSARY.
2. IF IMPLEMENTING PROTECTED-ONLY LEFT-TURN PHASING IS ANTICIPATED TO INCREASE QUEUE LENGTHS TO BEYOND THE AVAILABLE MEDIAN STORAGE LENGTH (AND DECELERATION LENGTH, WHERE APPLICABLE), THE POTENTIAL FOR REAR-END COLLISIONS MAY INCREASE AND SHOULD BE CONSIDERED.
3. DETERMINE IF THE STORAGE LENGTH IS ADEQUATE FOR PROPER OPERATION OF LOOP DETECTORS (OR OTHER SENSOR TYPES).
4. IF THE ENGINEER IS UNABLE TO ASSESS THESE IMPACTS, A TRAFFIC STUDY SHOULD BE PREPARED.

SPLIT PHASING

ACCORDING TO THE TRAFFIC SIGNAL TIMING MANUAL, "SPLIT PHASING MAY BE HELPFUL IF ANY OF THE FOLLOWING CONDITIONS ARE PRESENT:

1. THERE IS A NEED TO ACCOMMODATE ONE OR MORE LEFT-TURN LANES ON EACH APPROACH, BUT SUFFICIENT WIDTH IS NOT AVAILABLE TO ENSURE ADEQUATE SEPARATION IN THE MIDDLE OF THE INTERSECTION. THIS PROBLEM MAY ALSO BE CAUSED BY A LARGE INTERSECTION SKEW ANGLE.
2. THE LARGER LEFT-TURN LANE VOLUME IS EQUAL TO ITS OPPOSING THROUGH LANE VOLUME DURING MOST HOURS OF THE DAY ("LANE VOLUME" REPRESENTS THE MOVEMENT VOLUME DIVIDED BY THE NUMBER OF LANES SERVING IT.)
3. THE WIDTH OF THE ROAD IS CONSTRAINED SUCH THAT AN APPROACH LANE IS SHARED BY THE THROUGH AND LEFT-TURN MOVEMENTS YET THE LEFT-TURN VOLUME IS SUFFICIENT TO JUSTIFY A LEFT-TURN PHASE.
4. ONE OF THE TWO APPROACHES HAS HEAVY VOLUME, THE OTHER APPROACH HAS MINIMAL VOLUME, AND ACTUATED CONTROL IS USED. IN THIS SITUATION, THE PHASE ASSOCIATED WITH THE LOW-VOLUME APPROACH WOULD RARELY BE CALLED AND THE INTERSECTION WOULD FUNCTION MORE NEARLY AS A "T" INTERSECTION.
5. CRASH HISTORY INDICATES AN UNUSUALLY LARGE NUMBER OF SIDESWIPE OR HEAD-ON CRASHES IN THE MIDDLE OF THE INTERSECTION AND INVOLVING LEFT-TURNING VEHICLES."

Westbound approach: Not recommended due to heavy and balanced through volumes. Going to split phase would adversely affect Kapiolani Boulevard.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE - 2

FIGURE
4

HCM 2010 Signalized Intersection Summary
3: Kamakee St & Kapiolani Blvd

8/30/2016

	→	↘	↙	←	↖	↗
Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱			↰↑↑↑	↰	↱
Traffic Volume (veh/h)	696	78	299	1717	67	66
Future Volume (veh/h)	696	78	299	1717	67	66
Number	2	12	1	6	7	14
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00	1.00		1.00	1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1900	1900	1863	1863	1863
Adj Flow Rate, veh/h	757	85	325	1866	73	72
Adj No. of Lanes	2	0	0	4	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2
Cap, veh/h	2139	240	427	2916	414	369
Arrive On Green	0.67	0.67	0.67	0.67	0.23	0.23
Sat Flow, veh/h	3302	360	550	4611	1774	1583
Grp Volume(v), veh/h	417	425	325	1866	73	72
Grp Sat Flow(s),veh/h/ln	1770	1799	550	1458	1774	1583
Q Serve(g_s), s	12.3	12.4	52.2	29.8	3.9	4.4
Cycle Q Clear(g_c), s	12.3	12.4	64.6	29.8	3.9	4.4
Prop In Lane		0.20	1.00		1.00	1.00
Lane Grp Cap(c), veh/h	1180	1199	427	2916	414	369
V/C Ratio(X)	0.35	0.35	0.76	0.64	0.18	0.19
Avail Cap(c_a), veh/h	1180	1199	427	2916	414	369
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	8.7	8.7	22.8	11.6	36.8	36.9
Incr Delay (d2), s/veh	0.8	0.8	7.8	0.5	0.9	1.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.3	6.4	10.2	12.1	2.0	2.0
LnGrp Delay(d),s/veh	9.6	9.5	30.7	12.1	37.7	38.1
LnGrp LOS	A	A	C	B	D	D
Approach Vol, veh/h	842			2191	145	
Approach Delay, s/veh	9.6			14.9	37.9	
Approach LOS	A			B	D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		86.0		34.0		86.0		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		80.0		28.0		80.0		
Max Q Clear Time (g_c+I1), s		14.4		6.4		66.6		
Green Ext Time (p_c), s		52.0		0.4		12.7		

Intersection Summary	
HCM 2010 Ctrl Delay	14.5
HCM 2010 LOS	B

HCM 2010 Signalized Intersection Summary
3: Kamakee St & Kapiolani Blvd

	→	↘	↙	←	↖	↗
Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↑↱			↑↑	↰	↱
Traffic Volume (veh/h)	1404	137	6	1011	162	308
Future Volume (veh/h)	1404	137	6	1011	162	308
Number	2	12	1	6	7	14
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00	1.00		1.00	1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1900	1900	1863	1863	1863
Adj Flow Rate, veh/h	1526	149	7	1099	176	335
Adj No. of Lanes	3	0	0	2	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2
Cap, veh/h	3141	307	34	2290	414	369
Arrive On Green	0.67	0.67	0.67	0.67	0.23	0.23
Sat Flow, veh/h	4880	460	6	3519	1774	1583
Grp Volume(v), veh/h	1098	577	589	517	176	335
Grp Sat Flow(s),veh/h/ln	1695	1782	1830	1610	1774	1583
Q Serve(g_s), s	19.2	19.2	0.0	18.9	10.1	24.7
Cycle Q Clear(g_c), s	19.2	19.2	18.5	18.9	10.1	24.7
Prop In Lane		0.26	0.01		1.00	1.00
Lane Grp Cap(c), veh/h	2260	1188	1251	1074	414	369
V/C Ratio(X)	0.49	0.49	0.47	0.48	0.43	0.91
Avail Cap(c_a), veh/h	2260	1188	1251	1074	414	369
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	9.9	9.9	9.7	9.8	39.2	44.7
Incr Delay (d2), s/veh	0.7	1.4	0.3	0.3	3.2	28.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	9.1	9.8	9.6	8.4	5.4	13.7
LnGrp Delay(d),s/veh	10.6	11.3	10.0	10.2	42.3	73.0
LnGrp LOS	B	B	B	B	D	E
Approach Vol, veh/h	1675			1106	511	
Approach Delay, s/veh	10.8			10.1	62.5	
Approach LOS	B			B	E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		86.0		34.0		86.0		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		80.0		28.0		80.0		
Max Q Clear Time (g_c+I1), s		21.2		26.7		20.9		
Green Ext Time (p_c), s		40.2		0.3		40.3		

Intersection Summary	
HCM 2010 Ctrl Delay	18.6
HCM 2010 LOS	B

2. CASE STUDY: WAIMANO HOME ROAD AND MOANALUA ROAD AND KUALA STREET

Existing Conditions

At the intersection of Moanalua Road, Kuala Street, and Waimano Home Road, the eastbound and westbound approaches operate as split phasing, the southbound left-turn operates as protected/permissive phasing, and the northbound left-turn operates as permissive-only. All approaches provide exclusive left-turn lanes.

Traffic counts were taken in October, 2012 – prior to the construction of a new dedicated northbound left-turn lane. However, field observations were taken in August, 2016. It should be noted that although a northbound protected + permissive phase has been constructed, it has not yet been implemented.

Traffic Observations & Analysis

The operations at this intersection are complex given that Moanalua Road and signalized Noelani Street are only separated by 100 feet and operate as a single clustered intersection. The signal phasing at this intersection is designed to allow two-step maneuvers between Noelani Street and Moanalua Road.

The current split-phase operations along Moanalua Road and Kuala Street appear to be inefficient and a long cycle length is required to accommodate all of the phases. Due to the long cycle lengths, queues extend in all directions. The eastbound through/right-turn movement in particular operates at LOS F with overcapacity conditions during both AM and PM peak hours of traffic. Many movements on the eastbound and westbound approaches also operate with LOS F conditions during the AM and PM peak hours of traffic.

The northbound and southbound approaches also experience queuing issues during both AM and PM peak hours of traffic. The northbound approach operates at LOS E(F) during the AM(PM) peak hour of traffic. Although some movements on the southbound approach operate at LOS A during AM and PM peak hours of traffic, this is likely a result of the clustered intersection operations which effectively clears traffic on the approach in tandem with the adjacent Noelani Street intersection. The heavy southbound left-turn movement operates at LOS E during the AM peak hour of traffic.

See Table C2-1 for a summary of the existing LOS analysis results.

Conclusions

See Table C2-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

<u>Northbound/Southbound</u>

The existing protected + permissive left-turn phasing should be maintained for the southbound approach. Protected + permissive left-turn phasing should be implemented for the northbound approach. Care should be taken as not to allow the southbound through movement queue to stack up during Noelani Street's east-west phase.

Eastbound/Westbound

Protected-only left-turn phasing should be implemented for the eastbound and westbound directions provided that the roadway geometry can accommodate it.

If the traffic signal phasing is modified, the traffic signal timing throughout the corridor should be optimized with the goal of reducing this intersection's cycle length and determining whether or not uncoordinated operations could be beneficial to reduce wasted green time.

See Table C2-1 for a summary of the LOS analysis results for the proposed left-turn phasing scenario.

Table C2-1: Level of Service Summary Table

Intersection	Existing Conditions						Proposed Conditions					
	AM			PM			AM			PM		
	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
2. Moanalua Road/Kuala Street/Waimano Home Road												
NB LT	67.2	0.71	E	114.7	0.89	F	90.0	0.87	F	125.0	0.93	F
NB TH/RT	73.3	0.86	E	161.4	1.11	F*	69.8	0.83	E	67.2	0.62	E
EB LT	61.3	0.58	E	54.2	0.31	D	97.5	0.61	F	108.5	0.65	F
EB TH/RT	173.4	1.22	F*	130.8	1.13	F*	83.1	0.98	F	122.8	1.11	F*
EB RT	86.8	0.17	F	56.7	0.48	E	76.0	0.17	E	56.0	0.47	E
WB LT	49.4	0.17	D	84.6	0.71	F	45.2	0.15	D	82.1	0.71	F
WB TH/RT	53.1	0.53	D	62.1	0.35	E	53.1	0.53	D	61.6	0.35	E
SB LT	60.6	0.82	E	8.7	0.41	A	60.5	0.82	E	9.8	0.41	A
SB TH/RT	2.5	0.57	A	0.5	0.37	A	9.6	0.63	A	4.3	0.40	A
Overall	63.6	0.91	E	86.7	0.85	F	54.3	0.88	D	71.7	0.81	E

Table C2-2: Left-Turn Warrant Guidelines for Case Study Summary

Waimano Home Road & Moanalua Road/Kuala Street

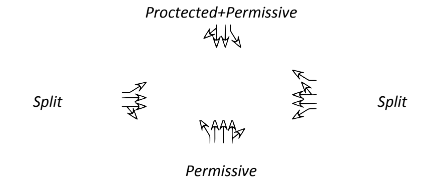
North-South (Waimano Home Road)

No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced. Going to split-phase would increase the cycle length and decrease the efficiency of the intersection.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	Yes. *It should be noted that subsequent to data collection, a dedicated northbound left-turn lane was constructed. Although it has been designed, the nrothbound protected-permissive phase has not yet been activated.*	
b)	**<u>If answer to 2a is "No":</u>** **Should a left-turn lane be installed?**	N/A.	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	Northbound & Southbound - Protected+Permissive (Desirable) or Protected Only Phasing.	Northbound - Implement Protected + Permissive phasing. Southbound - Maintain Protected + Permissive phasing.
3b.	**If <u>No</u> Exclusive Left-Turn Lane Exists (If answer to 2a <u>AND</u> 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History		
	Operational		
ii)	**<u>If answer to 3bi is "Yes" for Operational:</u>** **NYDOT shared left-turn lane**	N/A.	
4.	**Recommendation & Discussion**		
	Maintain Southbound Protected+Permissive Phasing for southbound approach. Implement the already-constructed Protected+Permissive Phasing for the northbound approach. Optimize the timings at this intersection to ensure that the northbound left-turn phase is short enough as not to cause overflow conditions in the southbound through movement.		

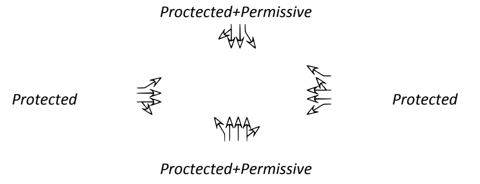
East-West (Moanalua Road/Kuala Street)

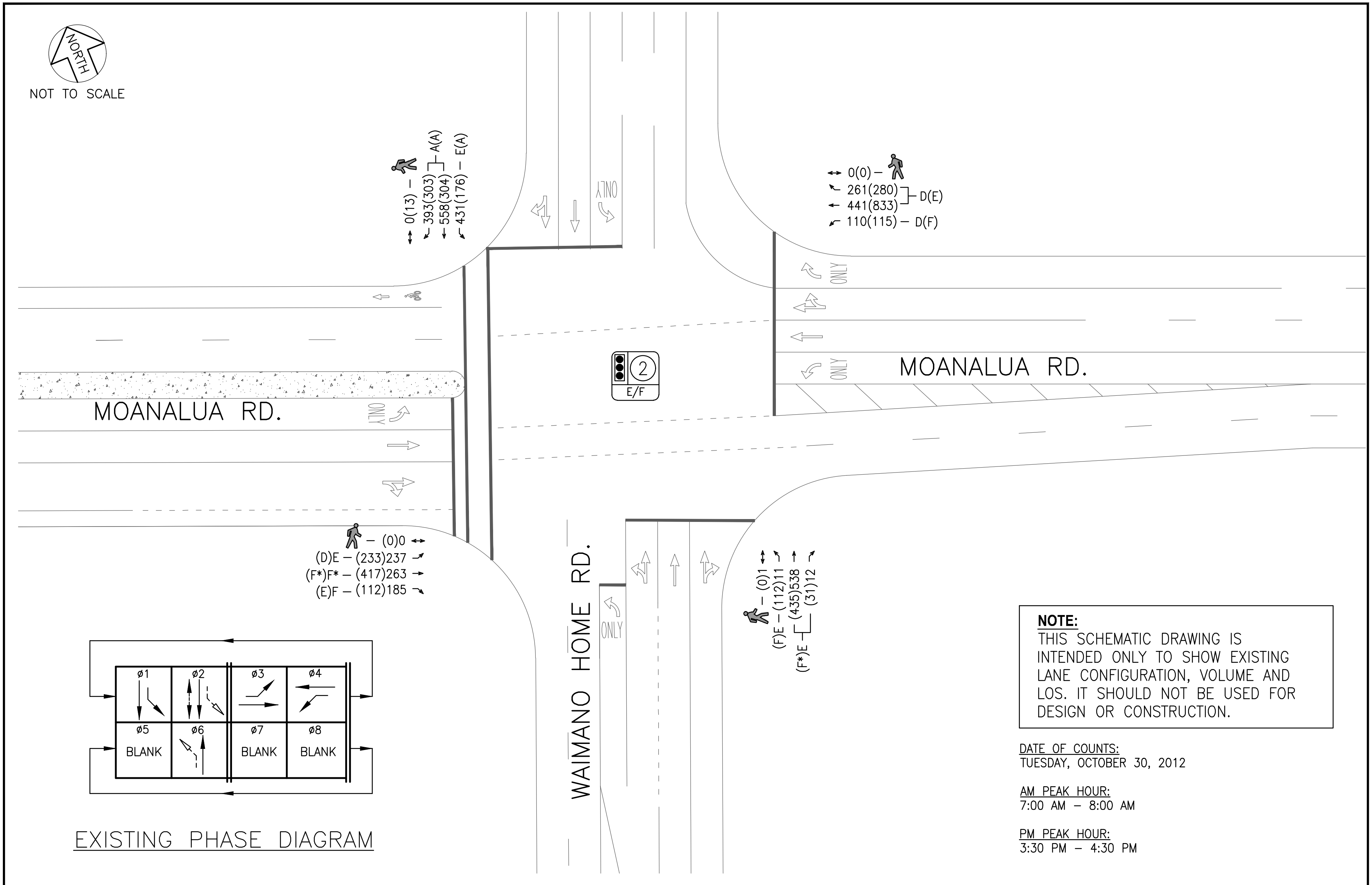
No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced; Moanalua Road and Kuala Street serve as a major East-West thoroughfare. The existing split-phase condition is partially responsible for the long cycle lengths at this intersection.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	Yes.	
b)	**<u>If answer to 2a is "No":</u>** **Should a left-turn lane be installed?**	N/A.	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	Eastbound & Westbound - Protected-Only phasing.	Implement Protected-Only phasing.
3b.	**If <u>No</u> Exclusive Left-Turn Lane Exists (If answer to 2a <u>AND</u> 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History		
	Operational		
ii)	**<u>If answer to 3bi is "Yes" for Operational:</u>** **NYDOT shared left-turn lane**	N/A.	
4.	**Recommendation & Discussion**		
	Implement Protected-Only phasing for the eastbound and westbound approaches. This should improve the efficiency of the intersection and allow for the possibility of reducing the cycle length.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing





EXISTING PHASE DIAGRAM

NOTE:
THIS SCHEMATIC DRAWING IS INTENDED ONLY TO SHOW EXISTING LANE CONFIGURATION, VOLUME AND LOS. IT SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION.

DATE OF COUNTS:
TUESDAY, OCTOBER 30, 2012

AM PEAK HOUR:
7:00 AM – 8:00 AM

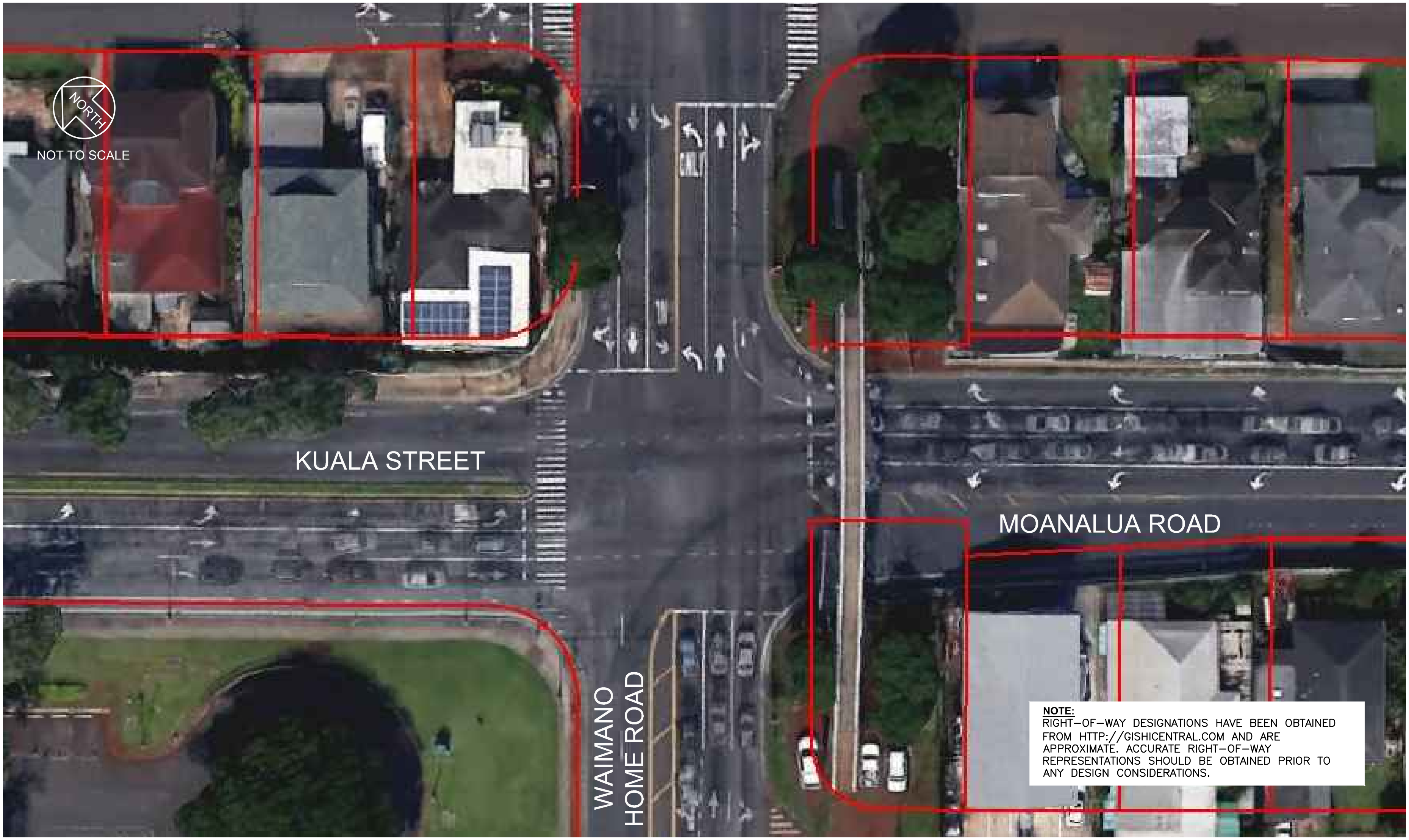
PM PEAK HOUR:
3:30 PM – 4:30 PM

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

EXISTING LANE CONFIGURATION, VOLUME, AND LOS

EXHIBIT
C2-1



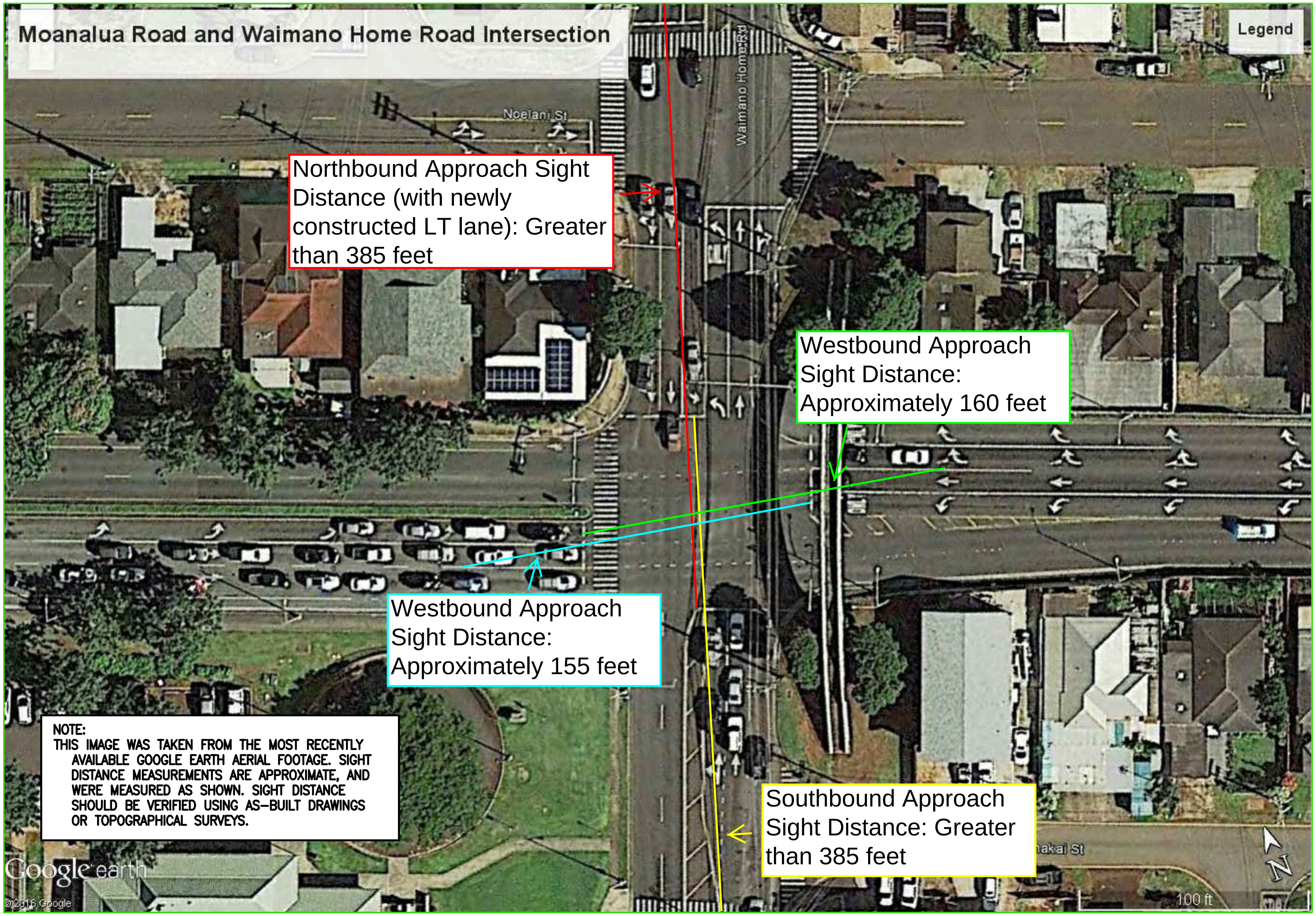
NOTE:
RIGHT–OF–WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT–OF–WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

G.I.S. APPROXIMATE RIGHT–OF–WAY BOUNDARIES

EXHIBIT
C2–2



NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

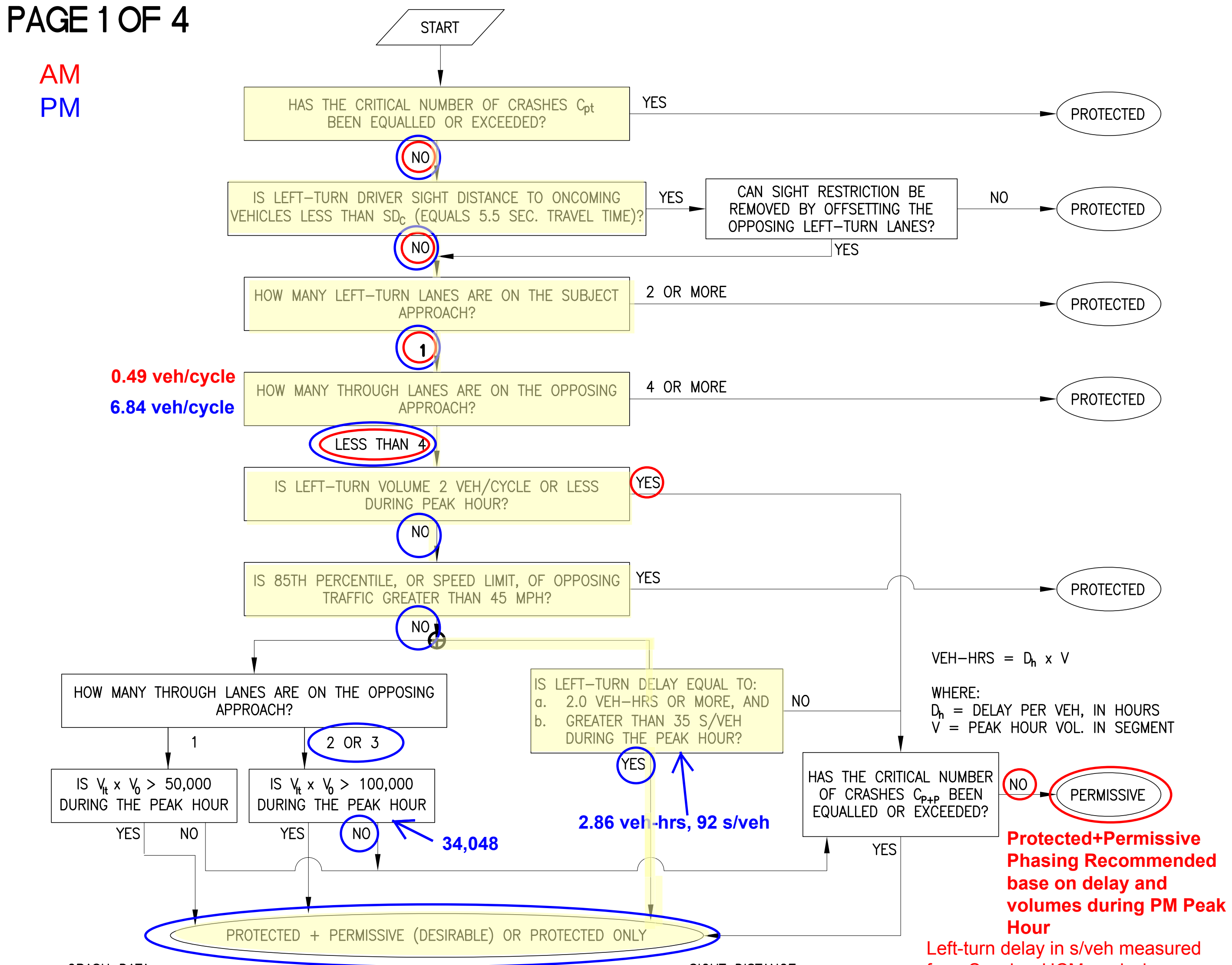
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

SIGHT DISTANCE ANALYSIS

EXHIBIT

C2-3

Moanalua Road/Kuala Street/Waimano Home Road - Northbound



CRASH DATA

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT: WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT-TURN-RELATED CRASH COUNT: WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	2
BOTH	2	18	9	3
BOTH	3	26	13	3

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⌖ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT-TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS-PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

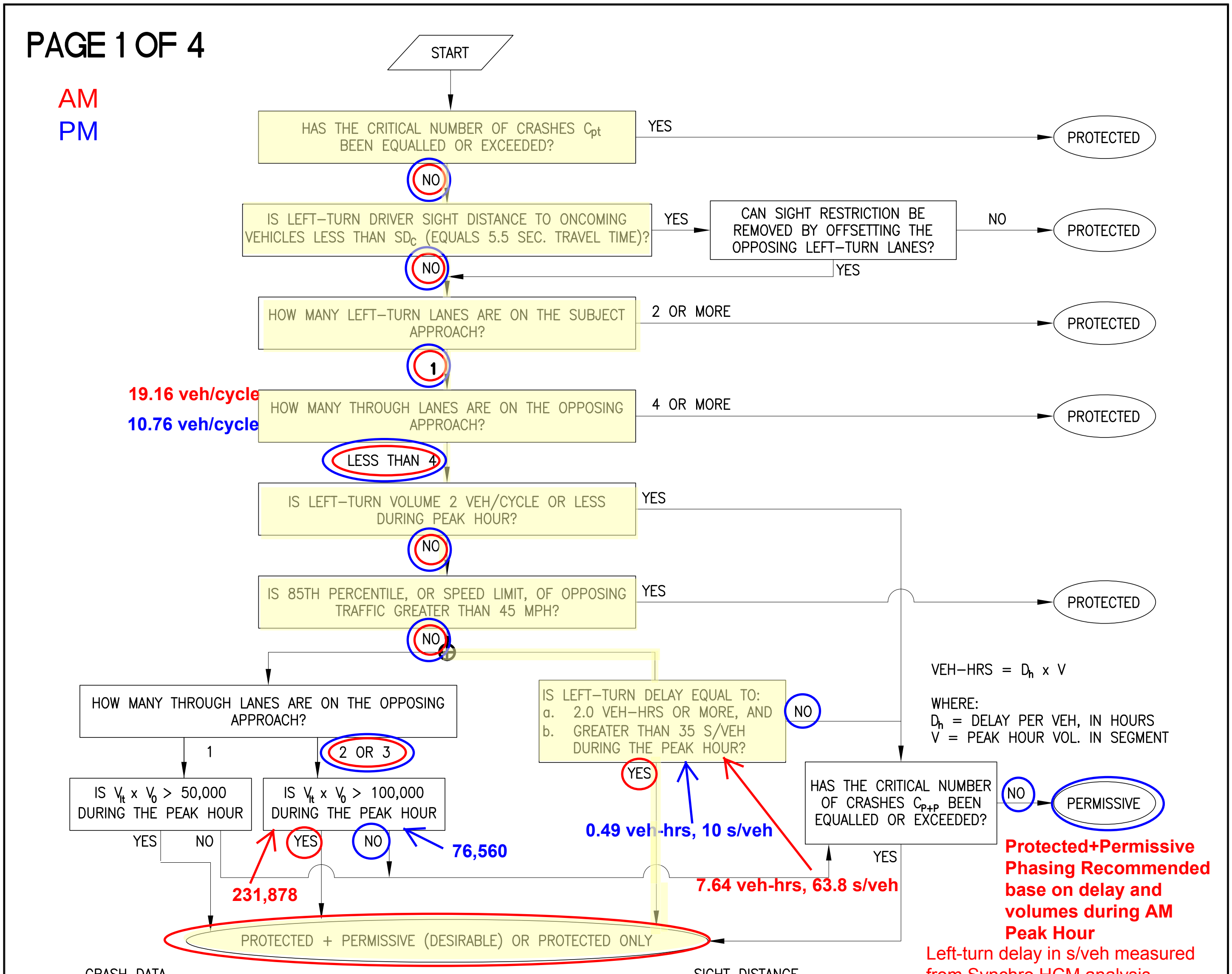
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

Moanalua Road/Kuala Street/Waimano Home Road - Southbound

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT-TURN-RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	2
BOTH	2	18	9	3
BOTH	3	26	13	3

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⌖ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT-TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS-PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

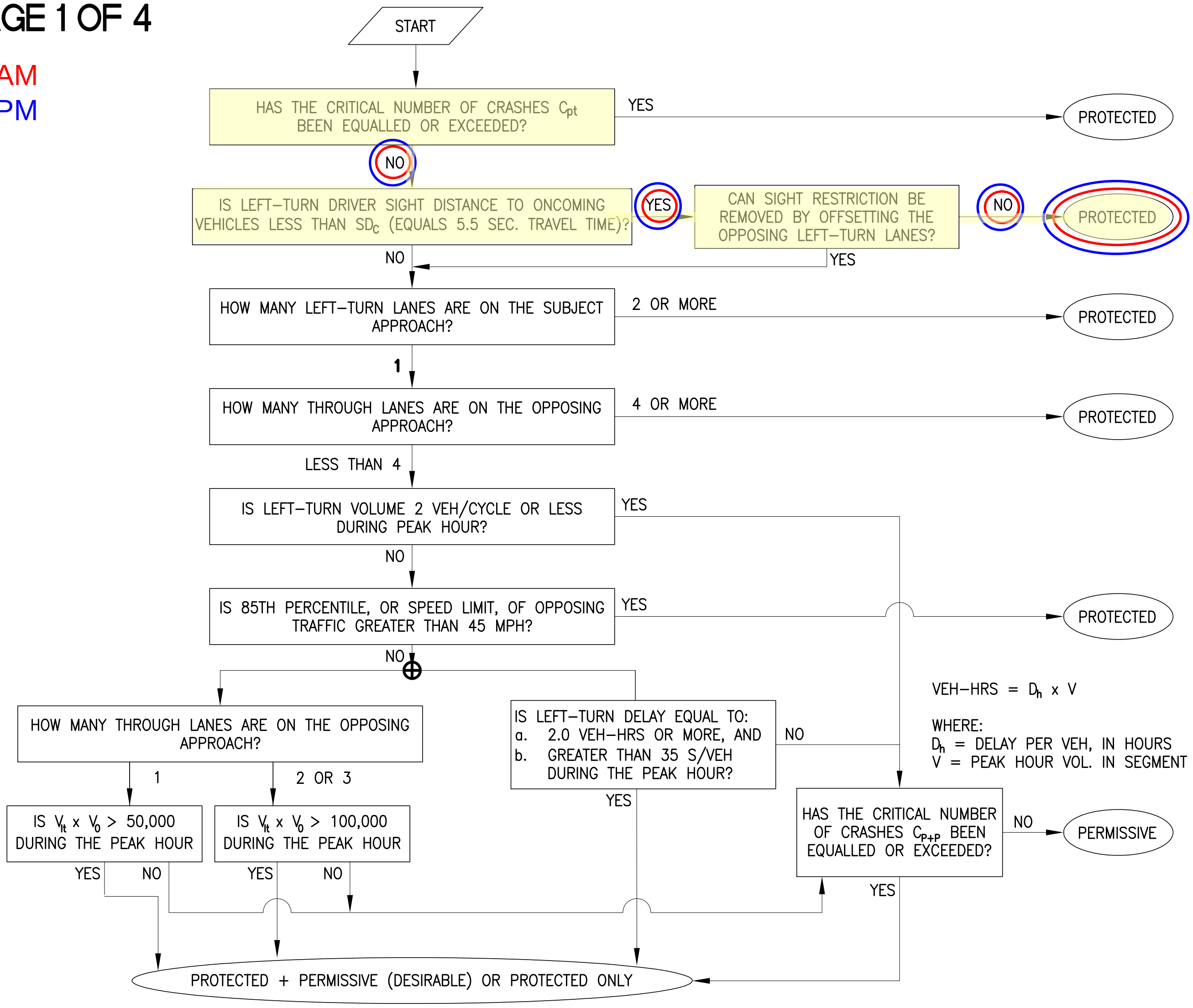
FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

Moanalua Road/Kuala Street/Waimano Home Road - Eastbound

PAGE 1 OF 4

AM
PM



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

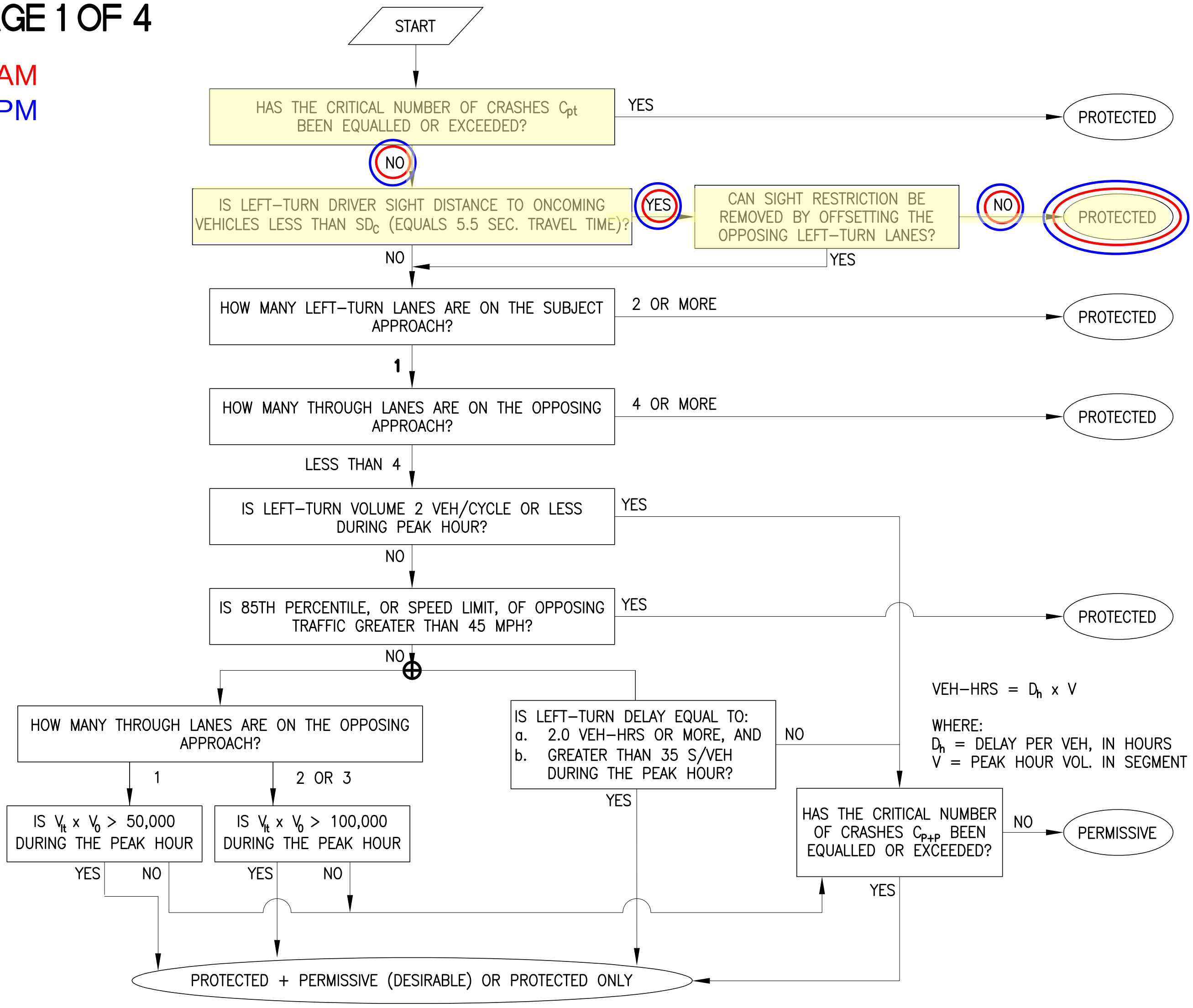
FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Moanalua Road/Kuala Street/Waimano Home Road - Westbound

PAGE 1 OF 4

AM
PM



CRASH DATA

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT	
		WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H
V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT-TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS-PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

HCM Signalized Intersection Capacity Analysis
6: Waimano Home Rd & Hoolaulea St

9/1/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations					↰	↱	↰	↑↱		↰	↑↱	
Traffic Volume (vph)	0	0	0	419	5	21	30	615	204	59	634	3
Future Volume (vph)	0	0	0	419	5	21	30	615	204	59	634	3
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	10	10	10	12	12	10	12	12
Grade (%)		0%			12%			5%			-5%	
Total Lost time (s)					4.0	4.0	6.0	6.0		6.0	6.0	
Lane Util. Factor					1.00	1.00	1.00	0.95		1.00	0.95	
Frpb, ped/bikes					1.00	1.00	1.00	0.99		1.00	1.00	
Flpb, ped/bikes					1.00	1.00	1.00	1.00		1.00	1.00	
Frt					1.00	0.85	1.00	0.96		1.00	1.00	
Flt Protected					0.95	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)					1558	1389	1610	3309		1692	3625	
Flt Permitted					0.95	1.00	0.29	1.00		0.20	1.00	
Satd. Flow (perm)					1558	1389	496	3309		364	3625	
Peak-hour factor, PHF	0.25	0.25	0.25	0.82	0.63	0.66	0.33	0.78	0.82	0.84	0.78	0.75
Adj. Flow (vph)	0	0	0	511	8	32	91	788	249	70	813	4
RTOR Reduction (vph)	0	0	0	0	0	21	0	35	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	519	11	91	1002	0	70	817	0
Confl. Peds. (#/hr)									1	1		
Turn Type				Perm	NA	Perm	Perm	NA		Perm	NA	
Protected Phases					4			2			2	
Permitted Phases				4		4	2			2		
Actuated Green, G (s)					29.8	29.8	43.6	43.6		43.6	43.6	
Effective Green, g (s)					29.8	29.8	43.6	43.6		43.6	43.6	
Actuated g/C Ratio					0.36	0.36	0.52	0.52		0.52	0.52	
Clearance Time (s)					4.0	4.0	6.0	6.0		6.0	6.0	
Vehicle Extension (s)					4.0	4.0	5.0	5.0		5.0	5.0	
Lane Grp Cap (vph)					556	496	259	1729		190	1895	
v/s Ratio Prot								c0.30			0.23	
v/s Ratio Perm					0.33	0.01	0.18			0.19		
v/c Ratio					0.93	0.02	0.35	0.58		0.37	0.43	
Uniform Delay, d1					25.8	17.4	11.6	13.6		11.8	12.3	
Progression Factor					1.00	1.00	1.00	1.00		1.00	1.00	
Incremental Delay, d2					23.1	0.0	1.7	0.8		2.5	0.3	
Delay (s)					49.0	17.4	13.4	14.4		14.3	12.6	
Level of Service					D	B	B	B		B	B	
Approach Delay (s)		0.0			47.1			14.3			12.7	
Approach LOS		A			D			B			B	

Intersection Summary			
HCM 2000 Control Delay	20.8	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.72		
Actuated Cycle Length (s)	83.4	Sum of lost time (s)	10.0
Intersection Capacity Utilization	77.0%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
71: Waimano Home Rd & Moanalua Rd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱	↱	↰	↑↑↱		↰	↑↱	
Traffic Volume (vph)	233	417	112	115	833	280	112	435	31	176	304	303
Future Volume (vph)	233	417	112	115	833	280	112	435	31	176	304	303
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Grade (%)		0%			0%			3%			0%	
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	6.0	6.0		4.0	6.0	
Lane Util. Factor	1.00	0.95		1.00	0.91	0.91	1.00	0.91		1.00	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	0.98	1.00	1.00		1.00	0.99	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frt	1.00	0.97		1.00	1.00	0.85	1.00	0.99		1.00	0.93	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1770	3438		1770	3373	1417	1741	4937		1770	3258	
Flt Permitted	0.95	1.00		0.95	1.00	1.00	0.35	1.00		0.35	1.00	
Satd. Flow (perm)	1770	3438		1770	3373	1417	646	4937		644	3258	
Peak-hour factor, PHF	0.88	0.79	0.90	0.83	0.89	0.94	0.84	0.93	0.72	0.85	0.89	0.94
Adj. Flow (vph)	265	528	124	139	936	298	133	468	43	207	342	322
RTOR Reduction (vph)	0	9	0	0	1	96	0	4	0	0	82	0
Lane Group Flow (vph)	265	643	0	139	965	172	133	507	0	207	582	0
Confl. Peds. (#/hr)	4					4	2		8			2
Turn Type	Split	NA		Split	NA	Perm	Perm	NA		custom	NA	
Protected Phases	3	3		4	4			2		1 8	6 8	
Permitted Phases						4	2			6		
Actuated Green, G (s)	37.2	37.2		56.0	56.0	56.0	63.8	63.8		110.8	110.8	
Effective Green, g (s)	37.2	37.2		56.0	56.0	56.0	63.8	63.8		105.8	105.8	
Actuated g/C Ratio	0.17	0.17		0.25	0.25	0.25	0.29	0.29		0.48	0.48	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	6.0	6.0				
Vehicle Extension (s)	3.0	3.0		5.0	5.0	5.0	5.0	5.0				
Lane Grp Cap (vph)	299	581		450	858	360	187	1431		504	1566	
v/s Ratio Prot	0.15	c0.19		0.08	c0.29			0.10		c0.07	0.18	
v/s Ratio Perm						0.12	c0.21			0.13		
v/c Ratio	0.89	1.11		0.31	1.13	0.48	0.71	0.35		0.41	0.37	
Uniform Delay, d1	89.3	91.4		66.3	82.0	69.6	69.9	61.8		34.3	36.1	
Progression Factor	1.00	1.00		0.81	0.82	0.79	1.00	1.00		0.25	0.01	
Incremental Delay, d2	25.4	70.0		0.8	63.4	1.9	14.7	0.3		0.2	0.3	
Delay (s)	114.7	161.4		54.2	130.8	56.7	84.6	62.1		8.7	0.5	
Level of Service	F	F		D	F	E	F	E		A	A	
Approach Delay (s)		147.9			108.6			66.7			2.5	
Approach LOS		F			F			E			A	

Intersection Summary			
HCM 2000 Control Delay	86.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.85		
Actuated Cycle Length (s)	220.0	Sum of lost time (s)	25.0
Intersection Capacity Utilization	115.6%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

HCM Signalized Intersection Capacity Analysis
71: Waimano Home Rd & Moanalua Rd

9/1/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱	↱	↰	↑↑↱		↰	↑↱	
Traffic Volume (vph)	237	263	185	110	441	261	11	538	12	431	558	393
Future Volume (vph)	237	263	185	110	441	261	11	538	12	431	558	393
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Grade (%)		0%			0%			3%			0%	
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	4.0	6.0		4.0	6.0	
Lane Util. Factor	1.00	0.95		1.00	0.91	0.91	1.00	0.91		1.00	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00	0.99	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frt	1.00	0.94		1.00	0.97	0.85	1.00	1.00		1.00	0.94	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1770	3314		1770	3303	1441	1743	4985		1770	3290	
Flt Permitted	0.95	1.00		0.95	1.00	1.00	0.12	1.00		0.25	1.00	
Satd. Flow (perm)	1770	3314		1770	3303	1441	219	4985		461	3290	
Peak-hour factor, PHF	0.97	0.72	0.69	0.78	0.94	0.75	0.75	0.86	0.63	0.88	0.88	0.87
Adj. Flow (vph)	244	365	268	141	469	348	15	626	19	490	634	452
RTOR Reduction (vph)	0	82	0	0	10	208	0	2	0	0	80	0
Lane Group Flow (vph)	244	551	0	141	556	43	15	643	0	490	1006	0
Confl. Peds. (#/hr)							8		1			8
Turn Type	Prot	NA		Prot	NA	Perm	pm+pt	NA		custom	NA	
Protected Phases	3	8		7	4		5	2		1 9	6 9	
Permitted Phases						4	2			6		
Actuated Green, G (s)	25.4	32.0		21.0	27.6	27.6	43.3	39.3		91.0	78.0	
Effective Green, g (s)	25.4	32.0		21.0	27.6	27.6	43.3	39.3		86.0	78.0	
Actuated g/C Ratio	0.16	0.20		0.13	0.17	0.17	0.27	0.25		0.54	0.49	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	4.0	6.0				
Vehicle Extension (s)	3.0	2.0		5.0	5.0	5.0	3.0	5.0				
Lane Grp Cap (vph)	280	662		232	569	248	97	1224		597	1603	
v/s Ratio Prot	c0.14	c0.17		0.08	c0.17		0.00	0.13		c0.22	0.31	
v/s Ratio Perm						0.03	0.04			c0.22		
v/c Ratio	0.87	0.83		0.61	0.98	0.17	0.15	0.53		0.82	0.63	
Uniform Delay, d1	65.7	61.4		65.6	65.9	56.5	44.4	52.3		27.7	30.3	
Progression Factor	1.00	1.00		1.34	0.81	1.32	1.00	1.00		1.95	0.29	
Incremental Delay, d2	24.3	8.4		9.6	29.5	1.3	0.7	0.8		6.4	0.8	
Delay (s)	90.0	69.8		97.5	83.1	76.0	45.2	53.1		60.5	9.6	
Level of Service	F	E		F	F	E	D	D		E	A	
Approach Delay (s)		75.4			83.3			52.9			25.4	
Approach LOS		E			F			D			C	

Intersection Summary			
HCM 2000 Control Delay	54.3	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.88		
Actuated Cycle Length (s)	160.0	Sum of lost time (s)	25.0
Intersection Capacity Utilization	89.5%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

HCM Signalized Intersection Capacity Analysis
71: Waimano Home Rd & Moanalua Rd

9/1/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱	↱	↰	↑↑↱		↰	↑↱	
Traffic Volume (vph)	233	417	112	115	833	280	112	435	31	176	304	303
Future Volume (vph)	233	417	112	115	833	280	112	435	31	176	304	303
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Grade (%)		0%			0%			3%			0%	
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	4.0	6.0		4.0	6.0	
Lane Util. Factor	1.00	0.95		1.00	0.91	0.91	1.00	0.91		1.00	0.95	
Frpb, ped/bikes	1.00	1.00		1.00	1.00	0.98	1.00	1.00		1.00	0.99	
Flpb, ped/bikes	1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00	1.00	
Frt	1.00	0.97		1.00	1.00	0.85	1.00	0.99		1.00	0.93	
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00		0.95	1.00	
Satd. Flow (prot)	1770	3438		1770	3373	1417	1743	4937		1770	3258	
Flt Permitted	0.95	1.00		0.95	1.00	1.00	0.29	1.00		0.35	1.00	
Satd. Flow (perm)	1770	3438		1770	3373	1417	536	4937		647	3258	
Peak-hour factor, PHF	0.88	0.79	0.90	0.83	0.89	0.94	0.84	0.93	0.72	0.85	0.89	0.94
Adj. Flow (vph)	265	528	124	139	936	298	133	468	43	207	342	322
RTOR Reduction (vph)	0	9	0	0	1	96	0	4	0	0	77	0
Lane Group Flow (vph)	265	643	0	139	965	172	133	507	0	207	587	0
Confl. Peds. (#/hr)	4					4	2		8			2
Turn Type	Prot	NA		Prot	NA	Perm	pm+pt	NA		custom	NA	
Protected Phases	3	8		7	4		5	2		1 9	6 9	
Permitted Phases						4	2			6		
Actuated Green, G (s)	35.6	66.0		26.5	56.9	56.9	68.5	64.5		111.5	98.5	
Effective Green, g (s)	35.6	66.0		26.5	56.9	56.9	68.5	64.5		106.5	98.5	
Actuated g/C Ratio	0.16	0.30		0.12	0.26	0.26	0.31	0.29		0.48	0.45	
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	4.0	6.0				
Vehicle Extension (s)	3.0	2.0		5.0	5.0	5.0	3.0	5.0				
Lane Grp Cap (vph)	286	1031		213	872	366	188	1447		507	1458	
v/s Ratio Prot	c0.15	0.19		0.08	c0.29		c0.01	0.10		c0.07	0.18	
v/s Ratio Perm						0.12	c0.21			0.13		
v/c Ratio	0.93	0.62		0.65	1.11	0.47	0.71	0.35		0.41	0.40	
Uniform Delay, d1	90.9	66.3		92.4	81.5	68.8	70.6	61.2		33.9	40.9	
Progression Factor	1.00	1.00		1.10	0.82	0.79	1.00	1.00		0.28	0.10	
Incremental Delay, d2	34.1	0.9		6.5	56.0	1.9	11.5	0.3		0.2	0.3	
Delay (s)	125.0	67.2		108.5	122.8	56.0	82.1	61.6		9.8	4.3	
Level of Service	F	E		F	F	E	F	E		A	A	
Approach Delay (s)		83.9			108.3			65.8			5.6	
Approach LOS		F			F			E			A	

Intersection Summary			
HCM 2000 Control Delay	71.7	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.81		
Actuated Cycle Length (s)	220.0	Sum of lost time (s)	25.0
Intersection Capacity Utilization	99.3%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

3. CASE STUDY: MONSARRAT AVENUE AND LEAHI AVENUE

Existing Conditions

At the intersection of Monsarrat Avenue and Leahi Avenue, all approaches operate with permissive left-turn phasing. Exclusive left-turn pockets are provided on both eastbound and westbound approaches along Monsarrat Avenue. A shared left-turn/through/right-turn lane is provided at both Leahi Avenue northbound and southbound approaches. See Exhibit C3-1 for the existing intersection layout.

Traffic Observations & Analysis

The flow of traffic along Monsarrat Avenue appears to be relatively constant between the AM and PM peak hours of traffic. For approximately 30 minutes during the AM peak hour, westbound through queuing spills back over 2,000 feet past Campbell Avenue in the single through lane on Monsarrat Avenue. During the busiest 15-minutes of that AM peak, few gaps are provided for the westbound left-turning vehicles to complete their movement, forming westbound left-turn queues up to 7-8 vehicles long that can take multiple cycles to clear and sometimes restricts the westbound through movement. Additionally, queues from vehicles accessing the Waikiki Elementary School parking lot on the south side of the intersection occasionally spill back into the study intersection, further restricting the westbound left-turn movement. Although HCM analysis indicates the westbound left-turn movement operating at LOS C during the AM and PM peak hours of traffic, the queue spillback is primarily due to the short left-turn pocket provided at the intersection. Eastbound left-turn queues are infrequent and contained within the left-turn pocket.

The nearby Kapiolani Park and Waikiki Elementary School generates a steady flow of pedestrian traffic on all four crosswalks of the intersection, which adds to the slow progression through the intersection. During the AM peak hour, a crossing guard is positioned at the southwest corner of the intersection to aid students and parents using the crosswalks to get to the school.

See Table C3-1 for a summary of the LOS analysis results for the existing conditions.

Conclusions

See Table C3-2 for the summary of analysis and recommendations regarding the left-turn treatment at this intersection.

<u>Northbound/Southbound Approaches</u>

The existing permissive phasing should be maintained for the northbound and southbound Leahi Avenue approaches. Although neither of the northbound or southbound approaches currently include dedicated left-turn lanes, it is infeasible to install dedicated left-turn lanes due to right-of-way constraints and the lack of its need on the southbound approach based on the guidelines in Figure 1. As crash history thresholds are not exceeded and operations are adequate, the existing permissive phasing appears to be appropriate.

Eastbound/Westbound Approaches

The existing permissive phasing should be maintained for the eastbound and westbound approaches.

As both eastbound and westbound approaches include dedicated left-turn lanes, Figure 1 was utilized to determine the appropriate left-turn phasing. Both approaches resulted in a recommendation of permissive left-turn phasing, provided that the sight distance restriction could be removed by offsetting the opposing left-turn lanes. Although the westbound left-turn lane experiences some queuing and spillback during the busiest 15-minutes of the AM peak, it operates adequately for majority of the day. Lengthening the westbound left-turn pocket can be considered to help alleviate this issue.

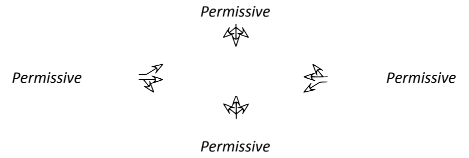
Table C3-1: Level of Service Summary Table

Intersection	Existing Conditions					
	AM			PM		
	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
3. Monsarrat Avenue/Leahi Avenue						
NB LT/TH/RT	25.7	0.58	C	29.2	0.50	C
EB LT	47.1	0.27	D	32.4	0.12	C
EB TH/RT	12.5	0.53	B	11.9	0.57	B
WB LT	19.0	0.36	B	20.9	0.44	C
WB TH/RT	97.6	1.14	F*	24.6	0.87	C
SB LT/TH/RT	25.3	0.59	C	34.0	0.69	C
Overall	49.6	-	D	22.2	-	C

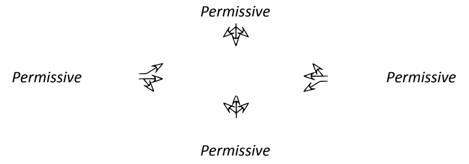
Table C3-2: Left-Turn Warrant Guidelines Summary
Monsarrat Avenue & Leahi Avenue

North-South (Leahi Avenue)				East-West (Monsarrat Avenue)			
No.		Conclusion/Discussion	Action Recommended?	No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**			**1.**	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced for a minor street. Going to split-phase would adversely affect Monsarrat Avenue.*			**Is Split-Phase Recommended?**	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Monsarrat Avenue.*	
2.	**Exclusive Left-Turn Lane Consideration**			**2.**	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	No.		**a)**	**Do the approaches have left-turn lanes?**	Yes.	
b)	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	No. *The existing right-of-way appears too narrow on the northbound approach to accommodate an additional median lane. On both northbound and southbound approaches, Flowchart in Figure 1 would recommend permissive phasing if dedicated left-turn lane is available; therefore, the need for a dedicated left-turn lane and protected phasing is not currently present.*		**b)**	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	N/A. *Dedicated left-turn lanes included on both approaches.*	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**			**3a.**	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A. *In lieu of left-turn lane.*			**Flow-Chart (Figure 1) result**	Westbound approach - Permissive phasing. . Eastbound approach - Permissive phasing.	Westbound approach - Maintain existing permissive phasing. Eastbound approach - Maintain existing permissive phasing.
3b.	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**			**3b.**	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**			**i)**	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History	No. *0 northbound and southbound left-turn related crashes from July 2009 to September 2012.*	Maintain existing permissive phasing.		***Crash History***		
	Operational	No. *Northbound and southbound left-turn movements operate at LOS C(C) and LOS C(C), respectively, during the AM(PM) peak hours.*			***Operational***		
ii)	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane warrant satisfied?**	N/A.		**ii)**	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane warrant satisfied?**	N/A.	
4.	**Recommendation & Discussion**			**4.**	**Recommendation & Discussion**		
	Maintain existing permissive phasing.				Maintain existing permissive phasing.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing



NORTH

NOT TO SCALE

LEGEND

##(##) – AM(PM) PEAK HOUR OF TRAFFIC VOLUMES

X(X) – AM(PM) LOS

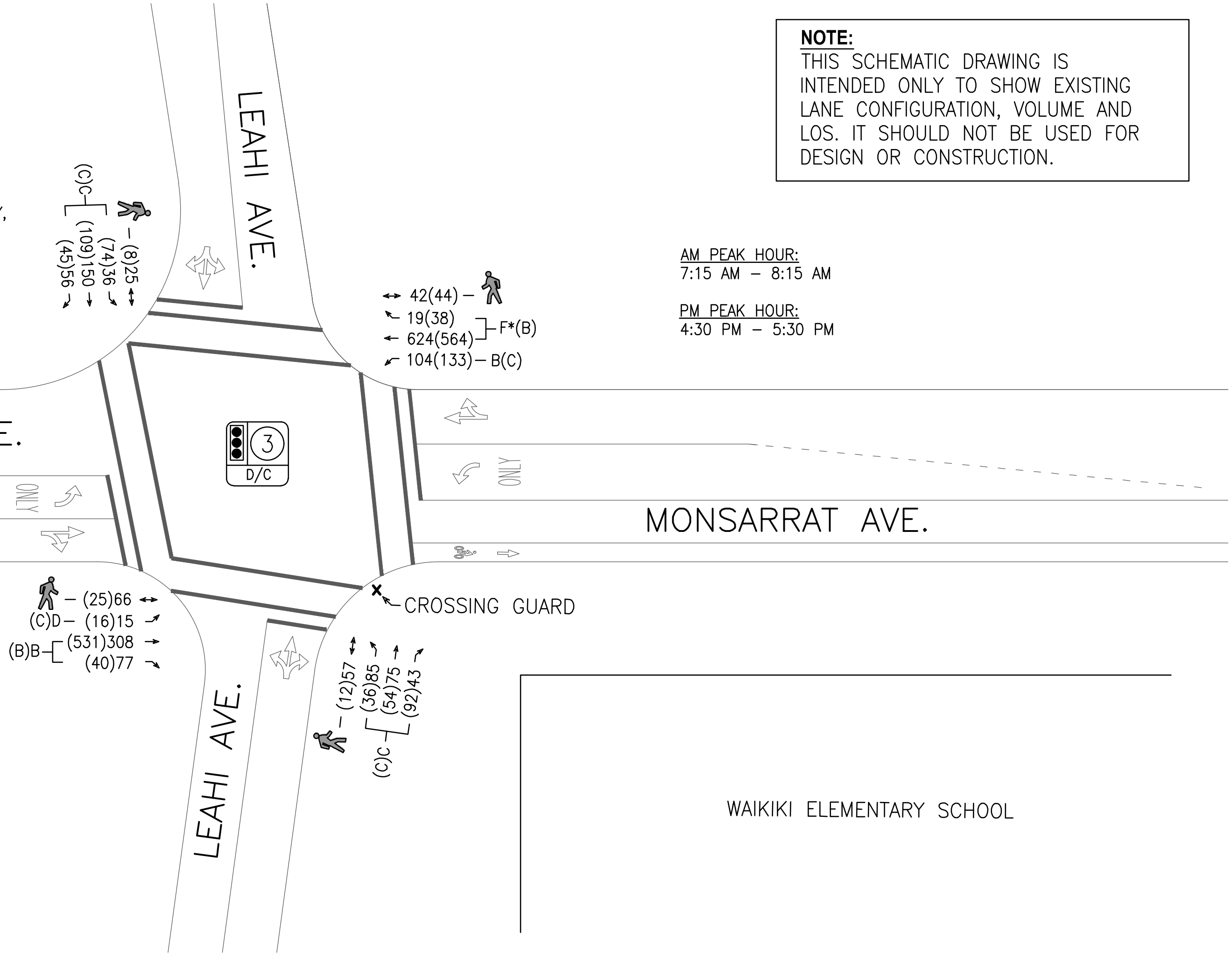
Y X/X – SIGNALIZED INTERSECTION Y, OVERALL AM/PM LOS

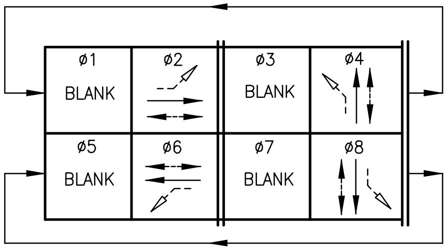
Y – INTERSECTION Y

NOTE:
THIS SCHEMATIC DRAWING IS INTENDED ONLY TO SHOW EXISTING LANE CONFIGURATION, VOLUME AND LOS. IT SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION.

AM PEAK HOUR:
7:15 AM – 8:15 AM

PM PEAK HOUR:
4:30 PM – 5:30 PM





EXISTING PHASE DIAGRAM

EXISTING CONTROLLER

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

EXISTING LANE CONFIGURATION, VOLUME AND LOS

EXHIBIT

C3-1

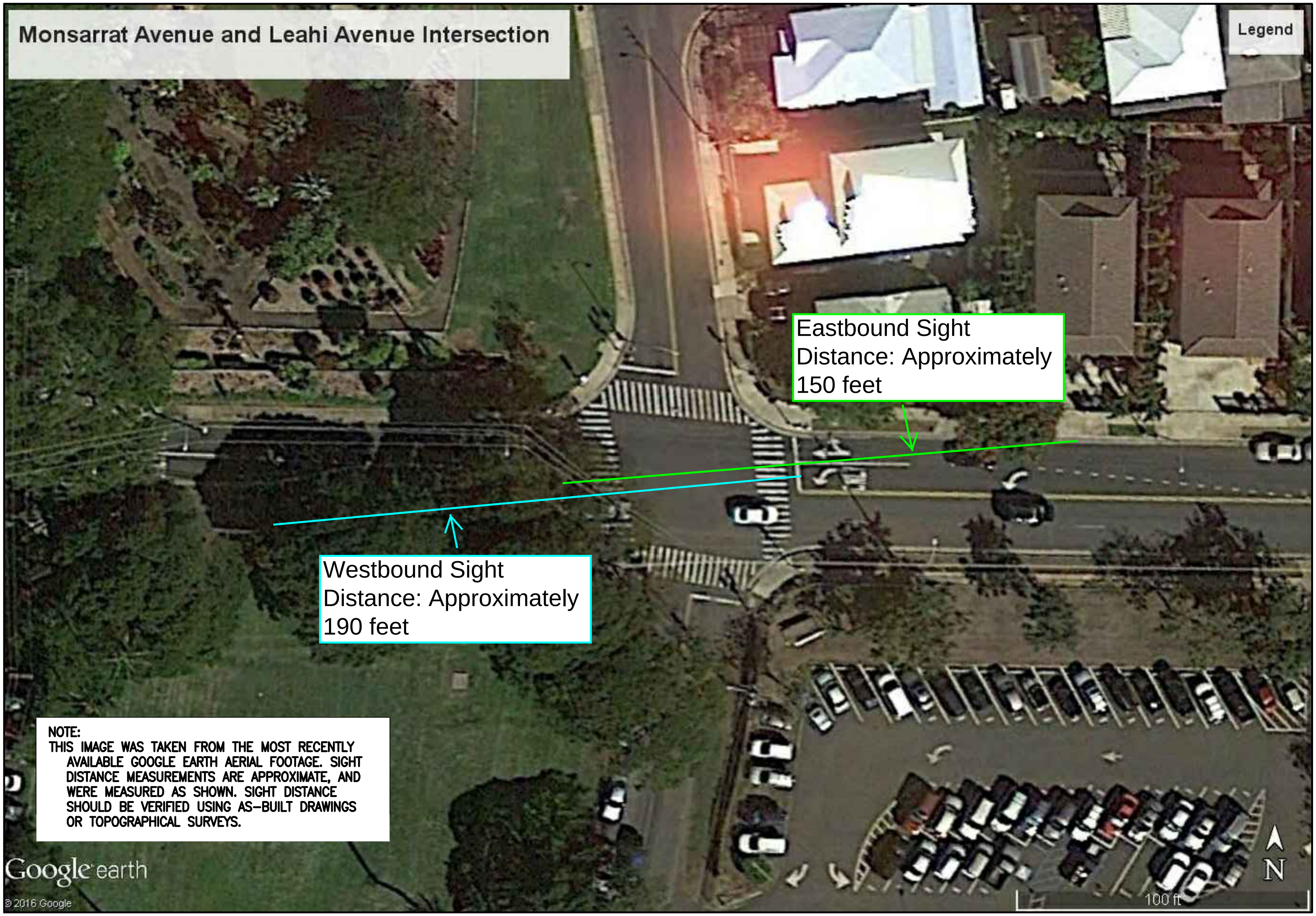
NOTE:
RIGHT-OF-WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT-OF-WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

G.I.S. APPROXIMATE RIGHT-OF-WAY BOUNDARIES

EXHIBIT
C3-3



Monsarrat Avenue and Leahi Avenue Intersection

Eastbound Sight Distance: Approximately 150 feet

Westbound Sight Distance: Approximately 190 feet

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

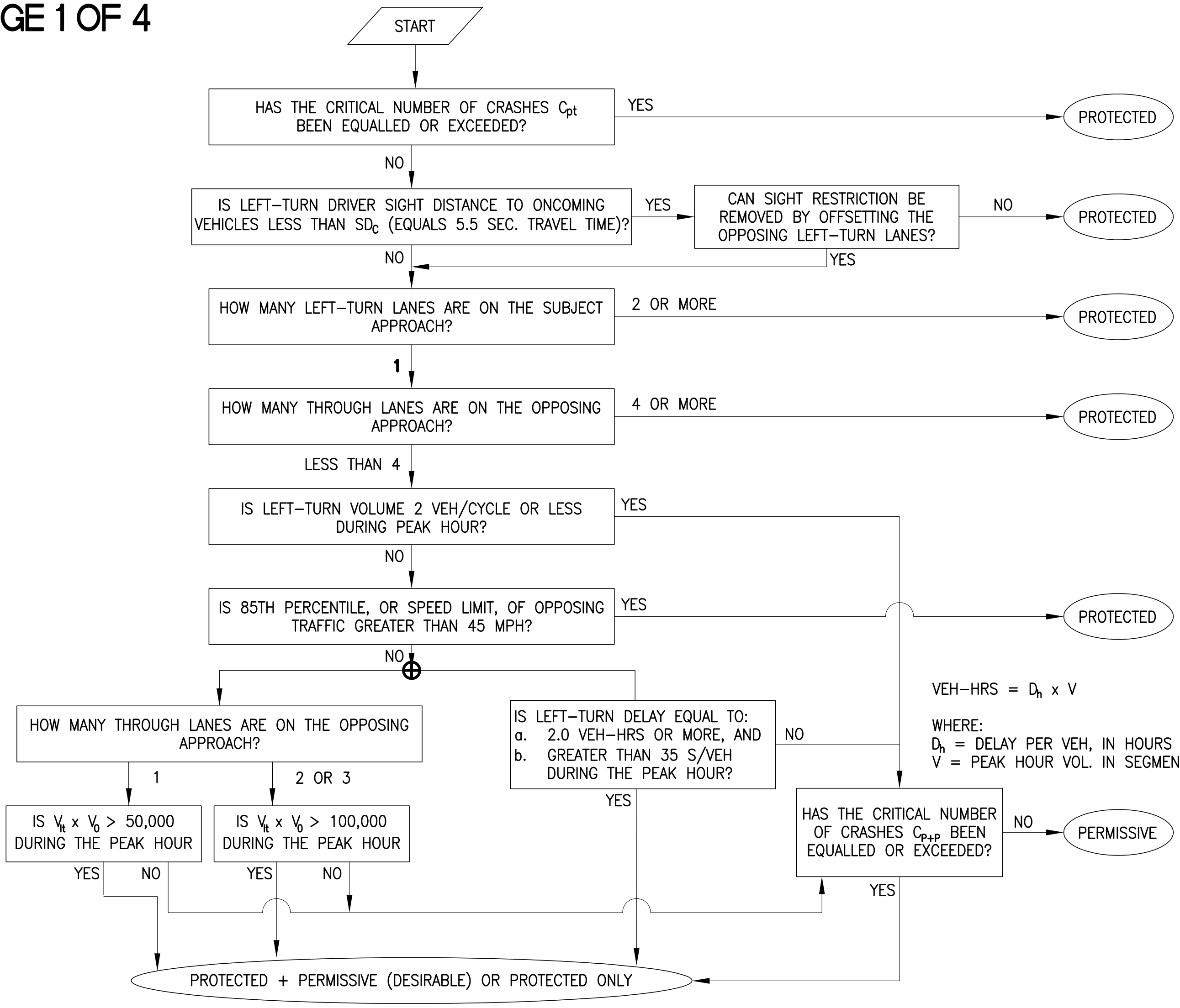
TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

SIGHT DISTANCE ANALYSIS

EXHIBIT
C3-4

PAGE 1 OF 4



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

PAGE 3 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT–TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT–TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT–TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE–RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT–TURN ARROW.

SPECIAL CASE: SHARED LEFT–TURN/THROUGH LANE (Northbound and Southbound Approaches)

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED–ONLY LEFT–TURN PHASING WHERE LEFT–TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT–TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE–ONLY LEFT–TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT–TURN PHASES FOR SHARED LEFT–TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT–TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT–TURN LANE:

NB
- **IF A DEDICATED LEFT–TURN LANE CAN BE FEASIBLY CONSTRUCTED,** UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT–TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.

SB
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT–TURN LANE,** CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT–TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT–TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:

    See Fig 1 - Not met
    - THE LEFT–TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT–TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT–TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT–TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT–TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT–TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,

    Operations Acceptable
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT–TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT–TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT–TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT–TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

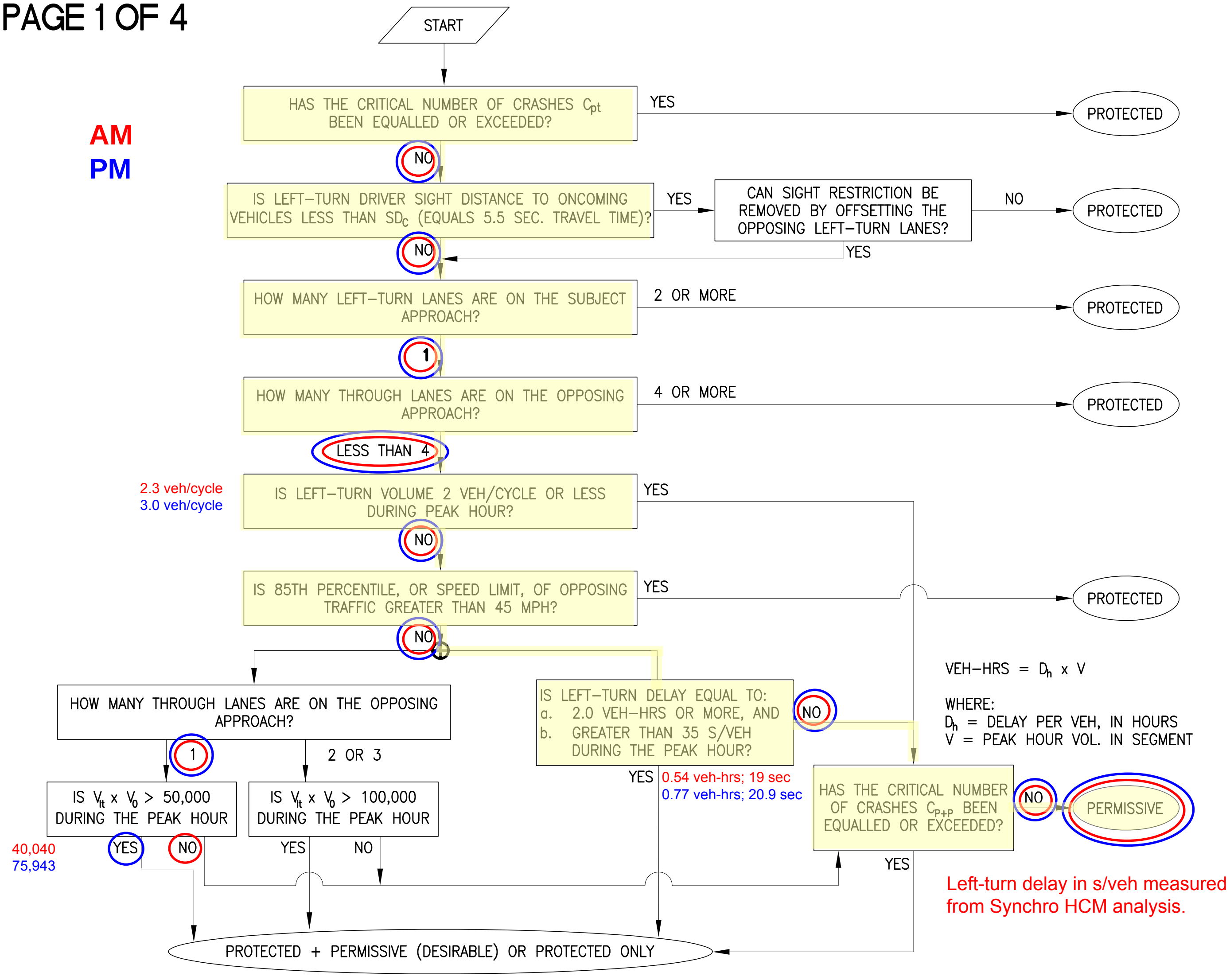
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE - 1

FIGURE
3

Monsarrat Avenue/Leahi Avenue Intersection Westbound

PAGE 1 OF 4



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT: WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT: WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

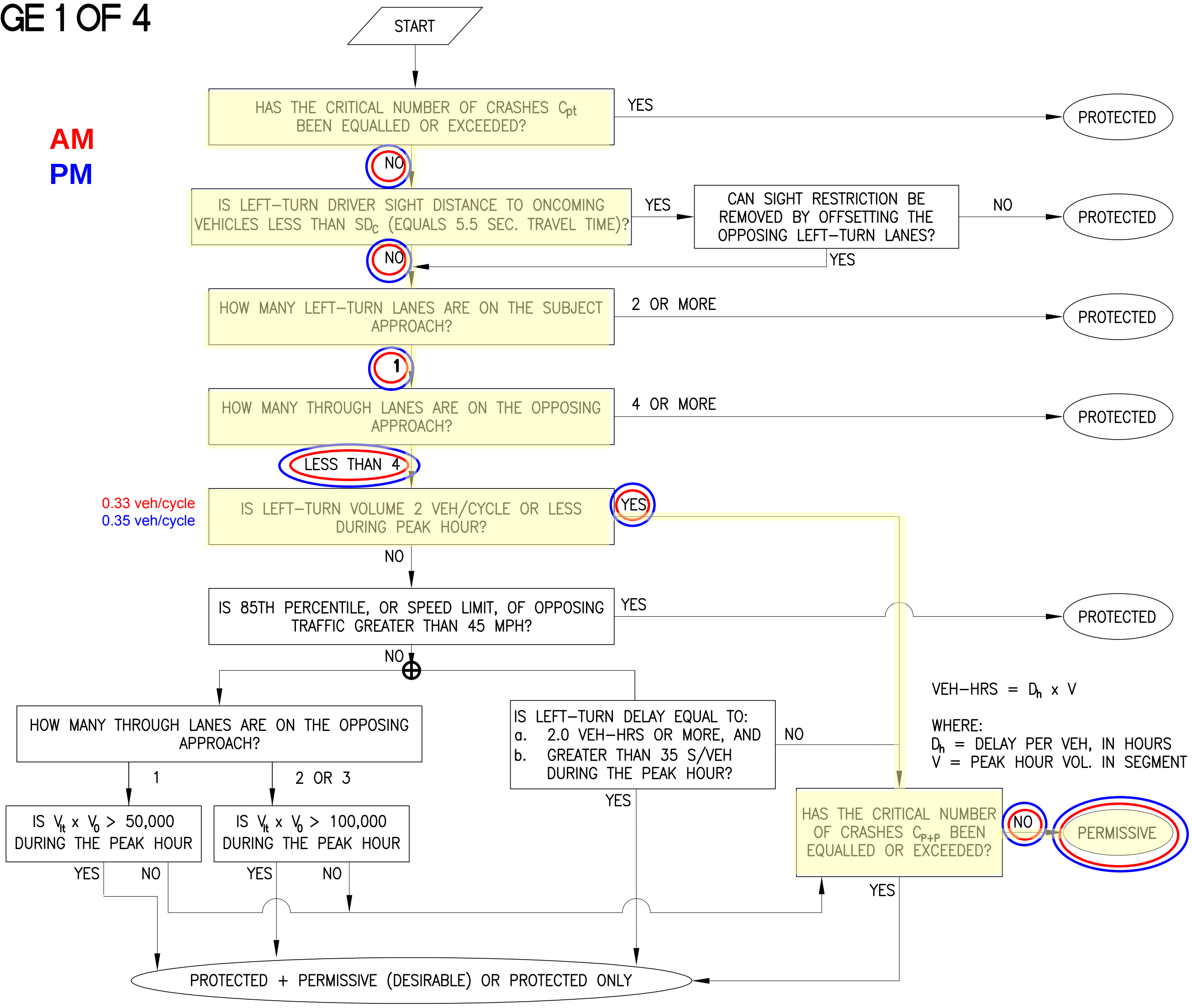
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Monsarrat Avenue/Leahi Avenue Intersection Eastbound

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

4. CASE STUDY: NUUANU AVENUE AND NORTH KUAKINI STREET AND SOUTH KUAKINI STREET

Existing Conditions

At the intersection of Nuuanu Avenue, North Kuakini Street, and South Kuakini Street, the westbound left-turn movement operates with permissive phasing and a shared left-turn/through/right-turn lane. All other approaches operate with permissive left-turn phasing and provide one shared left-turn/through lane and one shared through/right-turn lane. Crosswalks are provided on all four intersection approaches and are heavily used during both AM and PM peak hours due to its proximity to Prince David Kawananakoa Middle School and numerous bus stops along Nuuanu Avenue.

Traffic Observations & Analysis

Although traffic analysis indicates that the northbound and southbound left-turn/through movements operate at LOS F with overcapacity conditions, field observations indicate minimal queuing along the subject approaches, even with substantial left-turn volumes of 81(159) vehicles on the northbound approach and 127(33) vehicles on the southbound approach during the AM(PM) peak hour of traffic.

Heavy queuing is present on the eastbound approach of North Kuakini Street during the AM and PM peak hours of traffic. Vehicles completing the left-turn and right-turn movements from the eastbound shared lanes are constrained by the high pedestrian volumes on the adjacent crosswalks, which in turn restricts the through movement during the green phase. The eastbound left-turn/through movement operates at LOS F with overcapacity conditions during the AM peak hour and LOS D during the PM peak hour. Many eastbound and westbound left-turning vehicles at the tail end of the cycle complete their movement during the red signal due to the lack of sufficient gaps.

See Table C4-1 for a summary of the LOS analysis results.

Conclusions

See Table C4-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

Northbound/Southbound Approaches

The existing permissive left-turn phasing should be maintained for the northbound and southbound approaches.

Although the New York Department of Transportation Left-Turn Phase Warrant was satisfied for the northbound approach during the AM peak hour of traffic, field observations indicate that the northbound left-turn movement experiences minimal queuing and adequate gaps to complete the movement despite Synchro analysis indicating operations of LOS F. HCM analysis indicates minimal improvement in delay on the northbound approach but worsened operations on all other approaches of the intersection during the AM scenario. The northbound and southbound approaches during the PM scenario slightly worsened while the eastbound and westbound approaches remained the same. See Table C4-1 for a summary of the LOS analysis results for the considered northbound protected + permissive left-turn phasing. Simulation analysis of the intersection modeling protected + permissive left-turn phasing on the northbound approach indicates marginal improvement in queuing on the northbound approach and increased queuing on the southbound approach. See Table C4-3 below for a summary of the approach queues for the northbound left-turn protected + permissive phasing scenario.

As field observations indicate adequate existing operations and analysis yields marginal improvements with a protected + permissive left-turn phase, it is recommended that the northbound and southbound movements maintain the existing permissive phasing.

Eastbound/Westbound Approaches

The existing permissive left-turn phasing should be maintained for the eastbound and westbound approaches.

Protected + permissive phasing was considered for the eastbound movement. With eastbound protected + permissive left-turn phasing, HCM analysis indicates decreased delay on the eastbound approach and increased delay on the westbound approach during the AM and PM peak hours of traffic. See Table C4-1 for a summary of the LOS analysis results for the considered eastbound protected + permissive left-turn phasing. However, simulation analysis of the intersection with eastbound protected + permissive left-turn phasing indicates increased queue lengths on both eastbound and westbound approaches during the AM and PM peak hours of traffic. Therefore, it is recommended that the eastbound and westbound movements maintain the existing permissive phasing. See Table C4-3 below for a summary of the approach queues for the modeled scenario.

Table C4-3: Queuing Summary Table

	Existing (Permissive Phasing)		**Northbound Protected + Permissive Phasing**		**Eastbound Protected + Permissive Phasing**	
	AM	**PM**	**AM**	**PM**	**AM**	**PM**
Northbound Queue	310	289	210	277	294	277
Southbound Queue	382	172	477	208	397	161
Eastbound Queue	677	1622	911	1076	885	1848
Westbound Queue	529	80	509	80	643	91

Note: All queues reported are 95th percentile queues in the LT/TH lane, measured in feet.

Table C4-1: Level of Service Summary Table

	Existing Conditions						Northbound P+P Conditions						Eastbound P+P Conditions					
	AM			PM			AM			PM			AM			PM		
Intersection	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
4. Nuuanu Avenue/North Kuakini Street/South Kuakini Street																		
EB LT/TH/RT	527.9	2.09	F*	750.2	2.59	F*	527.9	2.60	F*	750.2	2.59	F*	437.2	1.89	F*	508.6	2.05	F*
WB LT/TH/RT	1610.9	4.45	F*	19.4	0.13	B	1610.9	4.45	F*	19.4	0.13	B	2113.6	5.54	F*	25.4	0.15	C
NB LT/TH/RT	19.2	0.64	B	30.9	0.89	C	19.0	0.63	B	32.0	0.90	C	19.2	0.64	B	30.9	0.89	C
SB LT/TH/RT	65.0	1.06	E	15.8	0.51	B	146.5	1.23	F*	23.0	0.63	C	65.0	1.06	E	15.8	0.51	B
Overall	357.2	2.44	F*	279.8	1.59	F*	391.3	2.60	F*	282.1	1.68	F*	391.5	2.55	F*	194.9	1.42	F*

**Intersection analyzed using HCM 2000 methodology due to HCM 2010 methodology currently not supporting analysis for protected + permissive phasing on shared lanes.

Table C4-2: Left-Turn Warrant Guidelines for Case Study Summary

Nuuanu Avenue & North Kuakini Street & South Kuakini Street

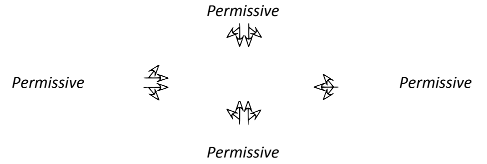
North-South (Nuuanu Avenue)

No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Nuuanu Avenue.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	No.	
b)	**<u>If answer to 2a is "No":</u>** **Should a left-turn lane be installed?**	No. *Road diet would likely have adverse imacts on all movements given the relatively heavy north-south volumes at this intersection. Existing right-of-way appears to be too narrow to accommodate an additional median lane.*	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A. *In lieu of left-turn lane.*	
3b.	**If <u>No</u> Exclusive Left-Turn Lane Exists (If answer to 2a <u>AND</u> 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**		
	Crash History	No. *3 northbound left-turn related crashes from May 2009 to November 2012. 0 southbound left-turn related crashes in the same time period.*	
	Operational	Yes. *Northbound and southbound left-turn movements operate at LOS F(C) and LOS F(B), respectively, during the AM(PM) peak hours of traffic, largely in part due to the heavy pedestrian volumes during the AM peak. However, field observations indicate that the NBLT and SBLT movement experiences minimal queuing.*	
ii)	**<u>If answer to 3bi is "Yes" for Operational:</u>** **NYDOT shared left-turn lane warrant satisfied?**	Yes. *NYDOT shared left-turn lane warrant satisfied for northbound approach during AM peak only. Northbound approach during PM peak and southbound approach during AM and PM peaks do not warrant.*	Exercise engineering judgment.
4.	**Recommendation & Discussion**		
	Although the NYDOT shared left-turn lane warrant is satisfied for the northbound approach during the AM peak, field observations indicate the northbound left-turn movement experienced minimal queuing and adequate gaps to complete the movement despite Synchro analysis indicating operations of LOS F. Analysis of the intersection modeling protected + permissive left-turn phasing on the northbound approach indicates marginal improvement in queuing on the northbound approach and increased queuing on the southbound approach. As field observations indicate adequate operations and analysis yields marginal improvements with a protected + permissive left-turn phase, it is recommended that the northbound and southbound movements maintain the existing permissive phasing.		

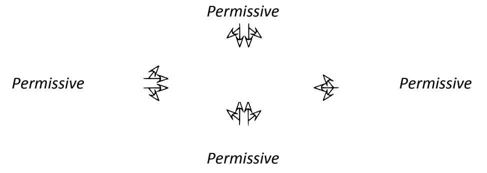
East-West (North Kuakini Street & South Kuakini Street)

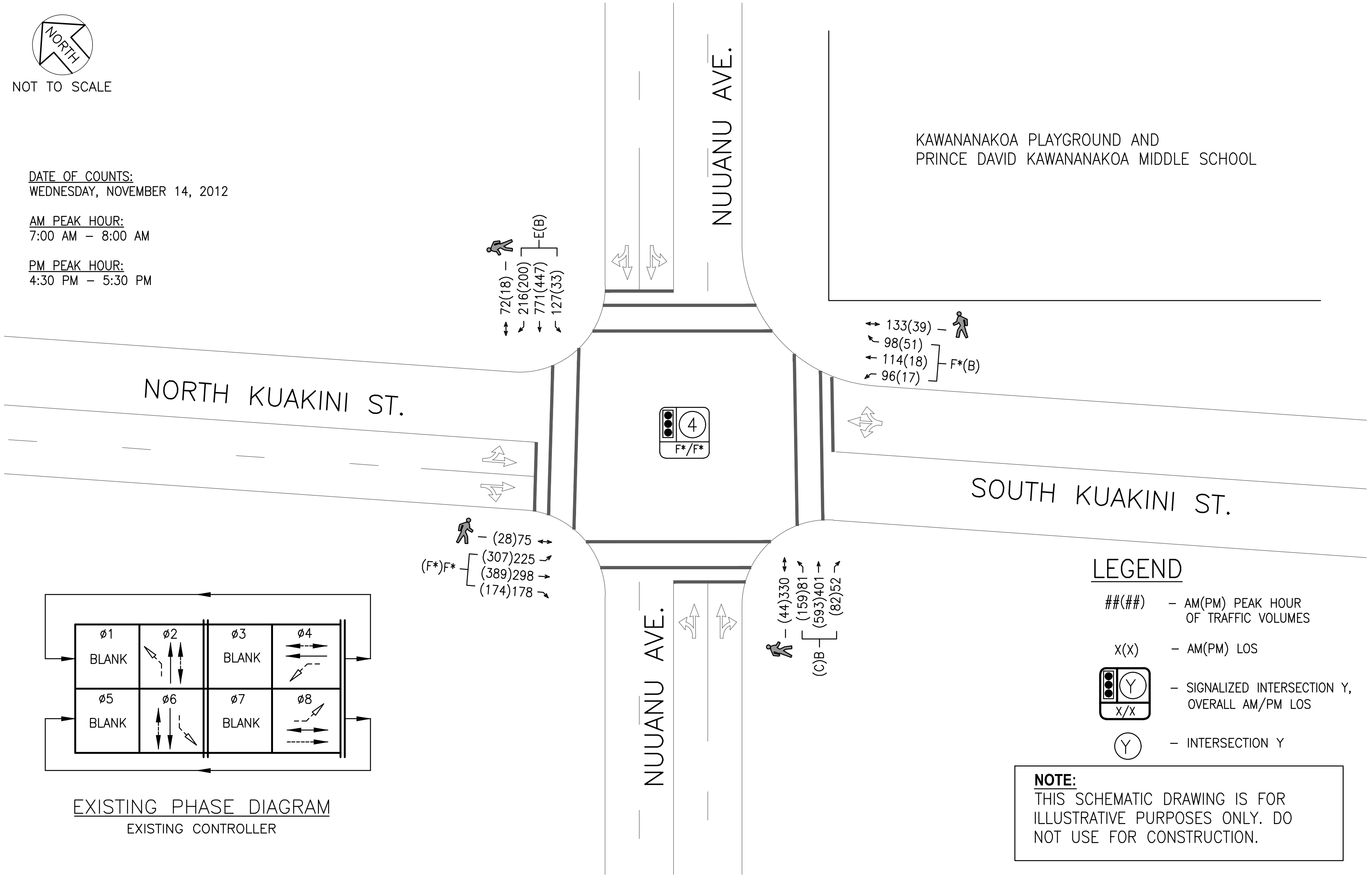
No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *Although the eastbound and westbound approaches are somewhat unbalanced in volume, split-phase operations would result in an overall increase in delay for the intersection.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	No.	
b)	**<u>If answer to 2a is "No":</u>** **Should a left-turn lane be installed?**	No. *Existing right-of-way appears to be too narrow to accommodate an additional median lane. On the eastbound approach, converting the shared left-turn/through lane is not an option due to the presence of parking during off-peak hours.*	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A. *In lieu of left-turn lane.*	
3b.	**If <u>No</u> Exclusive Left-Turn Lane Exists (If answer to 2a <u>AND</u> 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**		
	Crash History	No. *2 eastbound left-turn related crashes from May 2009 to November 2012. 0 westbound left-turn related crashes in the same time period.*	
	Operational	Yes. *The eastbound left-turn movement operates at LOS F with overcapacity conditions during AM peak hour of traffic and LOS D during the PM peak hour of traffic. The westbound left-turn movement operates adequately at LOS E(C) during the AM(PM) peak hours.*	
ii)	**<u>If answer to 3bi is "Yes" for Operational:</u>** **NYDOT shared left-turn lane warrant satisfied?**	No. *However, warrant does not take into account the reduced left-turn capacity due to the heavy pedestrian volume (133 eastbound left-turn conflicting pedestrians in AM, 39 in PM).*	Exercise engineering judgment.
4.	**Recommendation & Discussion**		
	Although the NYDOT shared left-turn warrant is not satisfied for the eastbound and westbound movements, the warrant does not take into account the reduced left-turn capacity due to the heavy pedestrian volumes; therefore, protected + permissive phasing was considered for the eastbound movement. However, analysis of the intersection modeling protected + permissive left-turn phasing on the eastbound approach indicates increased queue lengths on both eastbound and westbound approaches. Therefore, it is recommended that the eastbound and westbound movements maintain the existing permissive phasing.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing





DATE OF COUNTS:
WEDNESDAY, NOVEMBER 14, 2012

AM PEAK HOUR:
7:00 AM – 8:00 AM

PM PEAK HOUR:
4:30 PM – 5:30 PM

EXISTING PHASE DIAGRAM
EXISTING CONTROLLER

LEGEND

##(##) – AM(PM) PEAK HOUR OF TRAFFIC VOLUMES
X(X) – AM(PM) LOS
Y X/X – SIGNALIZED INTERSECTION Y, OVERALL AM/PM LOS
Y – INTERSECTION Y

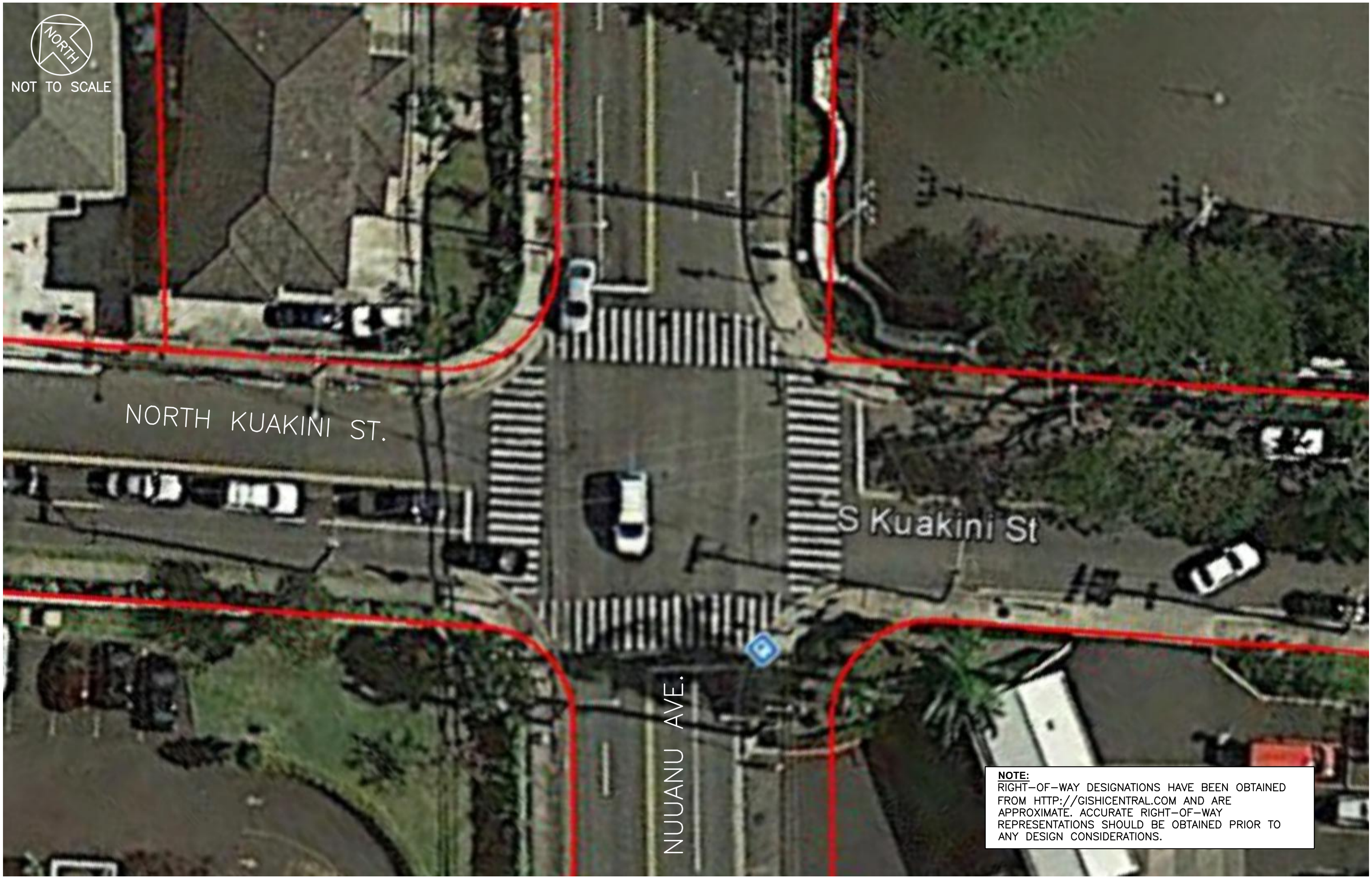
NOTE:
THIS SCHEMATIC DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. DO NOT USE FOR CONSTRUCTION.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

EXISTING LANE CONFIGURATION, VOLUME, AND LOS

EXHIBIT
C4-1



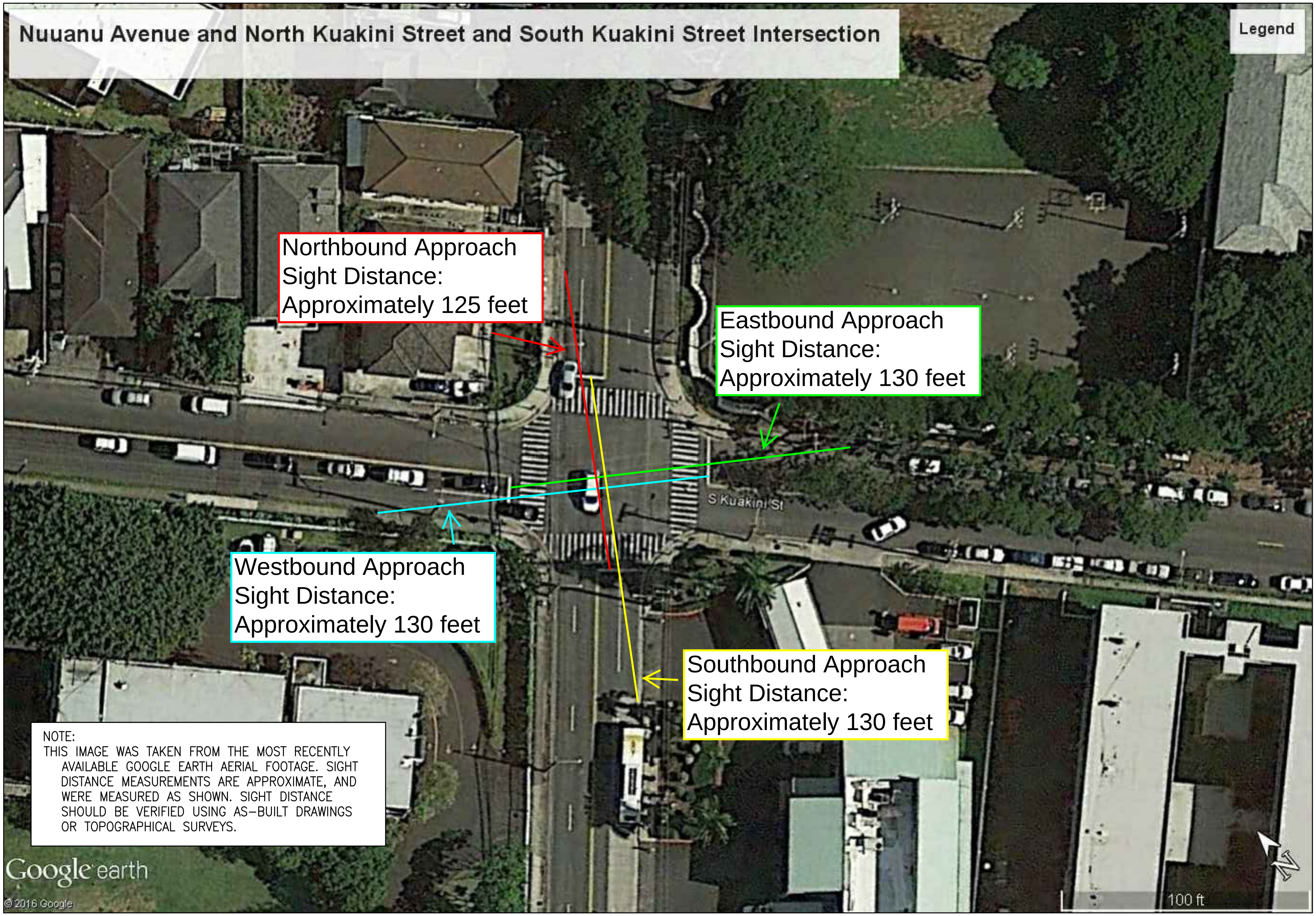
NOTE:
RIGHT-OF-WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT-OF-WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

G.I.S. APPROXIMATE RIGHT-OF-WAY BOUNDARIES

EXHIBIT
C4-2



Nuuanu Avenue and North Kuakini Street and South Kuakini Street Intersection

Northbound Approach
Sight Distance:
Approximately 125 feet

Eastbound Approach
Sight Distance:
Approximately 130 feet

Westbound Approach
Sight Distance:
Approximately 130 feet

Southbound Approach
Sight Distance:
Approximately 130 feet

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

SIGHT DISTANCE ANALYSIS

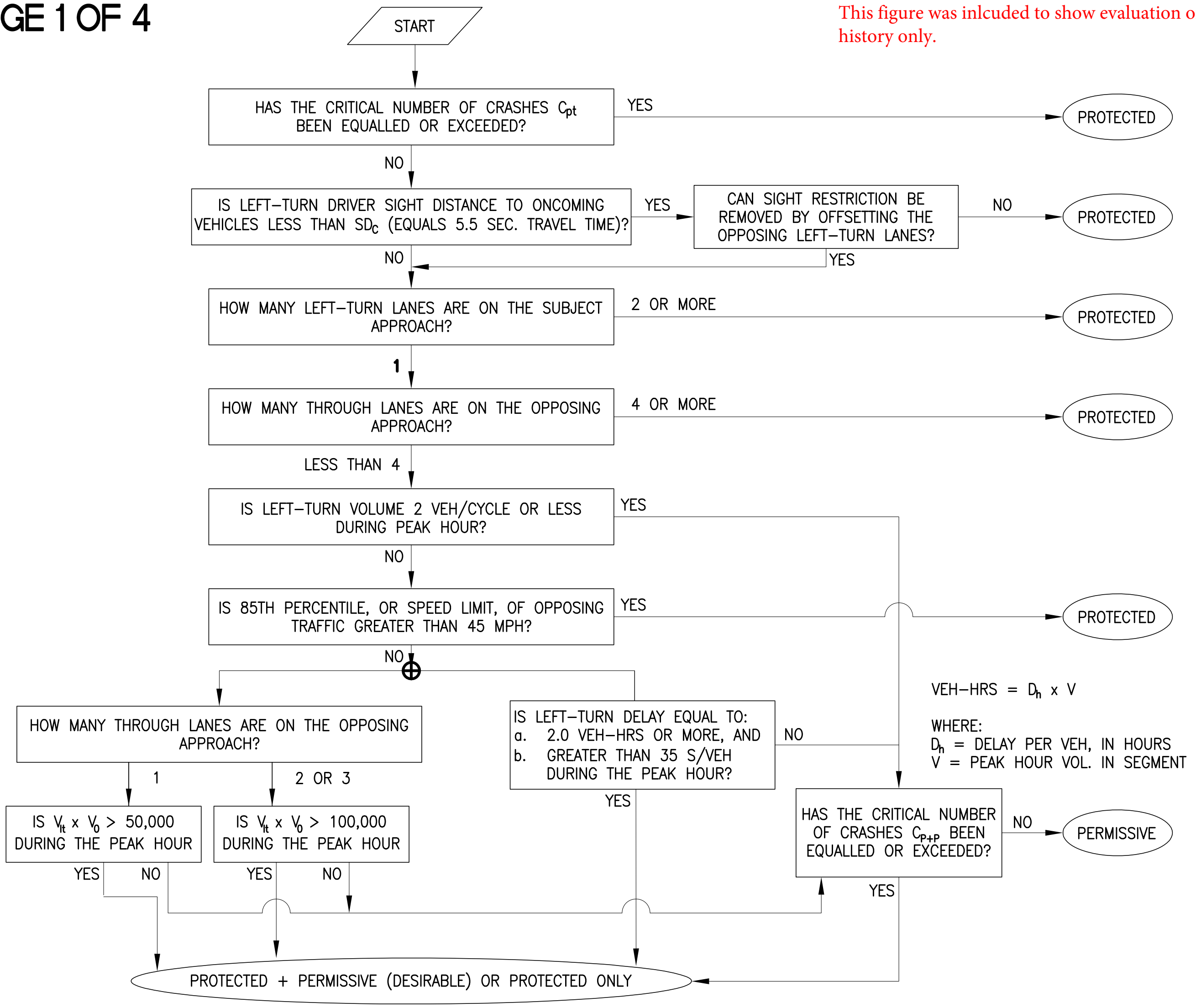
EXHIBIT

C4-3

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection

PAGE 1 OF 4

This figure was inlcuded to show evaluation of crash history only.



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	2
BOTH	2	18	9	3
BOTH	3	26	13	4

Not Met

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT-TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT-TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT-TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE-RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT-TURN ARROW.

SPECIAL CASE: SHARED LEFT-TURN/THROUGH LANE (Northbound, Southbound, Eastbound and Westbound Approaches)

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED-ONLY LEFT-TURN PHASING WHERE LEFT-TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT-TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE-ONLY LEFT-TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT-TURN PHASES FOR SHARED LEFT-TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT-TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT-TURN LANE:

- **IF A DEDICATED LEFT-TURN LANE CAN BE FEASIBLY CONSTRUCTED,** UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT-TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT-TURN LANE,** CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT-TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT-TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:
    - THE LEFT-TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT-TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT-TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT-TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT-TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.

    See Fig 1 - Does not meet
  - OPERATIONS: IF THE LEFT-TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT-TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT-TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT-TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT-TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

    NB, SB, EB, WB: NYDOT Warrant Completed

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE - 1

FIGURE

3

PAGE 3 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT-TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT-TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT-TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE-RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT-TURN ARROW.

SPECIAL CASE: SHARED LEFT-TURN/THROUGH LANE

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED-ONLY LEFT-TURN PHASING WHERE LEFT-TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT-TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE-ONLY LEFT-TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT-TURN PHASES FOR SHARED LEFT-TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT-TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT-TURN LANE:

- **IF A DEDICATED LEFT-TURN LANE CAN BE FEASIBLY CONSTRUCTED,** UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT-TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT-TURN LANE,** CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT-TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT-TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:
    - THE LEFT-TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT-TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT-TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT-TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT-TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT-TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT-TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT-TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT-TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT-TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

Northbound and Southbound Approaches: Not recommended. The through volume is heavy and balanced. Going to split-phase would adversely affect Nuuanu Avenue.

Eastbound and Westbound Approaches: Although the eastbound and westbound approaches are somewhat unbalanced in volume, split-phase operations would result in an overall increase in delay for the intersection.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

ATA AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE - 1

FIGURE
3

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - Nuuanu Avenue Northbound AM

Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles

(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 283 x 4 = 1132 vph

Using TABLE 1, f_{PCE} = 7.00

V_{TV} = 113 x 4 = 452 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate

(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 26 x 4 = 104 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 104 x 7.00 = 728 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 728 ÷ (452 + 728) = 0.617

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
2	.90
> 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 50-3 x 0.90 = 42.3 seconds

c = cycle length = 87 seconds

thus, (g/c)$_{LT}$ = 0.486

and C_{SLT} = [(1400 - 1132) (0.486) $_{LT}$] x 0.617 = 80.36 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 104 vph [✓ >] or < C_{SLT}* = 82.8 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection -
Nuuanu Avenue Northbound PM

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 184 x 4 = 736 vph

Using TABLE 1, f_{PCE} = 3.00

V_{TV} = 62 x 4 = 248 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 51 x 4 = 204 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 204 x 3.00 = 612 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 612 ÷ (248 + 612) = 0.712

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
$\geq$ 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 50-3 x 0.90 = 42.3 seconds

c = cycle length = 87 seconds

thus, $(g/c)_{LT}$ = 0.486

and C_{SLT} = [(1400 - 736) (0.559) $_{LT}$] x 0.712 = 229.77 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 204 vph > or [✓ <] C_{SLT}* = 229.77 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - Nuuanu Avenue Southbound AM

Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 129 x 4 = 516 vph

Using TABLE 1, f_{PCE} = 2.50

V_{TV} = 56 x 4 = 224 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 46 x 4 = 184 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 184 x 2.50 = 460 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 460 ÷ (224 + 460) = 0.673

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
≥ 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 50-3 x 0.90 = 42.3 seconds

c = cycle length = 87 seconds

thus, (g/c)$_{LT}$ = 0.486

and C_{SLT} = [(1400 - 516) (0.486) $_{LT}$] x 0.673 = 289.14 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 184 vph > or [✓ <] C_{SLT}* = 289.14 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - Nuuanu Southbound PM

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles

(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 196 x 4 = 784 vph

Using TABLE 1, f_{PCE} = 3.00

V_{TV} = 86 x 4 = 344 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate

(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 11 x 4 = 44 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 44 x 3.00 = 132 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 132 ÷ (344 + 132) = 0.277

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
$\geq$ 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 50-3 x 0.90 = 42.3 seconds

c = cycle length = 87 seconds

thus, (g/c)$_{LT}$ = 0.486

and C_{SLT} = [(1400 - 784) (0.486) $_{LT}$] x 0.277 = 82.93 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 44 vph   >   or   [✓ <] C_{SLT}* = 82.93 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - North Kuakini Street Eastbound AM

Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles

(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 69 x 4 = 276 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 36 x 4 = 144 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate

(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 62 x 4 = 248 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 248 x 2.00 = 496 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 496 ÷ (144 + 496) = 0.775

TABLE 2	
OPPOSING THRU LANES	f_q
[✓ 1]	[✓ .85]
2	.90
$\geq$ 3	.95

Left Turn Capacity

$$\boxed{C_{SLT} = [\,(1{,}400 - V_O)\,(\,g/c\,)_{LT}\,]\;f_{SLT}}$$

where:

$g = [\,G + Y + AR - 3.0\,] \times f_q$ = (37-3) x 0.85 = 28.9 seconds

c = cycle length = 87 seconds

thus, $(\,g/c\,)_{LT}$ = 0.332

and C_{SLT} = [(1400 - 276) (0.332) $_{LT}$] x 0.775 = 289.21 vph

or

$$\boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

$C_{SLT} = 2 \times (3600 \div C)$ = 82.76 vph

V_{LT}= 248 vph | > or [✓ <] | C_{SLT}^{*} = 289.21 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - North Kuakini Street Eastbound PM

Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 22 x 4 = 88 vph

Using TABLE 1, f_{PCE} = 1.50

V_{TV} = 5 x 4 = 20 vph

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 85 x 4 = 340 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 340 x 1.50 = 510 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 510 ÷ (20 + 510) = 0.962

where: V_{TV} = Thru vehicles in the shared lane.

TABLE 2	
OPPOSING THRU LANES	f_q
[✓ 1]	[✓ .85]
2	.90
$\geq$ 3	.95

Left Turn Capacity

$$\boxed{C_{SLT} = [\,(1{,}400 - V_O)\,(\,g/c\,)_{LT}\ ]\ f_{SLT}}$$

where:

g = [G + Y + AR – 3.0] x f_q = (37-3) x 0.85 = 28.9 seconds

c = cycle length = 87 seconds

thus, $(\,g/c\,)_{LT}$ = 0.332

and C_{SLT} = [(1400 - 88) (0.332) $_{LT}$] x 0.962 = 419.0 vph

or

$$\boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

C_{SLT} = 2 x (3600 ÷ C) = 82 vph

V_{LT}= 340 vph > or [✓ <] $C_{SLT}{}^*$ = 419.0 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - South Kuakini Street Westbound AM

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles (Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 124 x 4 = 496 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 38 x 4 = 152 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate (Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 32 x 4 = 128 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 128 x 2.00 = 256 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 256 ÷ (152 + 256) = 0.627

TABLE 2

OPPOSING THRU LANES	f_q
1	.85
2	.90
≥ 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 37-3 x 0.90 = 30.6 seconds

c = cycle length = 87 seconds   thus, (g/c)$_{LT}$ = 0.352

and C_{SLT} = [(1400 - 496) (0.352) $_{LT}$] x 0.627 = 199.52 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 128 vph   > or [✓ <] C_{SLT}* = 199.52 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Nuuanu Avenue/North Kuakini Street/South Kuakini Street Intersection - South Kuakini Street Westbound PM

Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles

(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 158 x 4 = 632 vph

Using TABLE 1, f_{PCE} = 2.50

V_{TV} = 56 x 4 = 224 vph

Left Turn Service Flow Rate

(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 6 x 4 = 24 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 24 x 2.50 = 60 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 60 ÷ (224 + 60) = 0.211

where: V_{TV} = Thru vehicles in the shared lane.

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
≥ 3	.95

Left Turn Capacity

$$\boxed{C_{SLT} = [\ (1{,}400 - V_O)\ (\ g/c\ )_{LT}\ ]\ f_{SLT}}$$

where:

g = [G + Y + AR – 3.0] x f_q = 37-3 x 0.90 = 30.6 seconds

c = cycle length = 87 seconds

thus, $(g/c)_{LT}$ = 0.352

and C_{SLT} = [(1400 - 632) (0.352) $_{LT}$] x 0.211 = 57.0 vph

or

$$\boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

C_{SLT} = 2 x (3600 ÷ C) = 82.8 vph

V_{LT}= 24 vph   >   or   [✓ <] C_{SLT}* = 82.8 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

3/17/2017

	⤴	→	⤵	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			✥			↰↑↱			↰↑↱	
Traffic Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Future Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		*0.60			1.00			0.95			0.95	
Frpb, ped/bikes		0.97			0.94			0.97			0.97	
Flpb, ped/bikes		0.97			1.00			1.00			0.98	
Frt		0.96			0.96			0.99			0.97	
Flt Protected		0.98			0.98			0.99			0.99	
Satd. Flow (prot)		1803			1686			3006			2926	
Flt Permitted		0.70			0.12			0.58			0.75	
Satd. Flow (perm)		1000			201			1764			2219	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	245	324	193	104	124	107	88	436	57	138	838	235
RTOR Reduction (vph)	0	18	0	0	19	0	0	9	0	0	24	0
Lane Group Flow (vph)	0	744	0	0	316	0	0	572	0	0	1187	0
Confl. Peds. (#/hr)	133		75	75		133	72		330	330		72
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			31.0			44.0			44.0	
Effective Green, g (s)		31.0			31.0			44.0			44.0	
Actuated g/C Ratio		0.36			0.36			0.51			0.51	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		356			71			892			1122	
v/s Ratio Prot												
v/s Ratio Perm		0.74			c1.57			0.32			c0.53	
v/c Ratio		2.09			4.45			0.64			1.06	
Uniform Delay, d1		28.0			28.0			15.7			21.5	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		499.9			1582.9			3.5			43.5	
Delay (s)		527.9			1610.9			19.2			65.0	
Level of Service		F			F			B			E	
Approach Delay (s)		527.9			1610.9			19.2			65.0	
Approach LOS		F			F			B			E	

Intersection Summary			
HCM 2000 Control Delay	357.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	2.44		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	12.0
Intersection Capacity Utilization	119.5%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

3/17/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↑↱			↰↑↱			↰↑↑↱			↰↑↑↱	
Traffic Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Future Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		0.95			1.00			0.95			0.95	
Frt		0.97			0.92			0.99			0.96	
Flt Protected		0.98			0.99			0.99			1.00	
Satd. Flow (prot)		3036			1732			3109			3038	
Flt Permitted		0.81			0.74			0.64			0.87	
Satd. Flow (perm)		1000			1288			1998			2647	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	334	423	189	18	20	55	173	645	89	36	486	217
RTOR Reduction (vph)	0	25	0	0	35	0	0	9	0	0	52	0
Lane Group Flow (vph)	0	921	0	0	58	0	0	898	0	0	687	0
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			31.0			44.0			44.0	
Effective Green, g (s)		31.0			31.0			44.0			44.0	
Actuated g/C Ratio		0.36			0.36			0.51			0.51	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		356			458			1010			1338	
v/s Ratio Prot												
v/s Ratio Perm		c0.92			0.04			c0.45			0.26	
v/c Ratio		2.59			0.13			0.89			0.51	
Uniform Delay, d1		28.0			18.9			19.3			14.4	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		722.2			0.6			11.6			1.4	
Delay (s)		750.2			19.4			30.9			15.8	
Level of Service		F			B			C			B	
Approach Delay (s)		750.2			19.4			30.9			15.8	
Approach LOS		F			B			C			B	

Intersection Summary			
HCM 2000 Control Delay	279.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.59		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	12.0
Intersection Capacity Utilization	94.5%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

Queuing and Blocking Report
Baseline

8/22/2016

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	B6	NB	NB	SB	SB
Directions Served	LT	TR	LTR	T	LT	TR	LT	TR
Maximum Queue (ft)	616	608	515	84	325	295	487	475
Average Queue (ft)	399	340	295	13	190	164	227	221
95th Queue (ft)	677	639	529	72	310	288	382	384
Link Distance (ft)	2323	2323	450	708	1379	1379	1264	1264
Upstream Blk Time (%)			13					
Queuing Penalty (veh)			0					
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Network Summary

Network wide Queuing Penalty: 0

Queuing and Blocking Report
Baseline

8/22/2016

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	NB	NB	SB	SB
Directions Served	LT	TR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	1306	1266	91	336	312	190	227
Average Queue (ft)	859	808	40	190	174	115	109
95th Queue (ft)	1622	1585	80	289	280	172	189
Link Distance (ft)	2323	2323	450	1379	1379	1264	1264
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)							
Storage Blk Time (%)							
Queuing Penalty (veh)							

Network Summary

Network wide Queuing Penalty: 0

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

8/22/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↑↱			↰↑↱			↰↑↑↱			↰↑↑↱	
Traffic Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Future Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		*0.60			1.00			0.95			0.95	
Frpb, ped/bikes		0.97			0.94			0.97			0.97	
Flpb, ped/bikes		0.97			1.00			1.00			0.98	
Frt		0.96			0.96			0.99			0.97	
Flt Protected		0.98			0.98			0.99			0.99	
Satd. Flow (prot)		1803			1686			3013			2922	
Flt Permitted		0.70			0.12			0.55			0.78	
Satd. Flow (perm)		1000			201			1663			2298	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	245	324	193	104	124	107	88	436	57	138	838	235
RTOR Reduction (vph)	0	18	0	0	19	0	0	9	0	0	24	0
Lane Group Flow (vph)	0	744	0	0	316	0	0	572	0	0	1187	0
Confl. Peds. (#/hr)	133		75	75		133	72		330	330		72
Turn Type	Perm	NA		Perm	NA		pm+pt	NA		Perm	NA	
Protected Phases		4			8		5	2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			31.0			44.0			36.0	
Effective Green, g (s)		31.0			31.0			44.0			36.0	
Actuated g/C Ratio		0.36			0.36			0.51			0.41	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		356			71			903			950	
v/s Ratio Prot								c0.03				
v/s Ratio Perm		0.74			c1.57			0.29			c0.52	
v/c Ratio		2.09			4.45			0.63			1.25	
Uniform Delay, d1		28.0			28.0			15.6			25.5	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		499.9			1582.9			3.4			121.0	
Delay (s)		527.9			1610.9			19.0			146.5	
Level of Service		F			F			B			F	
Approach Delay (s)		527.9			1610.9			19.0			146.5	
Approach LOS		F			F			B			F	

Intersection Summary			
HCM 2000 Control Delay	391.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	2.60		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	119.5%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

8/22/2016

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↑↱			↰↑↱			↰↑↑↱			↰↑↑↱	
Traffic Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Future Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		0.95			1.00			0.95			0.95	
Frt		0.97			0.92			0.99			0.96	
Flt Protected		0.98			0.99			0.99			1.00	
Satd. Flow (prot)		3036			1732			3109			3038	
Flt Permitted		0.81			0.74			0.59			0.87	
Satd. Flow (perm)		1000			1288			1862			2635	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	334	423	189	18	20	55	173	645	89	36	486	217
RTOR Reduction (vph)	0	25	0	0	35	0	0	9	0	0	52	0
Lane Group Flow (vph)	0	921	0	0	58	0	0	898	0	0	687	0
Turn Type	Perm	NA		Perm	NA		pm+pt	NA		Perm	NA	
Protected Phases		4			8		5	2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			31.0			44.0			36.0	
Effective Green, g (s)		31.0			31.0			44.0			36.0	
Actuated g/C Ratio		0.36			0.36			0.51			0.41	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		356			458			999			1090	
v/s Ratio Prot								c0.04				
v/s Ratio Perm		c0.92			0.04			c0.41			0.26	
v/c Ratio		2.59			0.13			0.90			0.63	
Uniform Delay, d1		28.0			18.9			19.5			20.2	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		722.2			0.6			12.5			2.8	
Delay (s)		750.2			19.4			32.0			23.0	
Level of Service		F			B			C			C	
Approach Delay (s)		750.2			19.4			32.0			23.0	
Approach LOS		F			B			C			C	

Intersection Summary			
HCM 2000 Control Delay	282.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.68		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	94.5%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	B6	NB	NB	SB	SB
Directions Served	LT	TR	LTR	T	LT	TR	LT	TR
Maximum Queue (ft)	784	717	477	190	228	211	534	537
Average Queue (ft)	468	411	268	69	133	110	301	298
95th Queue (ft)	911	870	509	372	210	191	477	462
Link Distance (ft)	2323	2323	450	708	1379	1379	1264	1264
Upstream Blk Time (%)			16	0				
Queuing Penalty (veh)			0	0				
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Network Summary

Network wide Queuing Penalty: 0

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	NB	NB	SB	SB
Directions Served	LT	TR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	953	929	106	316	289	231	226
Average Queue (ft)	646	599	39	186	169	134	130
95th Queue (ft)	1076	1049	80	277	268	208	215
Link Distance (ft)	2323	2323	450	1379	1379	1264	1264
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)							
Storage Blk Time (%)							
Queuing Penalty (veh)							

Network Summary

Network wide Queuing Penalty: 0

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

8/22/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			✥			↰↑↱			↰↑↱	
Traffic Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Future Volume (vph)	225	298	178	96	114	98	81	401	52	127	771	216
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		*0.60			1.00			0.95			0.95	
Frpb, ped/bikes		0.97			0.94			0.97			0.97	
Flpb, ped/bikes		0.99			0.99			1.00			0.98	
Frt		0.96			0.96			0.99			0.97	
Flt Protected		0.98			0.98			0.99			0.99	
Satd. Flow (prot)		1828			1676			3006			2926	
Flt Permitted		0.64			0.13			0.58			0.75	
Satd. Flow (perm)		1000			219			1764			2219	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	245	324	193	104	124	107	88	436	57	138	838	235
RTOR Reduction (vph)	0	18	0	0	19	0	0	9	0	0	24	0
Lane Group Flow (vph)	0	744	0	0	316	0	0	572	0	0	1187	0
Confl. Peds. (#/hr)	133		75	75		133	72		330	330		72
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	7	4			8			2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			23.0			44.0			44.0	
Effective Green, g (s)		31.0			23.0			44.0			44.0	
Actuated g/C Ratio		0.36			0.26			0.51			0.51	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		394			57			892			1122	
v/s Ratio Prot		c0.09										
v/s Ratio Perm		0.59			c1.44			0.32			c0.53	
v/c Ratio		1.89			5.54			0.64			1.06	
Uniform Delay, d1		28.0			32.0			15.7			21.5	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		409.2			2081.6			3.5			43.5	
Delay (s)		437.2			2113.6			19.2			65.0	
Level of Service		F			F			B			E	
Approach Delay (s)		437.2			2113.6			19.2			65.0	
Approach LOS		F			F			B			E	

Intersection Summary

HCM 2000 Control Delay	391.5	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	2.55		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	119.5%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

HCM Signalized Intersection Capacity Analysis
3: N Kuakini St/S Kuakini St & Nuuanu Ave

8/22/2016

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			✣			↰↑↱			↰↑↱	
Traffic Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Future Volume (vph)	307	389	174	17	18	51	159	593	82	33	447	200
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	16	12	12	12	12	12	12	12
Total Lost time (s)		6.0			6.0			6.0			6.0	
Lane Util. Factor		0.95			1.00			0.95			0.95	
Frt		0.97			0.92			0.99			0.96	
Flt Protected		0.98			0.99			0.99			1.00	
Satd. Flow (prot)		3036			1732			3109			3038	
Flt Permitted		0.79			0.77			0.64			0.87	
Satd. Flow (perm)		1000			1351			1998			2647	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	334	423	189	18	20	55	173	645	89	36	486	217
RTOR Reduction (vph)	0	25	0	0	40	0	0	9	0	0	52	0
Lane Group Flow (vph)	0	921	0	0	53	0	0	898	0	0	687	0
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	7	4			8			2			6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		31.0			23.0			44.0			44.0	
Effective Green, g (s)		31.0			23.0			44.0			44.0	
Actuated g/C Ratio		0.36			0.26			0.51			0.51	
Clearance Time (s)		6.0			6.0			6.0			6.0	
Vehicle Extension (s)		3.0			3.0			3.0			3.0	
Lane Grp Cap (vph)		449			357			1010			1338	
v/s Ratio Prot		c0.09										
v/s Ratio Perm		c0.64			0.04			c0.45			0.26	
v/c Ratio		2.05			0.15			0.89			0.51	
Uniform Delay, d1		28.0			24.5			19.3			14.4	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		480.6			0.9			11.6			1.4	
Delay (s)		508.6			25.4			30.9			15.8	
Level of Service		F			C			C			B	
Approach Delay (s)		508.6			25.4			30.9			15.8	
Approach LOS		F			C			C			B	

Intersection Summary			
HCM 2000 Control Delay	194.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.42		
Actuated Cycle Length (s)	87.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	94.5%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	B6	NB	NB	SB	SB
Directions Served	LT	TR	LTR	T	LT	TR	LT	TR
Maximum Queue (ft)	771	723	549	486	310	296	429	430
Average Queue (ft)	486	440	476	273	181	157	233	231
95th Queue (ft)	885	851	643	728	294	280	397	391
Link Distance (ft)	2323	2323	450	708	1379	1379	1264	1264
Upstream Blk Time (%)			70	11				
Queuing Penalty (veh)			0	0				
Storage Bay Dist (ft)								
Storage Blk Time (%)								
Queuing Penalty (veh)								

Network Summary

Network wide Queuing Penalty: 0

Intersection: 3: N Kuakini St/S Kuakini St & Nuuanu Ave

Movement	EB	EB	WB	NB	NB	SB	SB
Directions Served	LT	TR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	1833	1791	111	296	277	181	204
Average Queue (ft)	1194	1163	46	183	167	105	105
95th Queue (ft)	1848	1812	91	277	258	161	172
Link Distance (ft)	2323	2323	450	1379	1379	1264	1264
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)							
Storage Blk Time (%)							
Queuing Penalty (veh)							

Network Summary

Network wide Queuing Penalty: 0

5. CASE STUDY: KAILUA ROAD AND HAMAKUA DRIVE AND KAINEHE STREET

Existing Conditions

At the Kailua Road/Hamakua Drive/Kainehe Street intersection, the northbound and southbound approaches on Kailua Road include exclusive left-turn lanes and operate with permissive left-turn phasing. The westbound approach on Hamakua Drive services the left-turn movement with one exclusive left-turn lane and one shared left-turn/through/right-turn lane. The eastbound approach on Kainehe Street services the left-turn movement with a shared left-turn/through lane. The westbound and eastbound approaches operate with split phasing. See Exhibit C5-1 for the existing intersection layout.

Traffic Observations & Analysis

As a major intersection along a major arterial in Kailua with heavy volumes, a long cycle length, and split phasing, the intersection experiences queuing on all approaches during the AM and PM peak hours of traffic.

Queues along Hamakua Drive in the westbound direction can extend to Hekili Street during the AM peak period but generally clear within one (1) cycle length. Traffic analysis indicates this westbound left-turn movement operates at LOS D(E) during the AM(PM) peak hours of traffic. Split phasing along the eastbound and westbound approaches helps facilitate the large imbalance of left-turn volumes between the two approach movements. As a result of a long cycle length and split phasing, the eastbound left-turn/through movement operates at LOS E(F) during the AM(PM) peak hours of traffic.

The northbound left-turn movement operates at LOS D during the AM and PM peak hours of traffic but queues during the PM peak period often spill out of the short left-turn pocket and block the northbound through movement; however, left-turning vehicles that enter the intersection during its permissive phase help alleviate this issue. The length of the northbound left-turn pocket is currently constrained by the geometry of the bridge crossing a stream on the south side of the intersection. Observations also suggest that the operation of northbound vehicles may create unusual conflict scenarios due to the bus stop on the receiving side of the intersection.

See Table C5-1 for a summary of the LOS analysis results.

Conclusions

See Table C5-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

Northbound & Southbound Approaches

The existing permissive phasing should be maintained for the northbound and southbound approaches, provided that the sight distance restriction could be removed by offsetting the opposing left-turn lanes. This can be achieved by making lateral adjustments to the left-turn pocket, which may require cutting into the median on either the northbound, southbound, or both approaches. If feasible, the northbound left-turn storage length should be lengthened. The current storage lane length appears to be dictated by the nearby bridge width and the extension of this storage lane may require extensive work on the bridge.

Eastbound/Westbound Approach

The existing split-phase operations should be maintained for the eastbound and westbound approaches. The westbound traffic volumes are much heavier than the eastbound volumes, resulting in imbalanced approach volumes. Due to lack of available right-of-way and a large skew angle, other phasing options are not recommended.

Table C5-1: Level of Service Summary Table

Intersection	Existing Conditions					
	AM			PM		
	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
5. Kailua Road/Hamakua Drive/Kainehe Street						
NB LT	38.5	0.28	D	44.2	0.36	D
NB TH/RT	24.8	0.38	C	34.0	0.56	C
NB RT	25.9	0.39	C	39.7	0.66	D
EB LT/TH	65.1	0.85	E	96.9	0.93	F
EB RT	56.4	0.68	E	60.6	0.48	E
WB LT	48.7	0.80	D	57.5	0.70	E
SB LT	31.8	0.13	C	57.2	0.36	E
SB TH/RT	27.3	0.47	C	30.8	0.38	C
Overall	37.9	-	D	50.4	-	D

Table C5-2: Left-Turn Warrant Guidelines Summary
Kailua Road & Hamakua Drive & Kainehe Street

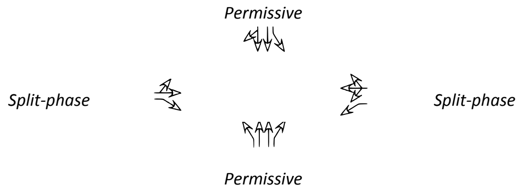
North-South (Kailua Road)

No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Kailua Road.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	Yes.	
b)	**If answer to 2a is "No": Should a left-turn lane be installed?**	N/A.	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	Permissive phasing. *Permissive phasing recommendation contingent on offsetting the left-turn lanes to meet sight distance requirements.*	Maintain existing permissive phasing.
3b.	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History		
	Operational		
ii)	**If answer to 3bi is "Yes" for Operational: NYDOT shared left-turn lane warrant satisfied?**	N/A.	
4.	**Recommendation & Discussion**		
	Maintain existing permissive phasing. This recommendation assumes that the sight distance restriction can be removed by offsetting the opposing left-turn lanes. See Figure C5-2 for a schematic diagram for accomplishing this.		

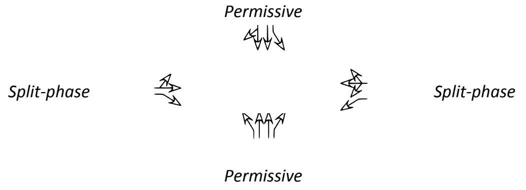
East-West (Hamakua Drive & Kainehe Street)

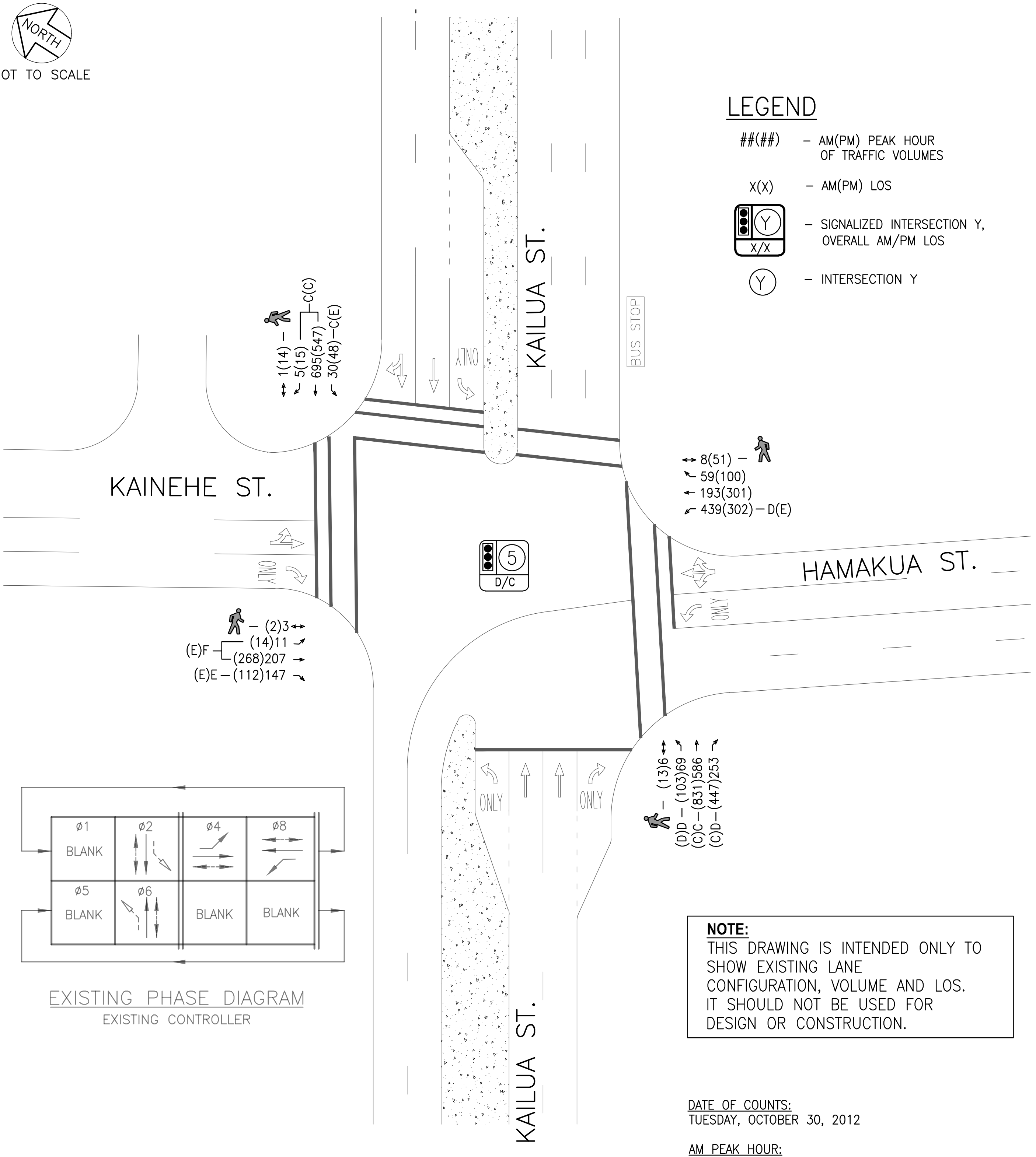
No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	Yes. *The westbound left-turn lane volume is heavier than its opposing (eastbound) through volume during the AM and PM peak hours. The westbound approach in general is also much heavier in terms of volume than the eastbound approach. Due to lack of available right-of-way and a large skew angle, other phasing options are not recommended.*	Maintain existing split-phase.
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	N/A.	
b)	**If answer to 2a is "No": Should a left-turn lane be installed?**		
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A.	
3b.	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History		
	Operational		
ii)	**If answer to 3bi is "Yes" for Operational: NYDOT shared left-turn lane warrant satisfied?**		
4.	**Recommendation & Discussion**		
	Maintain existing split-phasing.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing





EXISTING PHASE DIAGRAM
EXISTING CONTROLLER

LEGEND

##(##) – AM(PM) PEAK HOUR OF TRAFFIC VOLUMES

X(X) – AM(PM) LOS

Y X/X – SIGNALIZED INTERSECTION Y, OVERALL AM/PM LOS

Y – INTERSECTION Y

NOTE:
THIS DRAWING IS INTENDED ONLY TO SHOW EXISTING LANE CONFIGURATION, VOLUME AND LOS. IT SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION.

DATE OF COUNTS:
TUESDAY, OCTOBER 30, 2012

AM PEAK HOUR:
7:30 AM – 8:30 AM

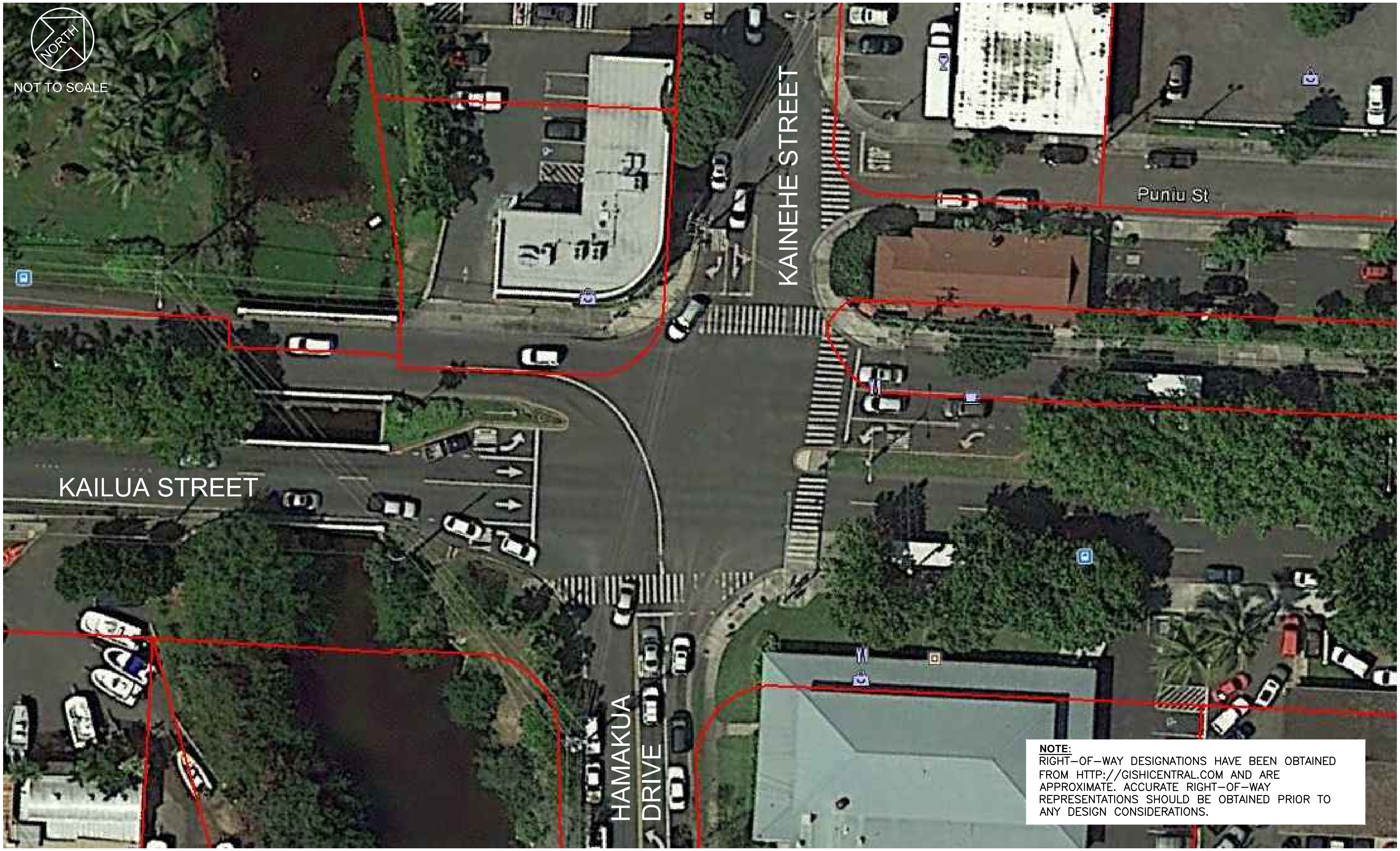
PM PEAK HOUR:
4:30 PM – 5:30 PM

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

EXISTING LANE CONFIGURATION, VOLUME, AND LOS

EXHIBIT
C5-1



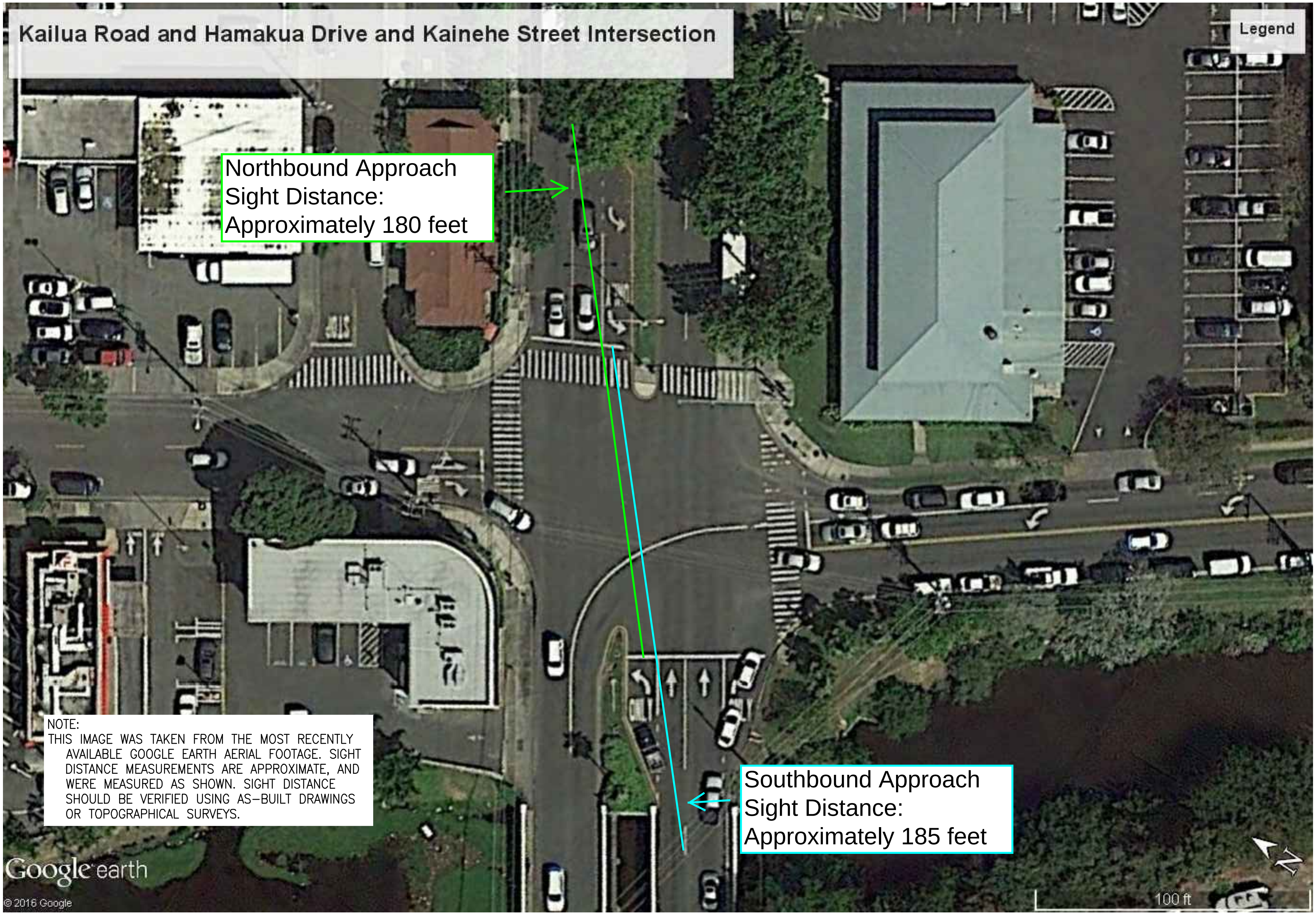
NOTE:
RIGHT–OF–WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT–OF–WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

G.I.S. APPROXIMATE RIGHT–OF–WAY BOUNDARIES

FIGURE
C5–2



Kailua Road and Hamakua Drive and Kainehe Street Intersection

Northbound Approach
Sight Distance:
Approximately 180 feet

Southbound Approach
Sight Distance:
Approximately 185 feet

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

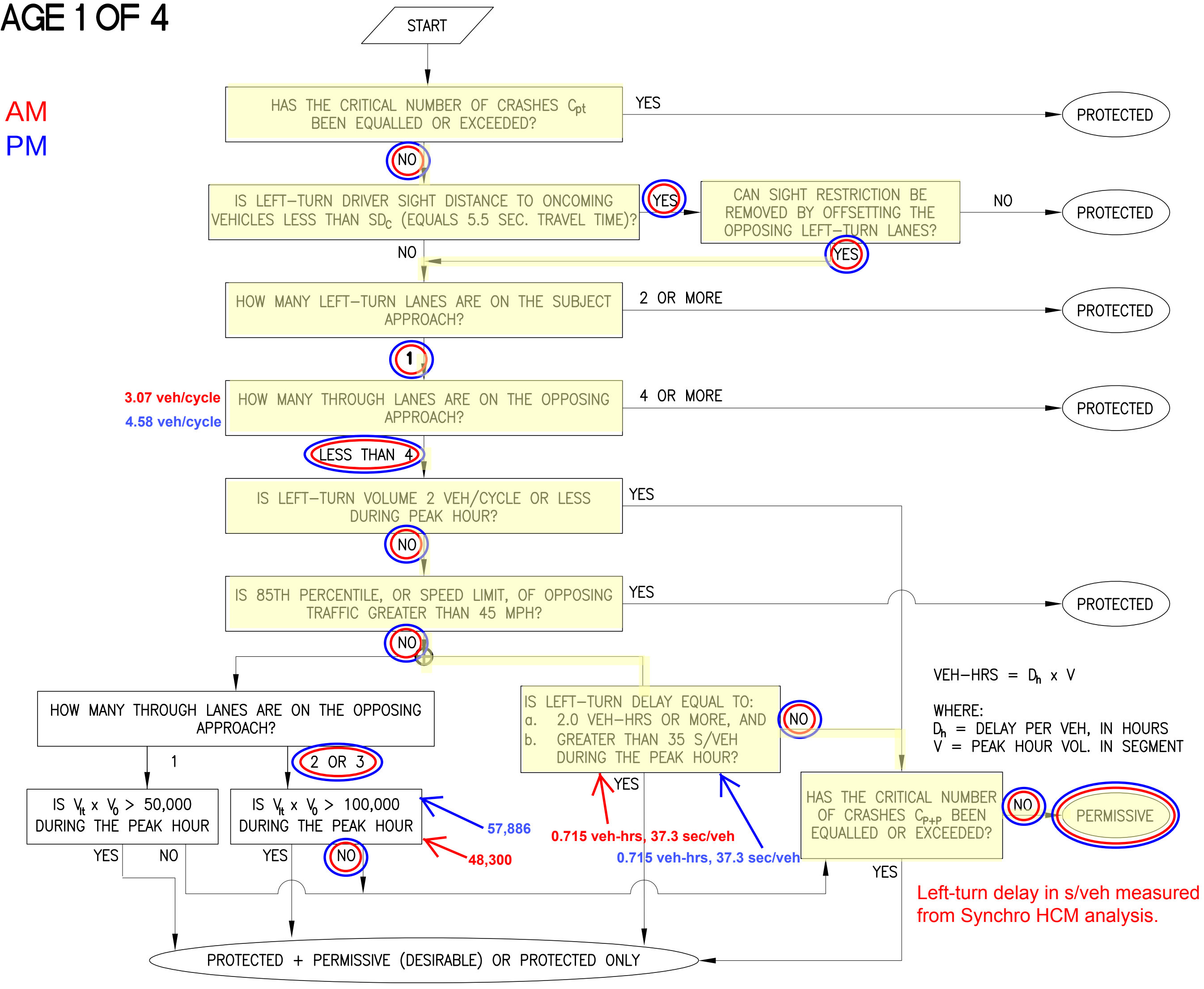
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

SIGHT DISTANCE ANALYSIS

FIGURE
C5-3

Kailua Road/Hamakua Drive/Kainehe Street - Kailua Road Northbound

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT	
		WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⌖ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT-TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS-PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

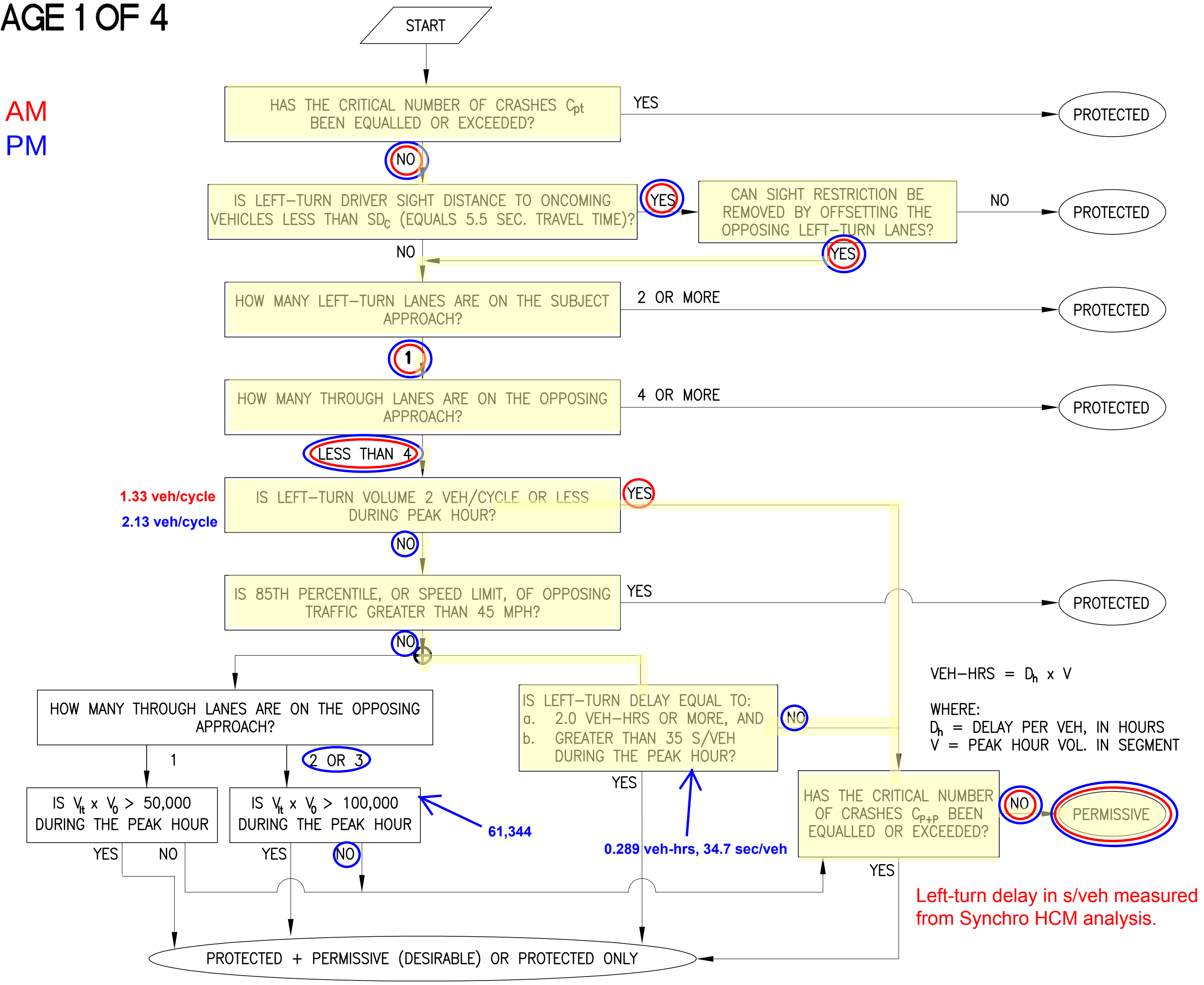
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

Kailua Road/Hamakua Drive/Kainehe Street - Kailua Road Southbound

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)
ONE	1	6	4
ONE	2	11	6
ONE	3	14	7
BOTH	1	11	6
BOTH	2	18	9
BOTH	3	26	13

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

HCM 2010 Signalized Intersection Summary
3: Kainehe St/Hamakua Dr & Kailua Rd

9/1/2016

	↰	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰	↱	↰	✥		↰	↑↱	↱	↰	↑↱	
Traffic Volume (veh/h)	11	207	147	439	193	59	69	586	253	30	695	5
Future Volume (veh/h)	11	207	147	439	193	59	69	586	253	30	695	5
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.99	1.00		0.99	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1863	1863	1863	1900	1863	1863	1863	1863	1863	1900
Adj Flow Rate, veh/h	12	225	160	376	352	64	75	637	275	33	755	5
Adj No. of Lanes	0	1	1	1	1	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	14	265	234	469	405	74	267	1671	705	259	1616	11
Arrive On Green	0.15	0.15	0.15	0.26	0.26	0.26	0.45	0.45	0.45	0.45	0.45	0.45
Sat Flow, veh/h	94	1764	1558	1774	1532	279	703	3725	1573	609	3604	24
Grp Volume(v), veh/h	237	0	160	376	0	416	75	637	275	33	371	389
Grp Sat Flow(s),veh/h/ln	1858	0	1558	1774	0	1811	703	1863	1573	609	1770	1858
Q Serve(g_s), s	16.3	0.0	12.8	26.0	0.0	28.9	11.0	15.0	15.4	5.0	19.2	19.2
Cycle Q Clear(g_c), s	16.3	0.0	12.8	26.0	0.0	28.9	30.2	15.0	15.4	20.0	19.2	19.2
Prop In Lane	0.05		1.00	1.00		0.15	1.00		1.00	1.00		0.01
Lane Grp Cap(c), veh/h	279	0	234	469	0	479	267	1671	705	259	793	833
V/C Ratio(X)	0.85	0.00	0.68	0.80	0.00	0.87	0.28	0.38	0.39	0.13	0.47	0.47
Avail Cap(c_a), veh/h	410	0	343	728	0	743	267	1671	705	259	793	833
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	54.5	0.0	52.9	45.2	0.0	46.2	35.9	24.1	24.3	30.8	25.3	25.3
Incr Delay (d2), s/veh	10.6	0.0	3.5	3.6	0.0	6.9	2.6	0.7	1.6	1.0	2.0	1.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	9.3	0.0	5.7	13.2	0.0	15.4	2.3	7.9	7.0	0.9	9.8	10.3
LnGrp Delay(d),s/veh	65.1	0.0	56.4	48.7	0.0	53.1	38.5	24.8	25.9	31.8	27.3	27.2
LnGrp LOS	E		E	D		D	D	C	C	C	C	C
Approach Vol, veh/h		397			792			987			793	
Approach Delay, s/veh		61.6			51.0			26.1			27.4	
Approach LOS		E			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		65.0		25.8		65.0		40.8
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		59.0		29.0		59.0		54.0
Max Q Clear Time (g_c+I1), s		22.0		18.3		32.2		30.9
Green Ext Time (p_c), s		15.5		1.4		13.4		3.9

Intersection Summary	
HCM 2010 Ctrl Delay	37.9
HCM 2010 LOS	D

Notes

HCM 2010 Signalized Intersection Summary
3: Kainehe St/Hamakua Dr & Kailua Rd

9/1/2016

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰	↱	↰	✥		↰	↑↱	↱	↰	↑↱	
Traffic Volume (veh/h)	14	268	112	302	301	100	103	831	447	48	547	15
Future Volume (veh/h)	14	268	112	302	301	100	103	831	447	48	547	15
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.91	1.00		0.94	1.00		0.98	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1863	1863	1863	1900	1863	1863	1863	1863	1863	1900
Adj Flow Rate, veh/h	15	291	122	328	327	109	112	938	463	52	595	16
Adj No. of Lanes	0	1	1	1	1	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	16	312	255	468	347	116	315	1667	697	145	1575	42
Arrive On Green	0.18	0.18	0.18	0.26	0.26	0.26	0.45	0.45	0.45	0.45	0.45	0.45
Sat Flow, veh/h	91	1767	1446	1774	1315	438	806	3725	1559	383	3520	95
Grp Volume(v), veh/h	306	0	122	328	0	436	112	938	463	52	299	312
Grp Sat Flow(s),veh/h/ln	1858	0	1446	1774	0	1754	806	1863	1559	383	1770	1845
Q Serve(g_s), s	26.0	0.0	12.1	26.7	0.0	39.0	17.2	29.8	37.4	18.6	18.0	18.0
Cycle Q Clear(g_c), s	26.0	0.0	12.1	26.7	0.0	39.0	35.2	29.8	37.4	48.3	18.0	18.0
Prop In Lane	0.05		1.00	1.00		0.25	1.00		1.00	1.00		0.05
Lane Grp Cap(c), veh/h	328	0	255	468	0	462	315	1667	697	145	792	825
V/C Ratio(X)	0.93	0.00	0.48	0.70	0.00	0.94	0.36	0.56	0.66	0.36	0.38	0.38
Avail Cap(c_a), veh/h	337	0	262	488	0	482	315	1667	697	145	792	825
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	65.0	0.0	59.3	53.2	0.0	57.7	41.1	32.6	34.8	50.5	29.4	29.4
Incr Delay (d2), s/veh	31.9	0.0	1.4	4.3	0.0	26.8	3.1	1.4	4.9	6.8	1.4	1.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	16.3	0.0	4.9	13.7	0.0	22.3	4.1	15.6	17.0	2.2	9.1	9.5
LnGrp Delay(d),s/veh	96.9	0.0	60.6	57.5	0.0	84.5	44.2	34.0	39.7	57.2	30.8	30.7
LnGrp LOS	F		E	E		F	D	C	D	E	C	C
Approach Vol, veh/h		428			764			1513			663	
Approach Delay, s/veh		86.5			72.9			36.5			32.8	
Approach LOS		F			E			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		77.6		34.2		77.6		48.2
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		69.0		29.0		69.0		44.0
Max Q Clear Time (g_c+I1), s		50.3		28.0		39.4		41.0
Green Ext Time (p_c), s		13.2		0.3		18.1		1.2

Intersection Summary		
HCM 2010 Ctrl Delay		50.4
HCM 2010 LOS		D

Notes

6. CASE STUDY: DILLINGHAM BOULEVARD AND KALIHI STREET

Existing Conditions

The Dillingham Boulevard and Kalihi Street intersection currently includes one shared through/right-turn lane and one shared left-turn/through lane on both the northbound and southbound Kalihi Street approaches. The eastbound and westbound approaches both include one exclusive left-turn lane, one through lane, and one shared through/right-turn lane. Left-turn phases on Dillingham Boulevard operate as protected-only, while left-turn phases on Kalihi Street operate as permissive. See Exhibit C6-1 for the existing intersection layout.

Traffic Observations & Analysis

Field observations reveal that vehicles making the southbound left-turn movement experience difficulty completing the movement during both AM and PM peak hours of traffic due to relatively heavy conflicting northbound through volumes during the PM peak and relatively high pedestrian volumes on the conflicting crosswalk on the east side of the intersection. During its peak, the queue in the southbound left-turn/through lane did not clear every cycle. Traffic analysis indicates this movement operates at LOS F with overcapacity conditions during both AM and PM peak hours of traffic.

Vehicles making the northbound left-turn movement were infrequent, with 16(36) vehicles making the movement during the AM(PM) peak hours of traffic. Generally, the northbound left-turn queue cleared every cycle. However, traffic analysis indicates that the movement operates at LOS F with overcapacity conditions during the PM peak hour. This is due to the fact that the left-turn movement shares a lane with the through movement, which during the PM peak backs up on Kalihi Street from School Street through Dillingham Boulevard, sometimes restricting northbound throughput at the subject intersection.

The eastbound and westbound left-turn movements generally operate adequately at LOS E(D) during the AM(PM) peak hours of traffic. See Table C6-1 for a summary of the LOS analysis results.

Conclusions

See Table C6-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

<u>Northbound/Southbound</u>

The existing permissive left-turn phasing should be maintained for the northbound and southbound approaches. Although neither of the northbound or southbound approaches currently include dedicated left-turn lanes, the existing right-of-way appears to be too narrow to accommodate an additional median lane and a road diet would have adverse impacts on all movements. As the New York Department of Transportation Left-Turn Phase Warrant was not satisfied for both northbound and southbound approaches, the existing permissive phasing appears to be appropriate.

Eastbound/Westbound

The existing protected left-turn phasing should be maintained for the eastbound and westbound approaches. As the approaches include dedicated left-turn lanes, Figure 1 was utilized to determine the appropriate left-turn phasing. The flowchart in Figure 1 yielded in a recommendation of permissive phasing for the eastbound left-turn movement and protected + permissive or protected-only phasing for the westbound left-turn movement. To maintain consistency and status quo, protected-only phasing is recommended for both eastbound and westbound movements.

Table C6-1: Level of Service Summary Table

Intersection	Existing Conditions					
	AM			PM		
	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
6. Dillingham Boulevard/Kalihi Street						
NB LT/TH	67.8	0.79	E	338.9	1.61	F*
NB TH/RT	48.9	0.66	D	125.5	1.10	F*
EB LT	67.1	0.78	E	47.1	0.82	D
EB TH/RT	26.1	0.75	C	19.5	0.65	B
WB LT	65.9	0.83	E	52.6	0.77	D
WB TH/RT	13.6	0.31	B	24.7	0.69	C
SB LT/TH	215.2	1.28	F*	491.5	1.89	F*
SB TH/RT	85.8	0.94	F	70.4	0.90	E
Overall	46.6	-	D	75.5	-	E

Table C6-2: Left-Turn Warrant Guidelines for Case Study Summary

Dillingham Boulevard & Kalihi Street

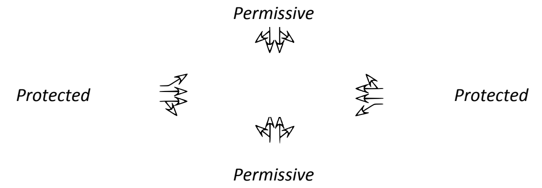
North-South (Kalihi Street)

No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced for a minor street. Going to split-phase would adversely affect Dillingham Boulevard.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	No.	
b)	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	No. *Road diet would likely have adverse imacts on all movements given the relatively heavy north-south volumes at this intersection. Existing right-of-way appears to be too narrow to accommodate an additional median lane.*	
3a.	**If Exclusive Left-Turn Lane Exists** **(If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	N/A. *In lieu of left-turn lane.*	
3b.	**If No Exclusive Left-Turn Lane Exists** **(If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**		
	Crash History	No. *4 southbound left-turn related crashes from April 2013 to October 2014.*	
	Operational	Yes. *Northbound and southbound left-turn movements operate at LOS E or LOS F and overcapacity conditions during the AM and PM peak hours of traffic. Southbound left-turn queue takes 2 cycles to clear during AM and PM peak hours.*	
ii)	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane**	No.	Maintain existing permissive phasing.
4.	**Recommendation & Discussion**		
	Maintain existing permissive phasing.		

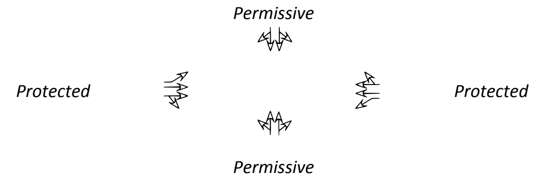
East-West (Dillingham Boulevard)

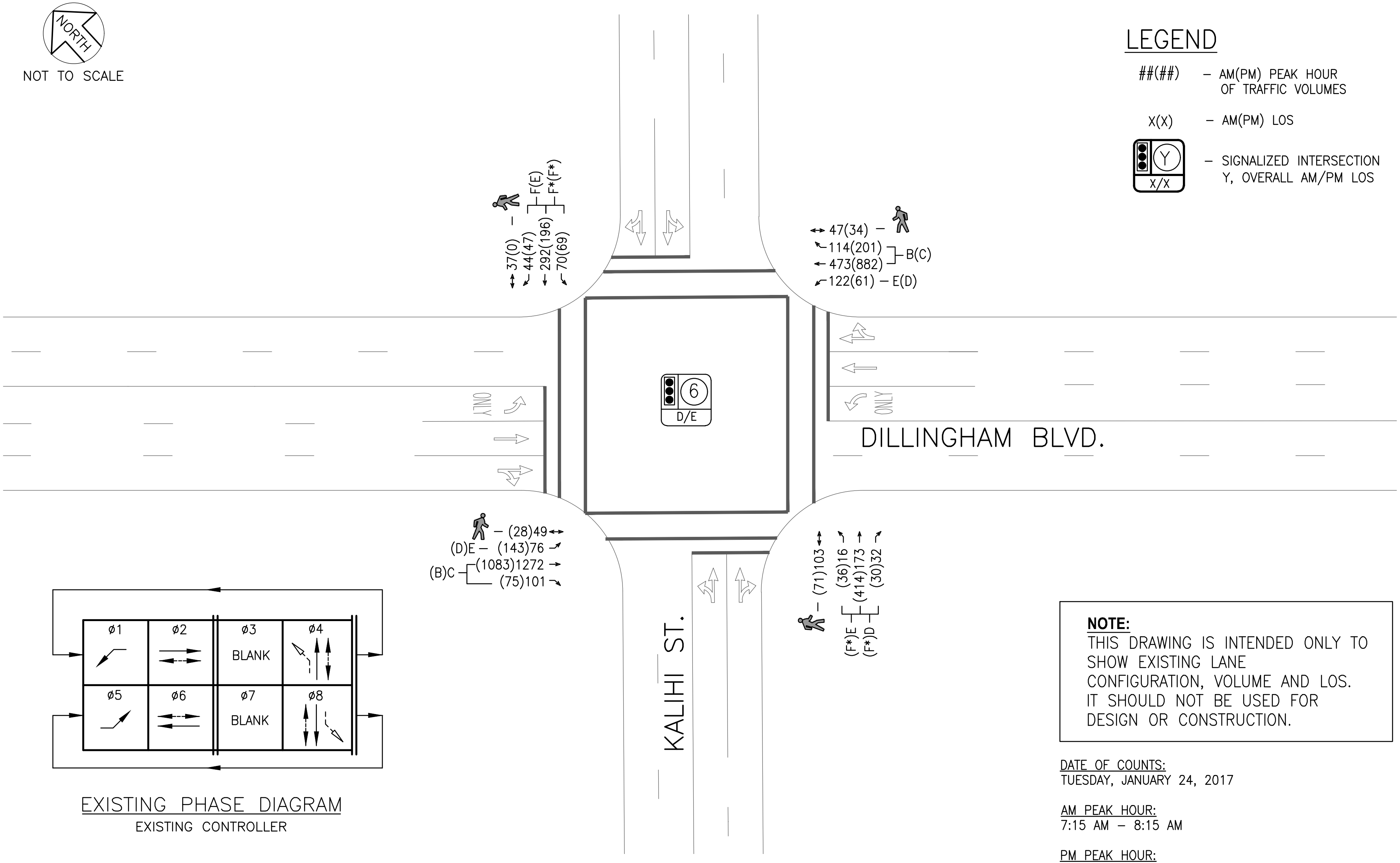
No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Dillingham Boulevard.*	
2.	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	Yes.	
b)	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	N/A. *Dedicated left-turn lanes included on both approaches.*	
3a.	**If Exclusive Left-Turn Lane Exists** **(If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	Eastbound - Protected + Permissive (Desirable) or Protected-only phasing. Westbound - Permissive phasing.	Maintain existing protected-only phasing.
3b.	**If No Exclusive Left-Turn Lane Exists** **(If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**	N/A.	
	Crash History		
	Operational		
ii)	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane**	N/A.	
4.	**Recommendation & Discussion**		
	Maintain existing protected-only phasing. Although protected + permissive phasing is desirable, the intersection experiences a significant amount of pedestrian movement due to its proximity to Kalihi Kai Elementary School. To reduce conflict points and to maintain status quo, protected-only is recommended.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing





LEGEND

##(##) – AM(PM) PEAK HOUR OF TRAFFIC VOLUMES

X(X) – AM(PM) LOS

Y X/X – SIGNALIZED INTERSECTION Y, OVERALL AM/PM LOS

EXISTING PHASE DIAGRAM

EXISTING CONTROLLER

NOTE:
THIS DRAWING IS INTENDED ONLY TO SHOW EXISTING LANE CONFIGURATION, VOLUME AND LOS. IT SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION.

DATE OF COUNTS:
TUESDAY, JANUARY 24, 2017

AM PEAK HOUR:
7:15 AM – 8:15 AM

PM PEAK HOUR:
3:30 PM – 4:30 PM

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

EXISTING LANE CONFIGURATION, VOLUME, AND LOS

EXHIBIT
C6–1

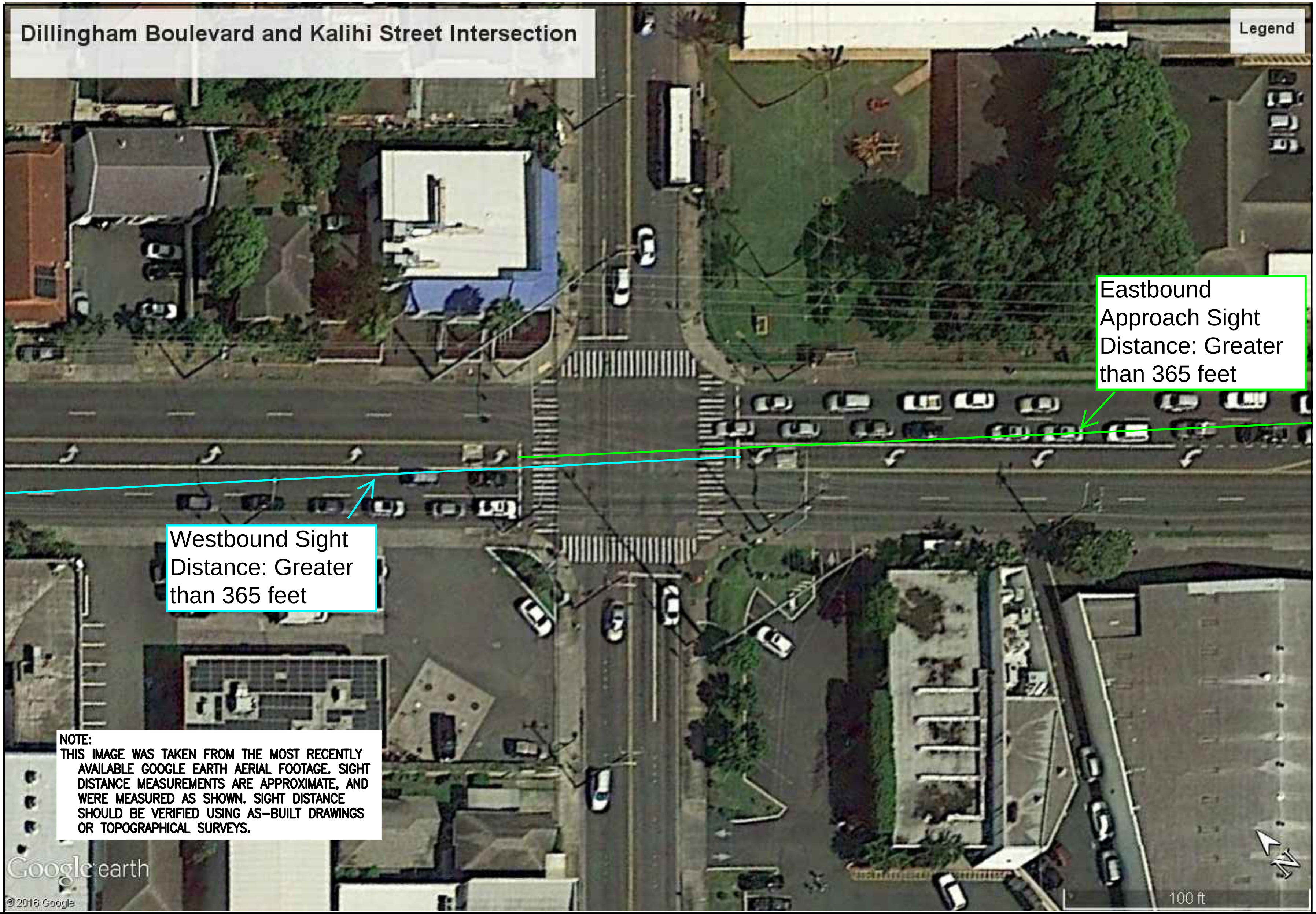
NOTE:
RIGHT-OF-WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT-OF-WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

G.I.S. APPROXIMATE RIGHT-OF-WAY BOUNDARIES

EXHIBIT
C6-2



Dillingham Boulevard and Kalihi Street Intersection

Eastbound Approach Sight Distance: Greater than 365 feet

Westbound Sight Distance: Greater than 365 feet

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

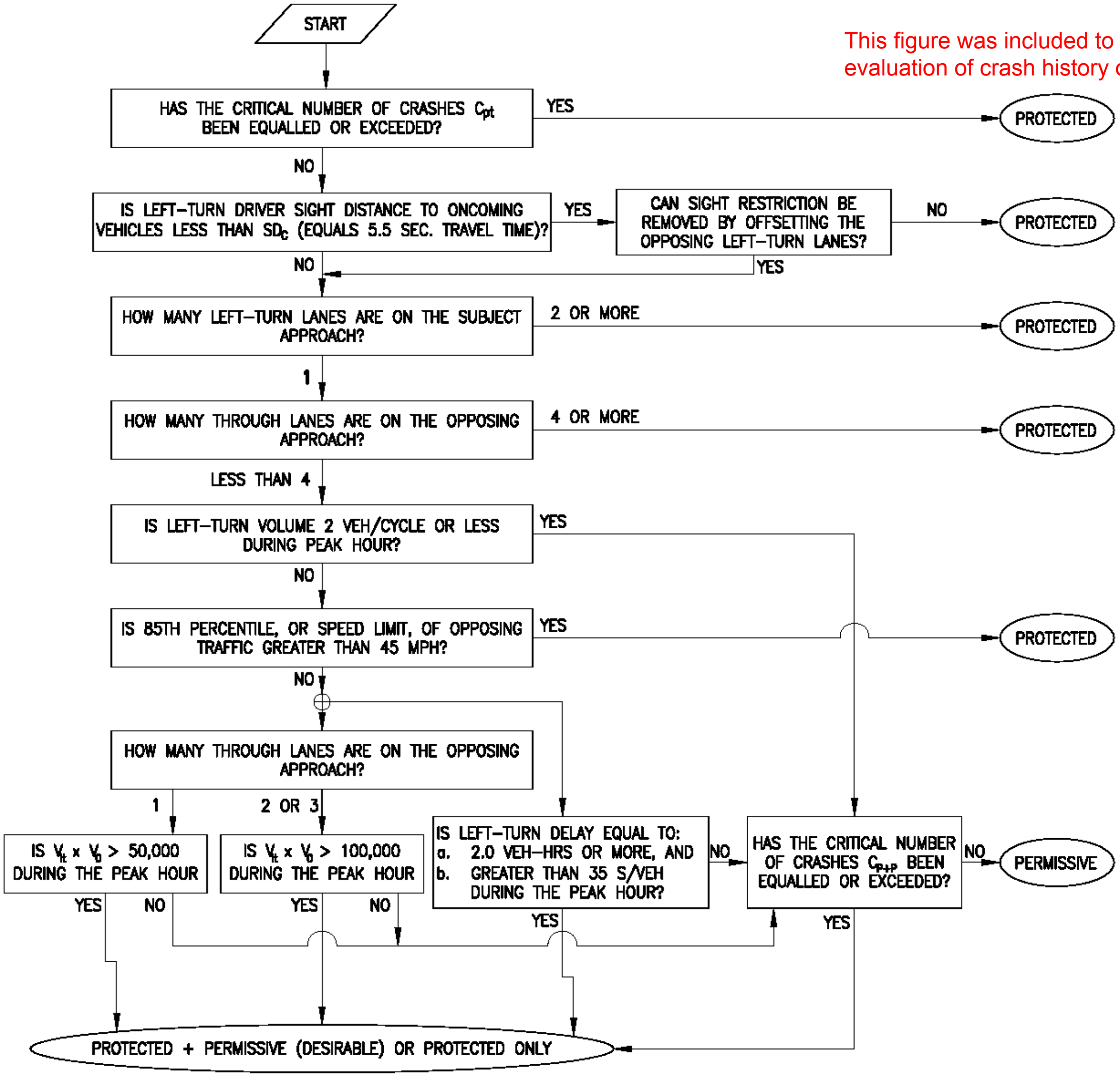
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

SIGHT DISTANCE ANALYSIS

EXHIBIT
C6-3

Dillingham Boulevard/Kalihi Street Intersection
(Northbound and Southbound)

This figure was included to show evaluation of crash history only.



CRASH DATA

	NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT		
			WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	WHEN CONSIDERING PROT.+PERM, C_{p+p} (CRASHES/PERIOD)	
	ONE	1	6	4	
	ONE	2	11	6	
	ONE	3	14	7	
Not Met	BOTH	1	11	6	2
	BOTH	2	18	9	4
	BOTH	3	26	13	4

SIGHT DISTANCE

ONCOMING TRAFFIC **DESIGN SPEED** (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_c (ft)*
25	**205**
30	**245**
35	**285**
40	**325**
45	**365**
50	**405**
55	**445**
60	**490**

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H
V_o = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

PAGE 3 OF 4

Dillingham Boulevard/Kalihi Street Intersection
(Northbound and Southbound)

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT–TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT–TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT–TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE–RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT–TURN ARROW.

SPECIAL CASE: SHARED LEFT–TURN/THROUGH LANE (Northbound and Southbound Approaches)

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED–ONLY LEFT–TURN PHASING WHERE LEFT–TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT–TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE–ONLY LEFT–TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT–TURN PHASES FOR SHARED LEFT–TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT–TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT–TURN LANE:

- **IF A DEDICATED LEFT–TURN LANE CAN BE FEASIBLY CONSTRUCTED,** UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT–TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT–TURN LANE,** CONSIDER THE FOLLOWING GUIDELINES:
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT–TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT–TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:

    See Fig 1 - Does not meet

    - THE LEFT–TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT–TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT–TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT–TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT–TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT–TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,

    NB: Operations Acceptable
    SB: Operations Acceptable

    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT–TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT–TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT–TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT–TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL
NEED FOR A LEFT–TURN PHASE - 1

FIGURE
3

PAGE 4 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED–ONLY LEFT–TURN PHASING

WHEN CONSIDERING INSTALLING PROTECTED–ONLY PHASING, DETERMINE THE IMPACT OF ROADWAY GEOMETRICS ON THE OPERATIONS OF THE INTERSECTION. MORE SPECIFICALLY:

1. PROTECTED–ONLY LEFT–TURN PHASING MAY INCREASE THE QUEUE LENGTHS FOR THE LEFT–TURN MOVEMENTS DUE TO THE MORE FINITE GREEN TIME DURING WHICH LEFT–TURNS CAN BE MADE. THEREFORE, CARE SHOULD BE TAKEN TO INCREASE THE STORAGE LENGTHS WHERE POSSIBLE AND DEEMED NECESSARY.
2. IF IMPLEMENTING PROTECTED–ONLY LEFT–TURN PHASING IS ANTICIPATED TO INCREASE QUEUE LENGTHS TO BEYOND THE AVAILABLE MEDIAN STORAGE LENGTH (AND DECELERATION LENGTH, WHERE APPLICABLE), THE POTENTIAL FOR REAR–END COLLISIONS MAY INCREASE AND SHOULD BE CONSIDERED.
3. DETERMINE IF THE STORAGE LENGTH IS ADEQUATE FOR PROPER OPERATION OF LOOP DETECTORS (OR OTHER SENSOR TYPES).
4. IF THE ENGINEER IS UNABLE TO ASSESS THESE IMPACTS, A TRAFFIC STUDY SHOULD BE PREPARED.

SPLIT PHASING

ACCORDING TO THE TRAFFIC SIGNAL TIMING MANUAL, "SPLIT PHASING MAY BE HELPFUL IF ANY OF THE FOLLOWING CONDITIONS ARE PRESENT:

1. THERE IS A NEED TO ACCOMMODATE ONE OR MORE LEFT–TURN LANES ON EACH APPROACH, BUT SUFFICIENT WIDTH IS NOT AVAILABLE TO ENSURE ADEQUATE SEPARATION IN THE MIDDLE OF THE INTERSECTION. THIS PROBLEM MAY ALSO BE CAUSED BY A LARGE INTERSECTION SKEW ANGLE.
2. THE LARGER LEFT–TURN LANE VOLUME IS EQUAL TO ITS OPPOSING THROUGH LANE VOLUME DURING MOST HOURS OF THE DAY ("LANE VOLUME" REPRESENTS THE MOVEMENT VOLUME DIVIDED BY THE NUMBER OF LANES SERVING IT.)
3. THE WIDTH OF THE ROAD IS CONSTRAINED SUCH THAT AN APPROACH LANE IS SHARED BY THE THROUGH AND LEFT–TURN MOVEMENTS YET THE LEFT–TURN VOLUME IS SUFFICIENT TO JUSTIFY A LEFT–TURN PHASE.
4. ONE OF THE TWO APPROACHES HAS HEAVY VOLUME, THE OTHER APPROACH HAS MINIMAL VOLUME, AND ACTUATED CONTROL IS USED. IN THIS SITUATION, THE PHASE ASSOCIATED WITH THE LOW–VOLUME APPROACH WOULD RARELY BE CALLED AND THE INTERSECTION WOULD FUNCTION MORE NEARLY AS A "T" INTERSECTION.
5. CRASH HISTORY INDICATES AN UNUSUALLY LARGE NUMBER OF SIDESWIPE OR HEAD–ON CRASHES IN THE MIDDLE OF THE INTERSECTION AND INVOLVING LEFT–TURNING VEHICLES."

Northbound and Southbound Approaches: Not recommended. The through volume is heavy and balanced for a minor street. Going to split-phase would adversely affect Dillingham Boulevard.

Eastbound and Westbound Approaches: Not recommended. The through volume is heavy and balanced. Going to split-phase would adversely affect Dillingham Boulevard.

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL
NEED FOR A LEFT–TURN PHASE – 2

FIGURE
4

Dillingham Boulevard & Kalihi Street Intersection - Kalihi Street Northbound AM Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 94 x 4 = 376 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 18 x 4 = 72 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 7 x 4 = 28 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 28 x 2.00 = 56 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 56 ÷ (72 + 56) = 0.438

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
$\geq$ 3	.95

Left Turn Capacity

$$\boxed{C_{SLT} = [\,(1{,}400 - V_O)\,(\,g/c\,)_{LT}\,]\ f_{SLT}}$$

where:

g = [G + Y + AR – 3.0] x f_q = 34-3 x 0.90 = 27.9 seconds

c = cycle length = 120 seconds

thus, $(\,g/c\,)_{LT}$ = 0.2325

and C_{SLT} = [(1400 - 376) (0.2325) $_{LT}$] x 0.438 = 104.28 vph

or

$$\boxed{C_{SLT} = 2 \text{ vehicles per signal cycle}}$$

$C_{SLT} = 2 \times (3600 \div C)$ = 60 vph

V_{LT}= 28 vph ☐ > or [✓ <] $C_{SLT}{}^*$ = 104.28 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Dillingham Boulevard & Kalihi Street Intersection - Kalihi Street Northbound PM Sheet 6 of 6

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 69 x 4 = 276 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 58 x 4 = 232 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 12 x 4 = 48 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 48 x 2.00 = 96 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 96 ÷ (232 + 96) = 0.293

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
$\geq$ 3	.95

Left Turn Capacity

C_{SLT} = [(1,400 – V_O) (g/c)$_{LT}$] f_{SLT}

where:

g = [G + Y + AR – 3.0] x f_q = 32-3 x 0.90 = 26.1 seconds

c = cycle length = 100 seconds

thus, (g/c)$_{LT}$ = 0.261

and C_{SLT} = [(1400 - 276) (0.261) $_{LT}$] x 0.293 = 85.96 vph

or

C_{SLT} = 2 vehicles per signal cycle

C_{SLT} = 2 x (3600 ÷ C) = 72 vph

V_{LT}= 48 vph > or [✓ <] C_{SLT}* = 85.96 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Dillingham Boulevard/Kalihi Street Intersection - Kalihi Street Southbound AM

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 63 x 4 = 252 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 41 x 4 = 164 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 22 x 4 = 88 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 88 x 2.00 = 176 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 176 ÷ (164 + 176) = 0.518

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
[✓ 2]	[✓ .90]
≥ 3	.95

Left Turn Capacity

$$C_{SLT} = [\ (1{,}400 - V_O)\ (\ g/c\ )_{LT}\ ]\ f_{SLT}$$

where:

g = [G + Y + AR – 3.0] x f_q = 34-3 x 0.90 = 27.9 seconds

c = cycle length = 120 seconds

thus, $(\ g/c\ )_{LT}$ = 0.233

and C_{SLT} = [(1400 - 252) (0.233) $_{LT}$] x 0.518 = 138.56 vph

or

$$C_{SLT} = 2 \text{ vehicles per signal cycle}$$

C_{SLT} = 2 x (3600 ÷ C) = 60 vph

V_{LT}= 88 vph > or [✓ <] C_{SLT}^* = 138.56 vph

*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Dillingham Boulevard & Kalihi Street Intersection - Kalihi Street Southbound PM

COMPUTATIONS

SHARED LEFT-TURN / THRU LANE

Adjustment Factor for Left-Turn Vehicles
(Opposing Thru Plus Right Turn Service Flow Rate)

V_O = (highest 15 minute count) x 4

V_O = 124 x 4 = 496 vph

Using TABLE 1, f_{PCE} = 2.00

V_{TV} = 22 x 4 = 88 vph

where: V_{TV} = Thru vehicles in the shared lane.

Left Turn Service Flow Rate
(Direction analyzed for Left-Turn Phase)

V_{LT} = (highest 15 minute count) x 4

V_{LT} = 22 x 4 = 88 vph

$V_{PCE} = V_{LT} \times f_{PCE}$ = 88 x 2.00 = 176 vph

$f_{SLT} = V_{PCE} \div (V_{TV} + V_{PCE})$ = 176 ÷ (88 + 176) = 0.667

TABLE 2	
OPPOSING THRU LANES	f_q
1	.85
2	.90
$\geq$ 3	.95

Left Turn Capacity

$$C_{SLT} = [\,(1{,}400 - V_O)\,(\,g/c\,)_{LT}\,]\;f_{SLT}$$

where:

$g = [\,G + Y + AR - 3.0\,] \times f_q$ = 32-3 x 0.90 = 26.1 seconds

c = cycle length = 100 seconds

thus, $(\,g/c\,)_{LT}$ = 0.261

and $C_{SLT} = [\,(\,1400 -$ 496 $)\,($ 0.261 $)_{LT}\,] \times$ 0.667 = 157.38 vph

or

C_{SLT} = 2 vehicles per signal cycle

$C_{SLT} = 2 \times (3600 \div C) =$ 72 vph

V_{LT}= 88 vph > or [✓ <] C_{SLT}* = 157.38 vph

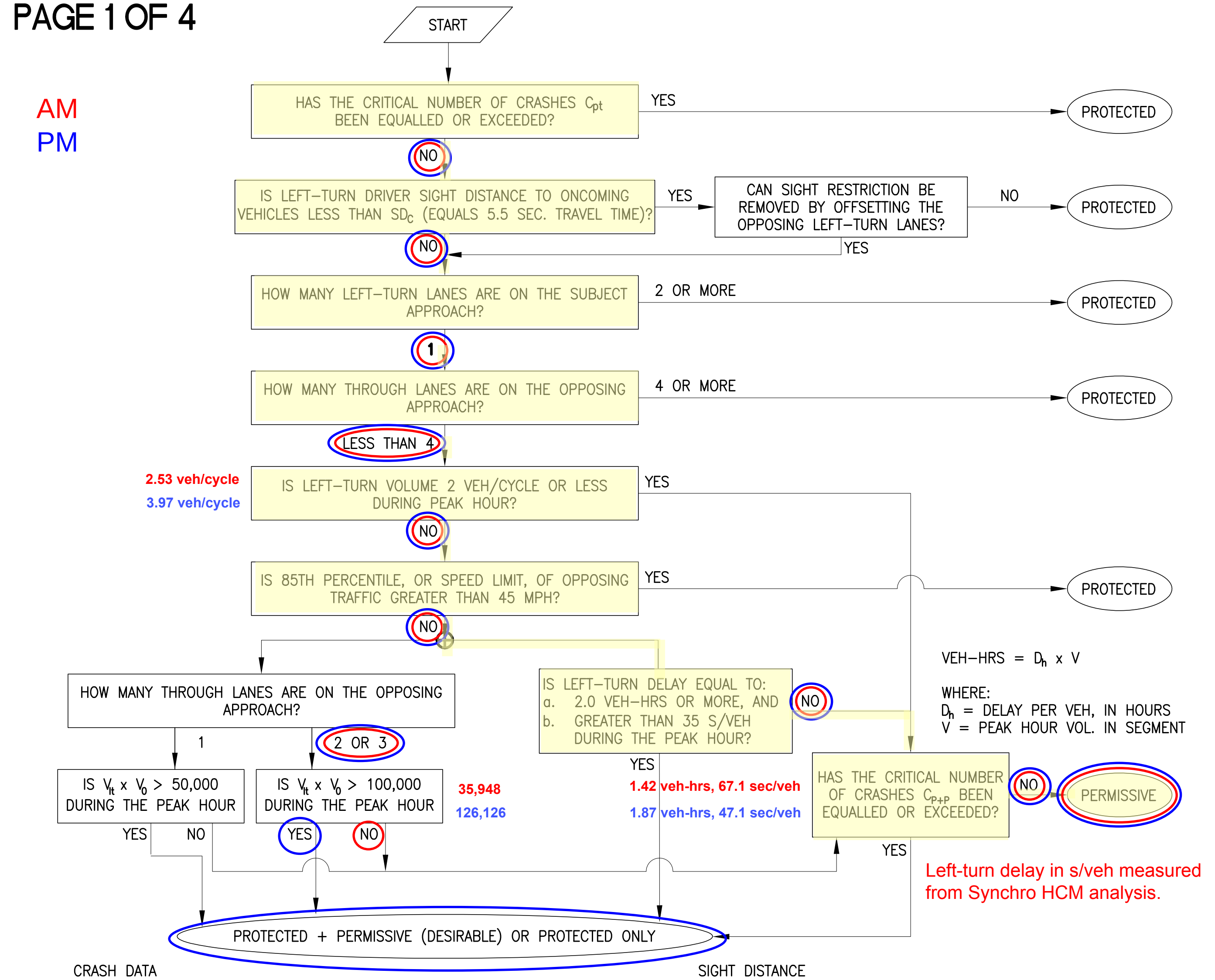
*Select the highest left turn capacity

-If V_{LT} (Left turn service flow rate) is greater than (>) the C_{SLT} (left turn capacity), the Warrant is satisfied and a left turn phase is needed.

-If V_{LT} is less then (<) the C_{SLT}, the Warrant is not satisfied because the signal and geometric design can accommodate the left turn volume at the intersection.

Dillingham Boulevard & Kalihi Street Intersection - Dillingham Blvd. Eastbound

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	0
BOTH	2	18	9	0
BOTH	3	26	13	0

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⌖ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

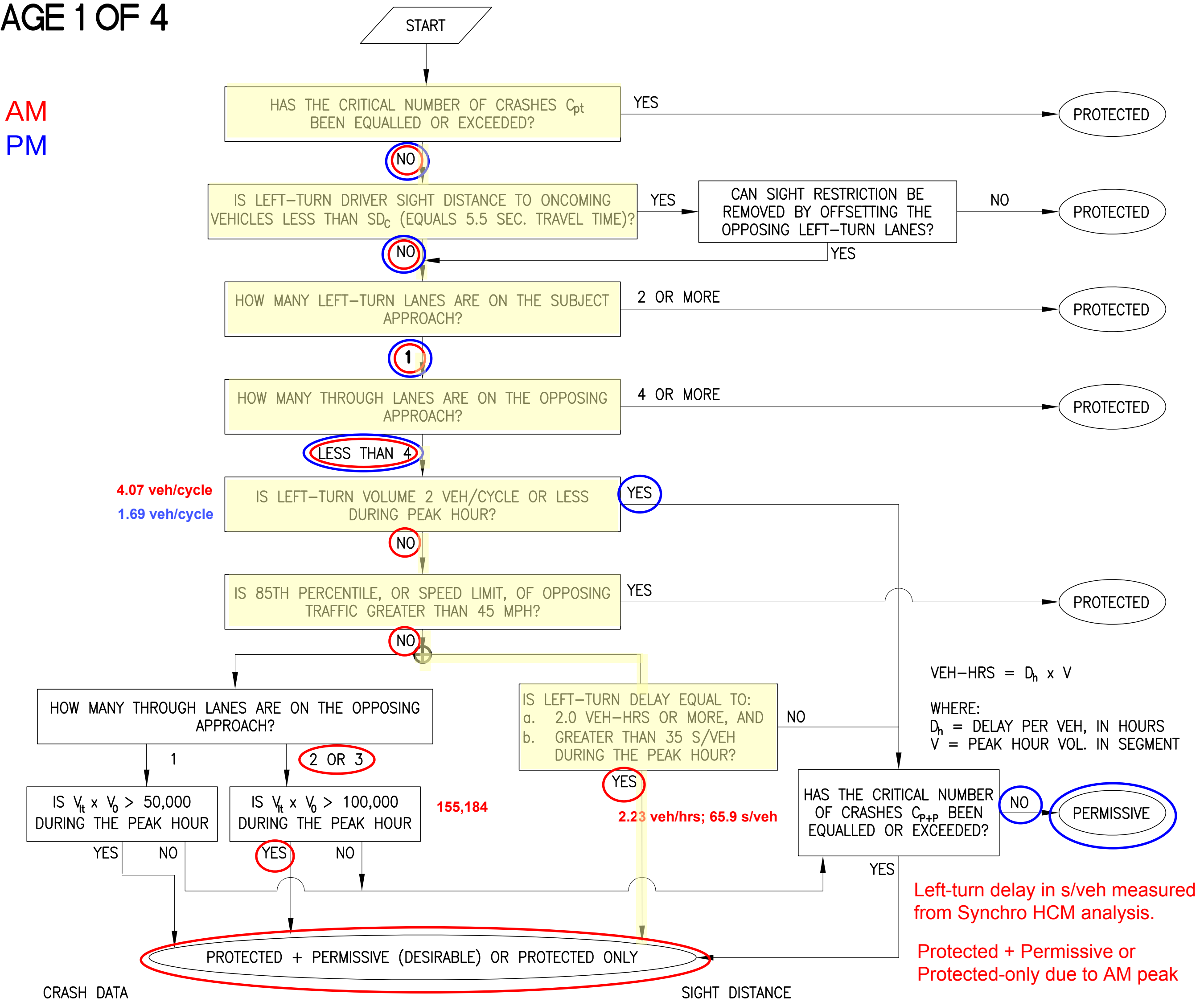
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Dillingham Boulevard & Kalihi Street Intersection - Dillingham Blvd. Westbound

PAGE 1 OF 4



Left-turn delay in s/veh measured from Synchro HCM analysis.

Protected + Permissive or Protected-only due to AM peak

CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	0
BOTH	2	18	9	0
BOTH	3	26	13	0

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⌖ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

HCM 2010 Signalized Intersection Summary
6: Kalihi Street & Dillingham Street

4/4/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱			↰↑↱			↰↑↱	
Traffic Volume (veh/h)	76	1272	101	122	473	114	16	173	32	70	292	44
Future Volume (veh/h)	76	1272	101	122	473	114	16	173	32	70	292	44
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.97	1.00		0.98	1.00		0.88	0.97		0.88
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1900	1013	1033	1900	1189	1213
Adj Flow Rate, veh/h	83	1383	110	133	514	124	17	188	35	76	317	48
Adj No. of Lanes	1	2	0	1	2	0	0	2	0	0	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	107	1827	145	161	1640	393	38	246	53	74	285	51
Arrive On Green	0.06	0.55	0.55	0.09	0.58	0.58	0.24	0.24	0.24	0.24	0.24	0.24
Sat Flow, veh/h	1774	3315	263	1774	2819	676	11	1019	218	138	1178	211
Grp Volume(v), veh/h	83	735	758	133	322	316	104	0	136	211	0	230
Grp Sat Flow(s),veh/h/ln	1774	1770	1808	1774	1770	1726	399	0	850	514	0	1012
Q Serve(g_s), s	5.5	38.3	38.8	8.8	11.2	11.3	2.3	0.0	17.4	11.6	0.0	26.7
Cycle Q Clear(g_c), s	5.5	38.3	38.8	8.8	11.2	11.3	29.0	0.0	17.4	29.0	0.0	26.7
Prop In Lane	1.00		0.15	1.00		0.39	0.16		0.26	0.36		0.21
Lane Grp Cap(c), veh/h	107	975	997	161	1029	1004	131	0	205	165	0	245
V/C Ratio(X)	0.78	0.75	0.76	0.83	0.31	0.32	0.79	0.00	0.66	1.28	0.00	0.94
Avail Cap(c_a), veh/h	370	975	997	251	1029	1004	131	0	205	165	0	245
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	55.6	20.7	20.8	53.6	12.8	12.9	41.2	0.0	41.1	51.5	0.0	44.6
Incr Delay (d2), s/veh	11.5	5.4	5.5	12.2	0.8	0.8	26.7	0.0	7.8	163.8	0.0	41.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.1	20.0	20.9	4.9	5.7	5.6	4.4	0.0	4.5	13.0	0.0	10.3
LnGrp Delay(d),s/veh	67.1	26.1	26.3	65.9	13.6	13.7	67.8	0.0	48.9	215.2	0.0	85.8
LnGrp LOS	E	C	C	E	B	B	E		D	F		F
Approach Vol, veh/h		1576			771			240			441	
Approach Delay, s/veh		28.3			22.7			57.1			147.8	
Approach LOS		C			C			E			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	14.9	71.1		34.0	11.2	74.8		34.0
Change Period (Y+Rc), s	4.0	5.0		5.0	4.0	5.0		5.0
Max Green Setting (Gmax), s	17.0	60.0		29.0	25.0	52.0		29.0
Max Q Clear Time (g_c+I1), s	10.8	40.8		31.0	7.5	13.3		31.0
Green Ext Time (p_c), s	0.2	13.7		0.0	0.2	21.7		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	46.6
HCM 2010 LOS	D

HCM 2010 Signalized Intersection Summary
6: Kalihi Street & Dillingham Street

4/4/2017

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱			↰↑↱			↰↑↱	
Traffic Volume (veh/h)	143	1083	75	61	882	201	36	414	30	69	196	47
Future Volume (veh/h)	143	1083	75	61	882	201	36	414	30	69	196	47
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.98	0.98		0.92	1.00		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1900	1010	1030	1900	980	1000
Adj Flow Rate, veh/h	155	1177	82	66	959	218	39	450	33	75	213	51
Adj No. of Lanes	1	2	0	1	2	0	0	2	0	0	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	189	1817	126	85	1380	313	46	323	30	56	185	56
Arrive On Green	0.11	0.54	0.54	0.05	0.48	0.48	0.27	0.27	0.27	0.27	0.27	0.27
Sat Flow, veh/h	1774	3353	233	1774	2854	648	18	1198	111	0	684	209
Grp Volume(v), veh/h	155	621	638	66	594	583	257	0	265	135	0	204
Grp Sat Flow(s),veh/h/ln	1774	1770	1816	1774	1770	1732	438	0	888	59	0	834
Q Serve(g_s), s	8.6	24.7	24.8	3.7	26.1	26.2	3.4	0.0	27.0	0.0	0.0	23.6
Cycle Q Clear(g_c), s	8.6	24.7	24.8	3.7	26.1	26.2	27.0	0.0	27.0	27.0	0.0	23.6
Prop In Lane	1.00		0.13	1.00		0.37	0.15		0.12	0.55		0.25
Lane Grp Cap(c), veh/h	189	959	984	85	855	837	160	0	240	72	0	225
V/C Ratio(X)	0.82	0.65	0.65	0.77	0.69	0.70	1.61	0.00	1.10	1.89	0.00	0.90
Avail Cap(c_a), veh/h	373	959	984	195	855	837	160	0	240	72	0	225
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	43.7	16.2	16.2	47.1	20.1	20.1	37.3	0.0	36.5	44.2	0.0	35.2
Incr Delay (d2), s/veh	3.3	3.4	3.3	5.5	4.6	4.8	301.6	0.0	89.0	447.2	0.0	35.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.4	13.0	13.3	1.9	13.8	13.6	17.8	0.0	12.5	10.9	0.0	7.6
LnGrp Delay(d),s/veh	47.1	19.5	19.5	52.6	24.7	24.9	338.9	0.0	125.5	491.5	0.0	70.4
LnGrp LOS	D	B	B	D	C	C	F		F	F		E
Approach Vol, veh/h		1414			1243			522			339	
Approach Delay, s/veh		22.5			26.3			230.6			238.6	
Approach LOS		C			C			F			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	8.8	59.2		32.0	14.7	53.3		32.0
Change Period (Y+Rc), s	4.0	5.0		5.0	4.0	5.0		5.0
Max Green Setting (Gmax), s	11.0	48.0		27.0	21.0	38.0		27.0
Max Q Clear Time (g_c+I1), s	5.7	26.8		29.0	10.6	28.2		29.0
Green Ext Time (p_c), s	0.0	17.9		0.0	0.3	8.9		0.0

Intersection Summary			
HCM 2010 Ctrl Delay			75.5
HCM 2010 LOS			E

7. CASE STUDY: WAIALAE AVENUE AND 6TH AVENUE

Existing Conditions

The Waialae Avenue and 6th Avenue intersection currently includes one left-turn lane on the northbound 6th Avenue approach and a shared left-turn/through approach on the southbound approach. The eastbound and westbound Waialae Avenue approaches service the left-turn movement with shared left-turn/through lanes. Left turns on all approaches operate with permitted phasing. See Exhibit C7-1 for the existing intersection layout.

Traffic Observations & Analysis

Field observations reveal that vehicles making eastbound and westbound left-turns often restrict throughput. However, the opposing through vehicles for the eastbound and westbound left-turn movements generally arrive in platoons, due to signalized intersections approximately 470 feet east and west of the intersection, and usually provides adequate gaps for vehicles making permissive left-turn movements. The eastbound and westbound left-turn/through movements operate adequately at LOS C or better during the AM and PM peak hours of traffic.

Busses stopping at the bus stop located approximately 150 feet east of the intersection affects throughput, as some drivers abruptly change lanes to maneuver around the stopped bus.

Moderate queuing was observed on the northbound left-turn movement approach. Traffic analysis indicates that this movement operates at LOS F with overcapacity conditions during the AM peak hour of traffic and LOS E during the PM peak hour of traffic.

See Table C7-1 for a summary of the existing LOS analysis results.

Conclusions

See Table C7-2 for the analysis and recommendations regarding the left-turn treatment at this intersection.

Eastbound/Westbound Approaches

The existing permissive left-turn phasing should be maintained for the eastbound and westbound approaches. Although neither of the eastbound or westbound approaches currently include dedicated left-turn lanes, guidelines in Figure 1 suggest that the current volumes and delay of the left-turn movements would not warrant a left-turn phase; thus, the need for an exclusive left-turn lane is not currently present. As crash history thresholds have not been met and operations are adequate, the existing permissive phasing appears to be appropriate.

Northbound/Southbound Approaches

The guidelines recommend implementing protected + permissive left-turn phasing for the northbound approach and maintaining the existing permissive left-turn phasing for the southbound approach. As the northbound approach includes a dedicated left-turn lane, Figure 1 was utilized to determine protected + permissive or protected-only phasing as the appropriate left-turn treatment. See Table C7-1 for a summary of the LOS analysis results for the proposed left-turn phasing conditions.

As crash history thresholds are not met and operations are adequate for the southbound approach, the existing permissive phasing appears to be appropriate.

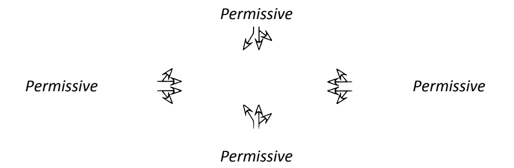
Table C7-1: Level of Service Summary Table

	Existing Conditions						Proposed Conditions					
	AM			PM			AM			PM		
Intersection	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS	HCM Delay	v/c Ratio	LOS
7. Waialae Avenue/6th Avenue												
NB LT	261.5	1.36	F*	79.9	0.86	E	51.3	0.74	D	43.8	0.73	D
NB TH/RT	42.4	0.71	D	32.6	0.70	C	35.8	0.64	D	43.2	0.82	D
EB LT/TH	9.8	0.35	A	21.0	0.48	C	11.7	0.37	B	15.9	0.43	B
EB TH/RT	10.2	0.37	B	21.8	0.50	C	12.2	0.39	B	16.5	0.44	B
WB LT/TH	14.0	0.61	B	19.2	0.37	B	16.8	0.65	B	14.6	0.33	B
WB TH/RT	14.8	0.63	B	19.5	0.39	B	17.8	0.67	B	14.8	0.34	B
SB LT/TH	41.7	0.68	D	29.2	0.37	C	43.4	0.64	D	46.7	0.57	D
SB RT	33.7	0.36	C	22.0	0.10	C	39.8	0.47	D	38.4	0.19	D
Overall	33.9	-	C	28.5	-	C	23.0	-	C	25.9	-	C

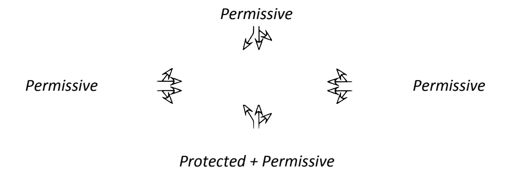
Table C7-2: Left-Turn Warrant Guidelines for Case Study Summary
Waialae Avenue & 6th Avenue

North-South (6th Avenue)				East-West (Waialae Avenue)			
No.		Conclusion/Discussion	Action Recommended?	No.		Conclusion/Discussion	Action Recommended?
1.	**Split-Phase Consideration**			**1.**	**Split-Phase Consideration**		
	Is Split-Phase Recommended?	No. *The through volume is heavy and balanced for a minor street. Going to split-phase would adversely affect Waialae Avenue.*			**Is Split-Phase Recommended?**	No. *The through volume is heavy and balanced. Going to split-phase would adversely affect Waialae Avenue.*	
2.	**Exclusive Left-Turn Lane Consideration**			**2.**	**Exclusive Left-Turn Lane Consideration**		
a)	**Do the approaches have left-turn lanes?**	Northbound Approach - Yes. Southbound Approach - No.		**a)**	**Do the approaches have left-turn lanes?**	No.	
b)	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	Southbound Approach - No. *The southbound left-turn movement is low volume. Flowchart in Figure 1 would recommend permissive phasing if dedicated left-turn lane is available; therefore, the need for a dedicated left-turn lane and protected phasing is not currently present.*		**b)**	**If answer to 2a is "No":** **Should a left-turn lane be installed?**	No. *The eastbound and westbound left-turn movements are low volume. Flowchart in Figure 1 would recommend permissive phasing if dedicated left-turn lane is available; therefore, the need for a dedicated left-turn lane and protected phasing is not currently present.*	
3a.	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**			**3a.**	**If Exclusive Left-Turn Lane Exists (If answer to 2a or 2b is "Yes")**		
	Flow-Chart (Figure 1) result	Northbound Approach - Protected + Permissive (Desirable) or Protected-only phasing.	Northbound Approach - Implement Protected + Permissive phasing		**Flow-Chart (Figure 1) result**	N/A. *In lieu of left-turn lane.*	
3b.	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**			**3b.**	**If No Exclusive Left-Turn Lane Exists (If answer to 2a AND 2b is "No")**		
i)	**Are there any issues caused by left-turn maneuvers?**			**i)**	**Are there any issues caused by left-turn maneuvers?**		
	Crash History	Southbound Approach - No. *0 southbound left-turn related crashes from May 2013 to May 2015.*	Southbound Approach - Maintain existing permissive phasing.		***Crash History***	No. *0 eastbound and westbound left-turn related crashes from May 2013 to May 2015.*	Maintain existing permissive phasing.
	Operational	Southbound Approach - No. *Southbound left-turn movements operate adequately at LOS D or better during the AM and PM peak hours of traffic.*			***Operational***	No. *Eastbound and westbound left-turn movements operate at LOS C or better during AM and PM peak hour of traffic.*	
ii)	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane warrant satisfied?**	N/A.		**ii)**	**If answer to 3bi is "Yes" for Operational:** **NYDOT shared left-turn lane warrant satisfied?**	N/A.	
4.	**Recommendation & Discussion**			**4.**	**Recommendation & Discussion**		
	Implement protected + permissive phasing for the northbound approach. Maintain existing permissive phasing for the southbound approach. It should be noted that adding a protected phase for the northbound approach will cause additional delay for the eastbound/westbound through movements, especially during the critical AM peak period. Should the phase be implemented, an optimization study should be conducted to optimize the throughput along the coordinated Waialae Avenue.				Maintain existing permissive phasing.		

Existing Lane Diagram/Left-Turn Phasing



Recommended Lane Diagram/Left-Turn Phasing



NORTH

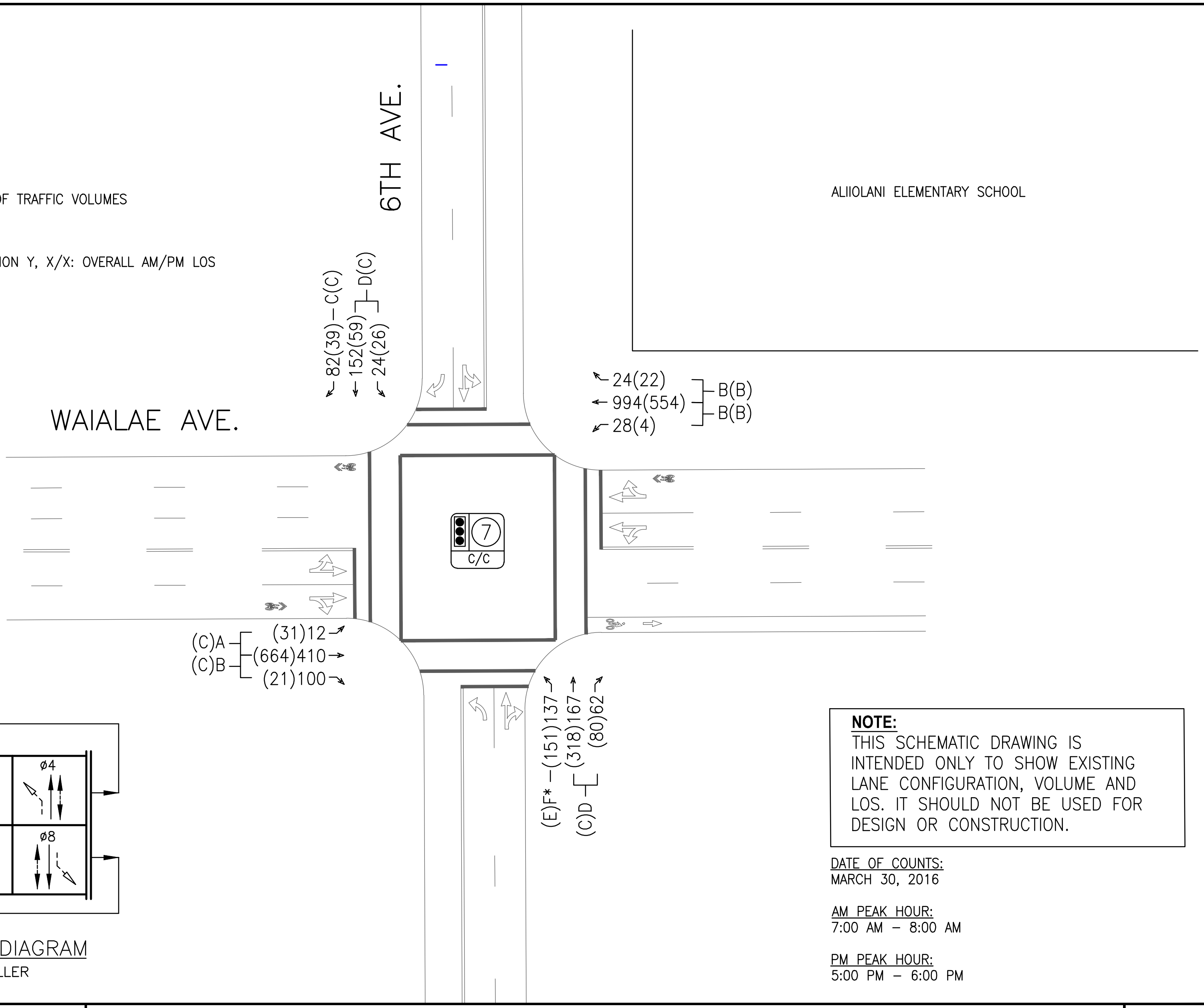
NOT TO SCALE

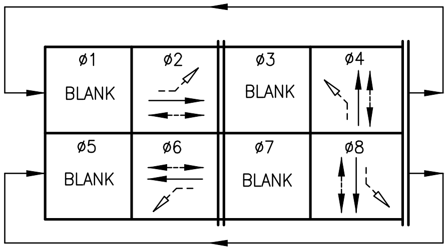
LEGEND

##(##) – AM(PM) PEAK HOUR OF TRAFFIC VOLUMES

Y X/X – SIGNALIZED INTERSECTION Y, X/X: OVERALL AM/PM LOS

X(X) – AM(PM) LOS





EXISTING PHASE DIAGRAM

EXISTING CONTROLLER

NOTE:
THIS SCHEMATIC DRAWING IS INTENDED ONLY TO SHOW EXISTING LANE CONFIGURATION, VOLUME AND LOS. IT SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION.

DATE OF COUNTS:
MARCH 30, 2016

AM PEAK HOUR:
7:00 AM – 8:00 AM

PM PEAK HOUR:
5:00 PM – 6:00 PM

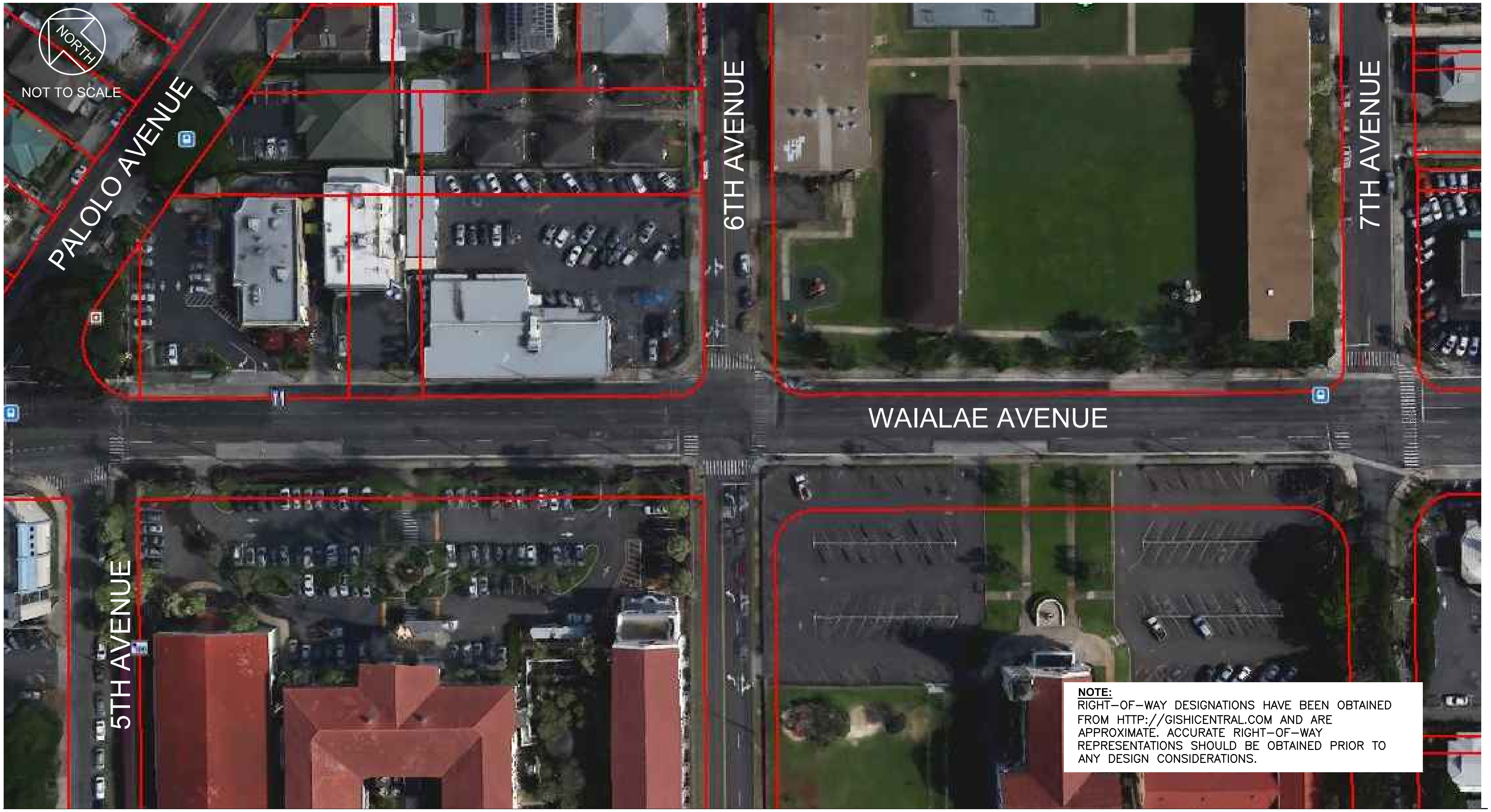
TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

EXISTING LANE CONFIGURATION, VOLUME, AND LOS

EXHIBIT

C7-1



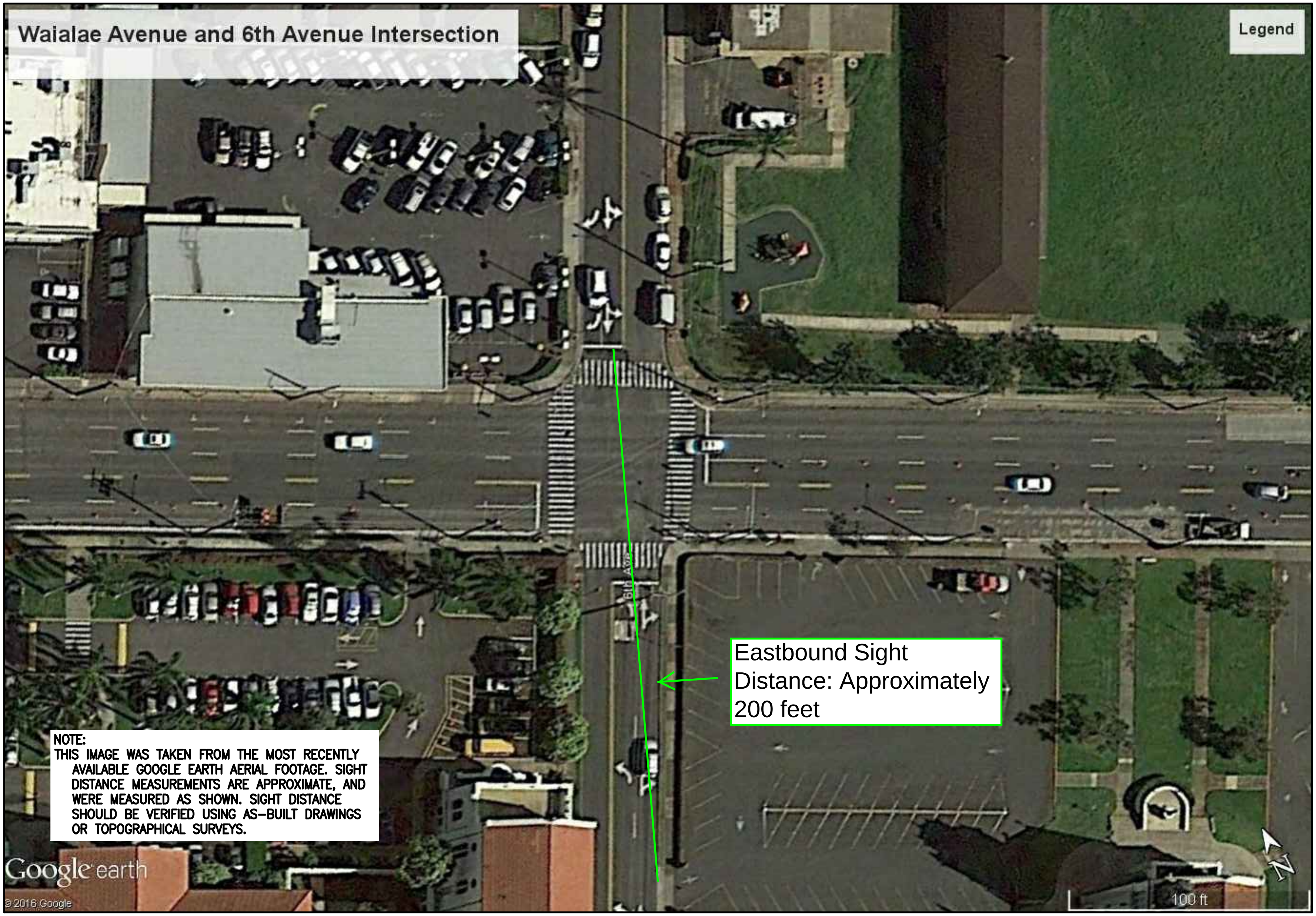
NOTE:
RIGHT-OF-WAY DESIGNATIONS HAVE BEEN OBTAINED FROM HTTP://GISHICENTRAL.COM AND ARE APPROXIMATE. ACCURATE RIGHT-OF-WAY REPRESENTATIONS SHOULD BE OBTAINED PRIOR TO ANY DESIGN CONSIDERATIONS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

G.I.S. APPROXIMATE RIGHT-OF-WAY BOUNDARIES

EXHIBIT
C7-2



Eastbound Sight Distance: Approximately 200 feet

NOTE:
THIS IMAGE WAS TAKEN FROM THE MOST RECENTLY AVAILABLE GOOGLE EARTH AERIAL FOOTAGE. SIGHT DISTANCE MEASUREMENTS ARE APPROXIMATE, AND WERE MEASURED AS SHOWN. SIGHT DISTANCE SHOULD BE VERIFIED USING AS-BUILT DRAWINGS OR TOPOGRAPHICAL SURVEYS.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL
PHASING GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

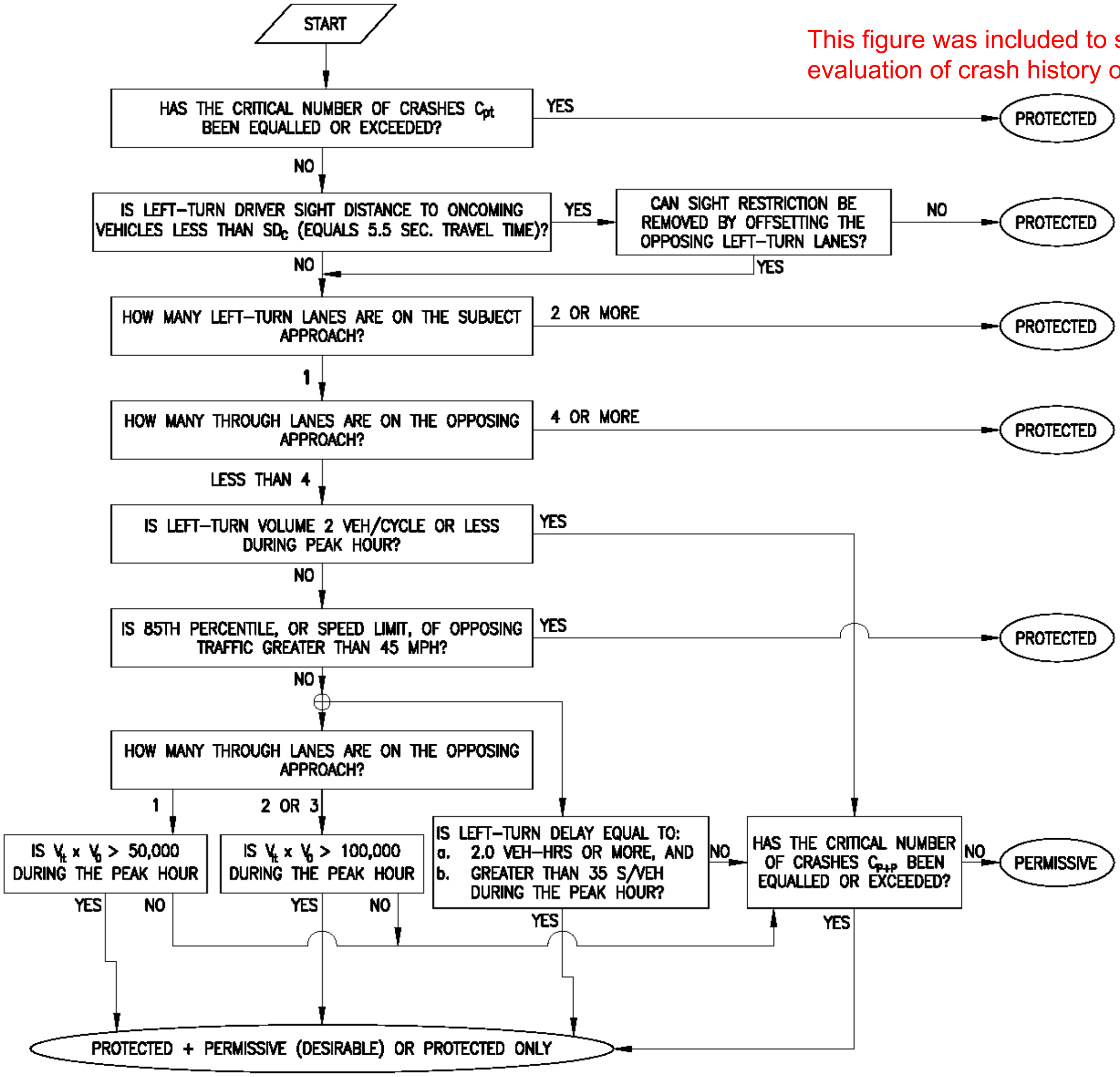
SIGHT DISTANCE ANALYSIS

EXHIBIT
C7-3

PAGE 1 OF 4

Waialae Avenue/6th Avenue Intersection

This figure was included to show evaluation of crash history only.



CRASH DATA

Not Met

NUMBER OF LEFT-TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT-TURN-RELATED CRASH COUNT WHEN CONSIDERING PROTECTED-ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT-TURN-RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	0
BOTH	2	18	9	0
BOTH	3	26	13	0

SIGHT DISTANCE

ONCOMING TRAFFIC **DESIGN SPEED** (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)*
25	**205**
30	**245**
35	**285**
40	**325**
45	**365**
50	**405**
55	**445**
60	**490**

VARIABLES

V_{lt} = LEFT-TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT-TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT-TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW-CHART HAS BEEN ADAPTED FROM THE LEFT-TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE

FIGURE
1

PAGE 3 OF 4

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED + PERMISSIVE LEFT-TURN PHASING

WHEN IMPLEMENTING PROTECTED + PERMISSIVE LEFT-TURN PHASING, CARE SHOULD BE TAKEN TO AVOID THE YELLOW TRAP, WHERE A LEFT-TURNING DRIVER FEELS FORCED INTO AN INTERSECTION WHEN IT IS UNSAFE TO DO SO. MEASURES THAT CAN BE TAKEN:

1. INSTITUTE SINGLE-RING STRUCTURE PHASING PLAN.
2. UTILIZE FLASHING YELLOW ARROW INDICATION INSTEAD OF GREEN BALL/LEFT-TURN ARROW.

SPECIAL CASE: SHARED LEFT-TURN/THROUGH LANE (Eastbound, Westbound and Southbound Approaches)

SUBSEQUENT TO THE PUBLICATION OF THE TRAFFIC SIGNAL TIMING MANUAL (BASIS OF THE RECOMMENDED GUIDELINES), THE 2009 MUTCD INTRODUCED A REQUIREMENT WHICH DISALLOWED PROTECTED-ONLY LEFT-TURN PHASING WHERE LEFT-TURN MOVEMENTS ARE NOT PROVIDED EXCLUSIVE LEFT-TURN LANES. THEREFORE, IN THESE CASES, PROTECTED + PERMISSIVE AND PERMISSIVE-ONLY LEFT-TURN PHASING ARE THE ONLY ACCEPTABLE OPTIONS.

ENGINEERING JUDGMENT SHOULD BE APPLIED WHEN PROTECTED + PERMISSIVE LEFT-TURN PHASES FOR SHARED LEFT-TURN/THROUGH LANES ARE BEING CONSIDERED. THE FOLLOWING FACTORS MAY BE CONSIDERED WHEN MAKING THE DETERMINATION WHETHER OR NOT TO IMPLEMENT PROTECTED + PERMISSIVE LEFT-TURN PHASING IN THE ABSENCE OF AN EXCLUSIVE LEFT-TURN LANE:

EB, WB
- **IF A DEDICATED LEFT-TURN LANE CAN BE FEASIBLY CONSTRUCTED**, UTILIZE THE FLOWCHART IN FIGURE 1; IF EITHER PROTECTED ONLY OR PROTECTED + PERMISSIVE PHASING IS RECOMMENDED, CONSIDER CONSTRUCTING THE DEDICATED LEFT-TURN LANE AND IMPLEMENTING THE APPROPRIATE PHASING.

SB
- **IF IT IS INFEASIBLE OR IMPRACTICABLE TO INSTALL A DEDICATED LEFT-TURN LANE**, CONSIDER THE FOLLOWING GUIDELINES:

  See Fig 1
  Does not meet
  - CRASH HISTORY: CONSIDER UTILIZING THE CRASH DATA THRESHOLDS FOR PROTECTED + PERMISSIVE PHASING (NEAR THE BOTTOM OF FIGURE 1). IF SAID CRASH THRESHOLDS HAVE BEEN MET, CONSIDER PROHIBITING LEFT-TURN MANEUVERS. HOWEVER, WHEN DECIDING WHETHER OR NOT TO PROHIBIT LEFT-TURN MANEUVERS, UTILIZE ENGINEERING JUDGMENT TO MAKE EXCEPTIONS TO THIS GUIDELINE. THE FOLLOWING EXCEPTIONS COULD BE CONSIDERED:
    - THE LEFT-TURN MOVEMENT PROVIDES SOLE OR PRIMARY ACCESS TO A SUBDIVISION OR PARCEL.
    - THE PROHIBITION OF THE LEFT-TURN MANEUVER WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES TO MOTORISTS TRAVELING ON ITS ALTERNATE ROUTE.
    - THE PROHIBITION WOULD CREATE UNACCEPTABLE OPERATIONAL ISSUES ALONG THE PRIMARY ROUTE.
    - IF THE LEFT-TURN PROHIBITION IS INFEASIBLE, CONSIDER ONE OF THE FOLLOWING:
      - PROVIDING PROTECTED + PERMISSIVE LEFT-TURN PHASING.
      - CONVERTING ONE OF THE THROUGH LANES INTO A DEDICATED LEFT-TURN LANE.
      - REMEDIAL OR TRAFFIC CALMING MEASURES THAT CAN BE CONSTRUCTED TO REDUCE THE POTENTIAL FOR ACCIDENTS.
  - OPERATIONS: IF THE LEFT-TURN PHASING IS RECOMMENDED FOR OPERATIONAL REASONS,

    SB: Operations
    Accetpable
    - CONSIDER UTILIZING THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION WARRANTS FOR INSTALLING A PROTECTED + PERMISSIVE PHASE FOR A SHARED LEFT-TURN/THROUGH LANE. SEE APPENDIX X FOR THE WARRANTS.
    - WHERE THE OPPOSING LANES (TO THE LEFT-TURN MANEUVER) REGULARLY EXPERIENCES CONGESTION, CONSIDER CONDUCTING A TRAFFIC STUDY TO DETERMINE THE IMPACT OF THE LEFT-TURN PHASING ON THE SURROUNDING ROADWAY NETWORK.

      BECAUSE THE LEFT-TURN MANEUVER WILL NOT BE ABLE TO BE EXPLICITLY DETECTED, ITS PHASE WILL ALWAYS ACTUATE AND LEAD TO SOME OPERATIONAL INEFFICIENCY.

TRAFFIC ASSESSMENT FOR
LEFT-TURN SIGNAL PHASING
GUIDELINES

ATA AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

GUIDELINES FOR DETERMINING THE POTENTIAL
NEED FOR A LEFT-TURN PHASE - 1

FIGURE
3

NOTES:

THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT-TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. ADDITIONAL CONSIDERATIONS ARE LISTED BELOW:

PROTECTED-ONLY LEFT-TURN PHASING

WHEN CONSIDERING INSTALLING PROTECTED-ONLY PHASING, DETERMINE THE IMPACT OF ROADWAY GEOMETRICS ON THE OPERATIONS OF THE INTERSECTION. MORE SPECIFICALLY:

1. PROTECTED-ONLY LEFT-TURN PHASING MAY INCREASE THE QUEUE LENGTHS FOR THE LEFT-TURN MOVEMENTS DUE TO THE MORE FINITE GREEN TIME DURING WHICH LEFT-TURNS CAN BE MADE. THEREFORE, CARE SHOULD BE TAKEN TO INCREASE THE STORAGE LENGTHS WHERE POSSIBLE AND DEEMED NECESSARY.
2. IF IMPLEMENTING PROTECTED-ONLY LEFT-TURN PHASING IS ANTICIPATED TO INCREASE QUEUE LENGTHS TO BEYOND THE AVAILABLE MEDIAN STORAGE LENGTH (AND DECELERATION LENGTH, WHERE APPLICABLE), THE POTENTIAL FOR REAR-END COLLISIONS MAY INCREASE AND SHOULD BE CONSIDERED.
3. DETERMINE IF THE STORAGE LENGTH IS ADEQUATE FOR PROPER OPERATION OF LOOP DETECTORS (OR OTHER SENSOR TYPES).
4. IF THE ENGINEER IS UNABLE TO ASSESS THESE IMPACTS, A TRAFFIC STUDY SHOULD BE PREPARED.

SPLIT PHASING

ACCORDING TO THE TRAFFIC SIGNAL TIMING MANUAL, "SPLIT PHASING MAY BE HELPFUL IF ANY OF THE FOLLOWING CONDITIONS ARE PRESENT:

1. THERE IS A NEED TO ACCOMMODATE ONE OR MORE LEFT-TURN LANES ON EACH APPROACH, BUT SUFFICIENT WIDTH IS NOT AVAILABLE TO ENSURE ADEQUATE SEPARATION IN THE MIDDLE OF THE INTERSECTION. THIS PROBLEM MAY ALSO BE CAUSED BY A LARGE INTERSECTION SKEW ANGLE.
2. THE LARGER LEFT-TURN LANE VOLUME IS EQUAL TO ITS OPPOSING THROUGH LANE VOLUME DURING MOST HOURS OF THE DAY ("LANE VOLUME" REPRESENTS THE MOVEMENT VOLUME DIVIDED BY THE NUMBER OF LANES SERVING IT.)
3. THE WIDTH OF THE ROAD IS CONSTRAINED SUCH THAT AN APPROACH LANE IS SHARED BY THE THROUGH AND LEFT-TURN MOVEMENTS YET THE LEFT-TURN VOLUME IS SUFFICIENT TO JUSTIFY A LEFT-TURN PHASE.
4. ONE OF THE TWO APPROACHES HAS HEAVY VOLUME, THE OTHER APPROACH HAS MINIMAL VOLUME, AND ACTUATED CONTROL IS USED. IN THIS SITUATION, THE PHASE ASSOCIATED WITH THE LOW-VOLUME APPROACH WOULD RARELY BE CALLED AND THE INTERSECTION WOULD FUNCTION MORE NEARLY AS A "T" INTERSECTION.
5. CRASH HISTORY INDICATES AN UNUSUALLY LARGE NUMBER OF SIDESWIPE OR HEAD-ON CRASHES IN THE MIDDLE OF THE INTERSECTION AND INVOLVING LEFT-TURNING VEHICLES."

Northbound/Southbound: Not recommended due to through volume being heavy and balanced for minor street. Split phasing would adversely affect Waialae Avenue

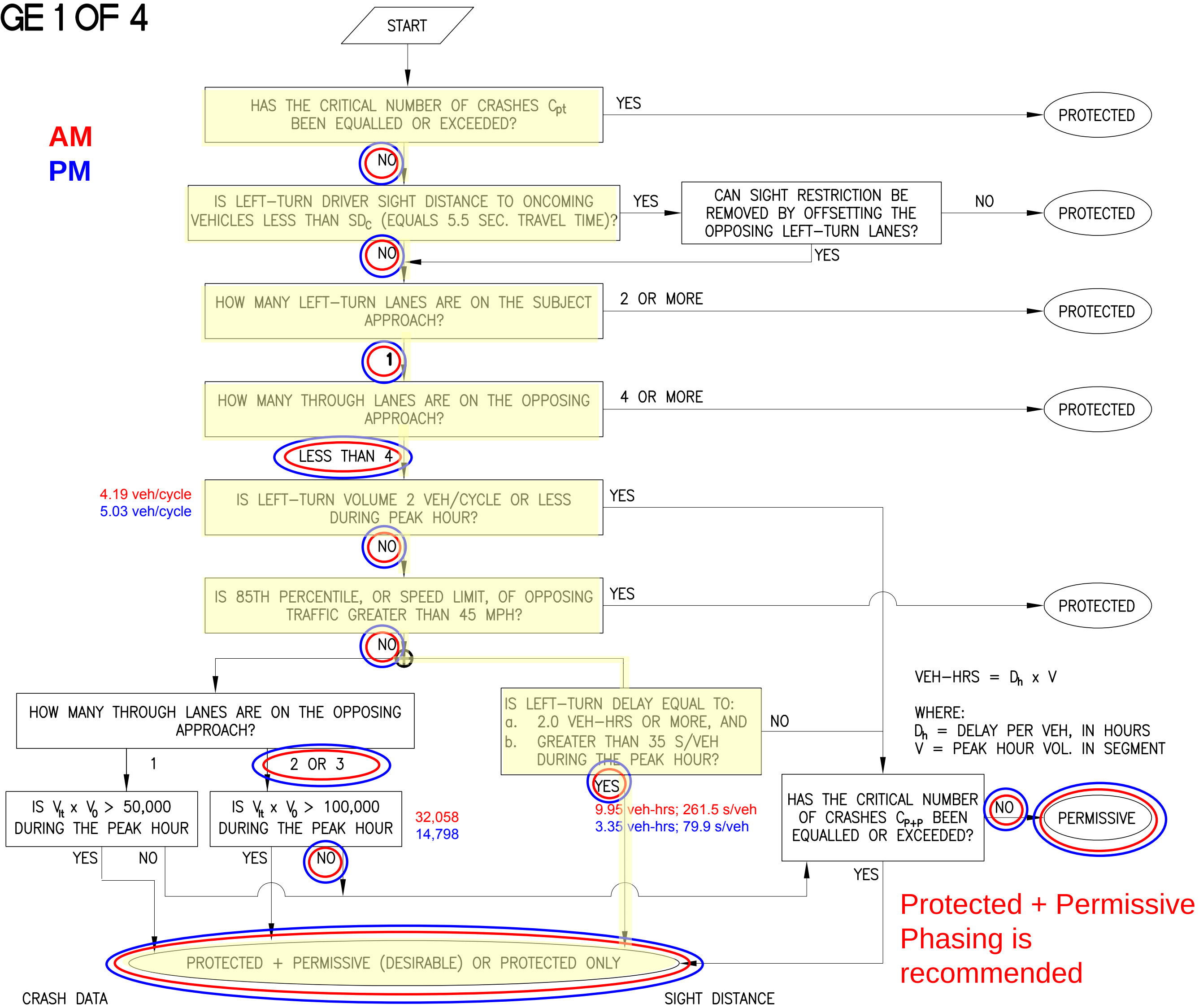
Eastbound/Westbound: Not recommended due to through volume being heavy and balanced. Split phasing would adversely affect Waialae Avenue

GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT-TURN PHASE - 2

FIGURE
4

Waialae Avenue & 6th Avenue Intersection - Northbound

PAGE 1 OF 4



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM., C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	0
BOTH	2	18	9	0
BOTH	3	26	13	0

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

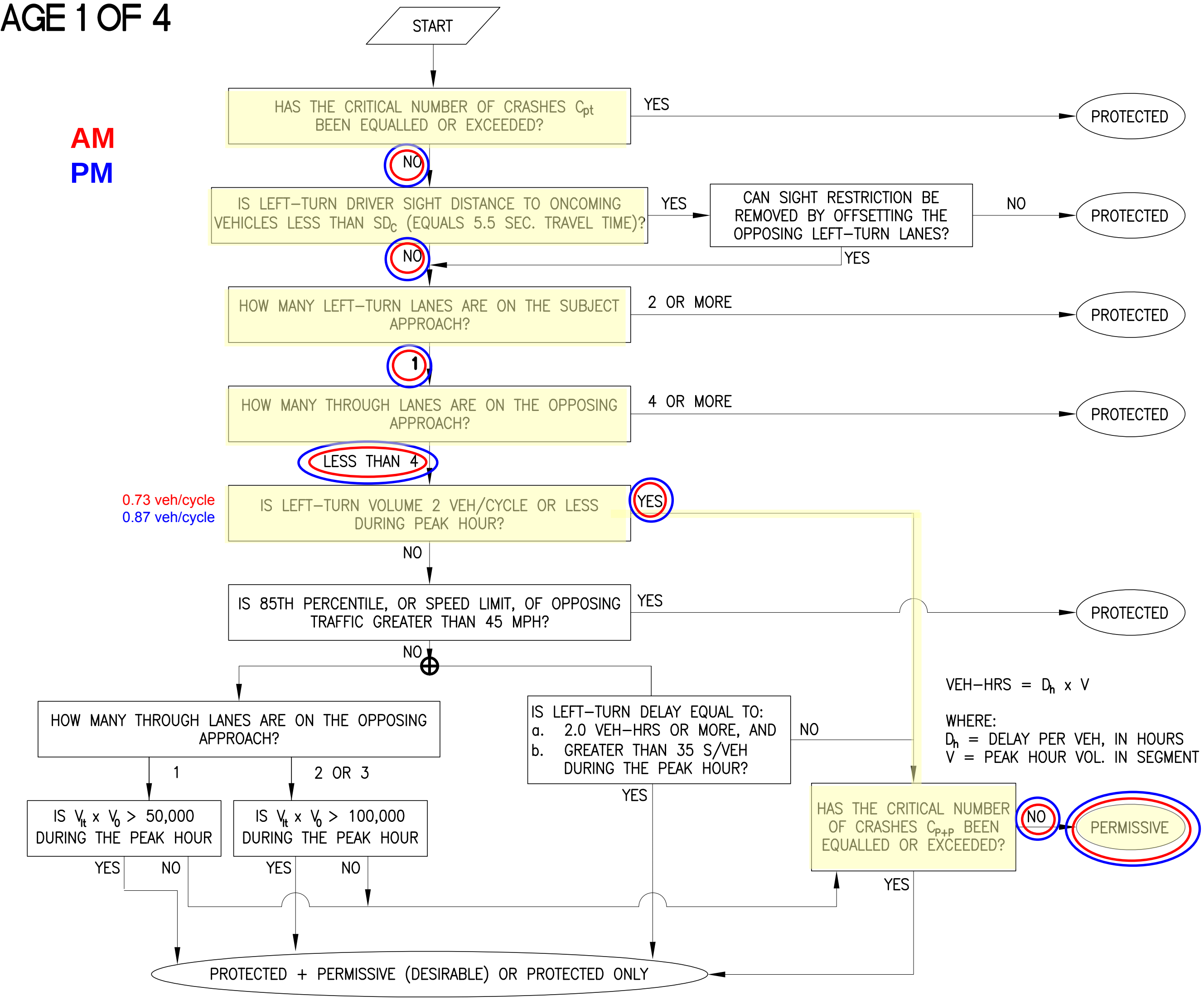
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Waialae Avenue & 6th Avenue Intersection - Southbound (With Left-Turn Lane Installed)

PAGE 1 OF 4



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	*0*
BOTH	2	18	9	*0*
BOTH	3	26	13	*0*

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

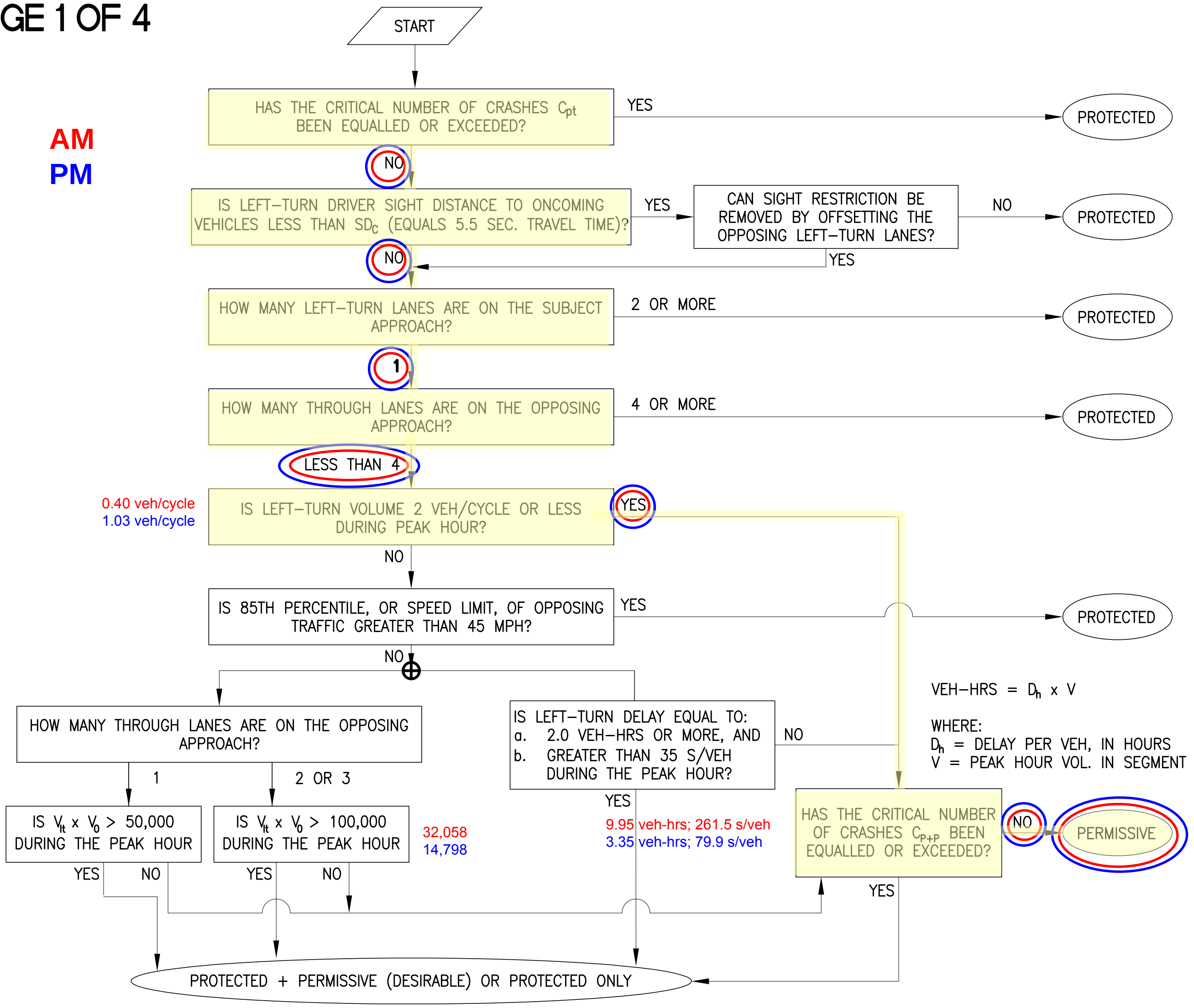
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Waialae Avenue/6th Avenue Eastbound Approach (With Left-turn Lane Installed)

PAGE 1 OF 4



CRASH DATA

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	
ONE	2	11	6	
ONE	3	14	7	
BOTH	1	11	6	0
BOTH	2	18	9	0
BOTH	3	26	13	0

Not Met

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

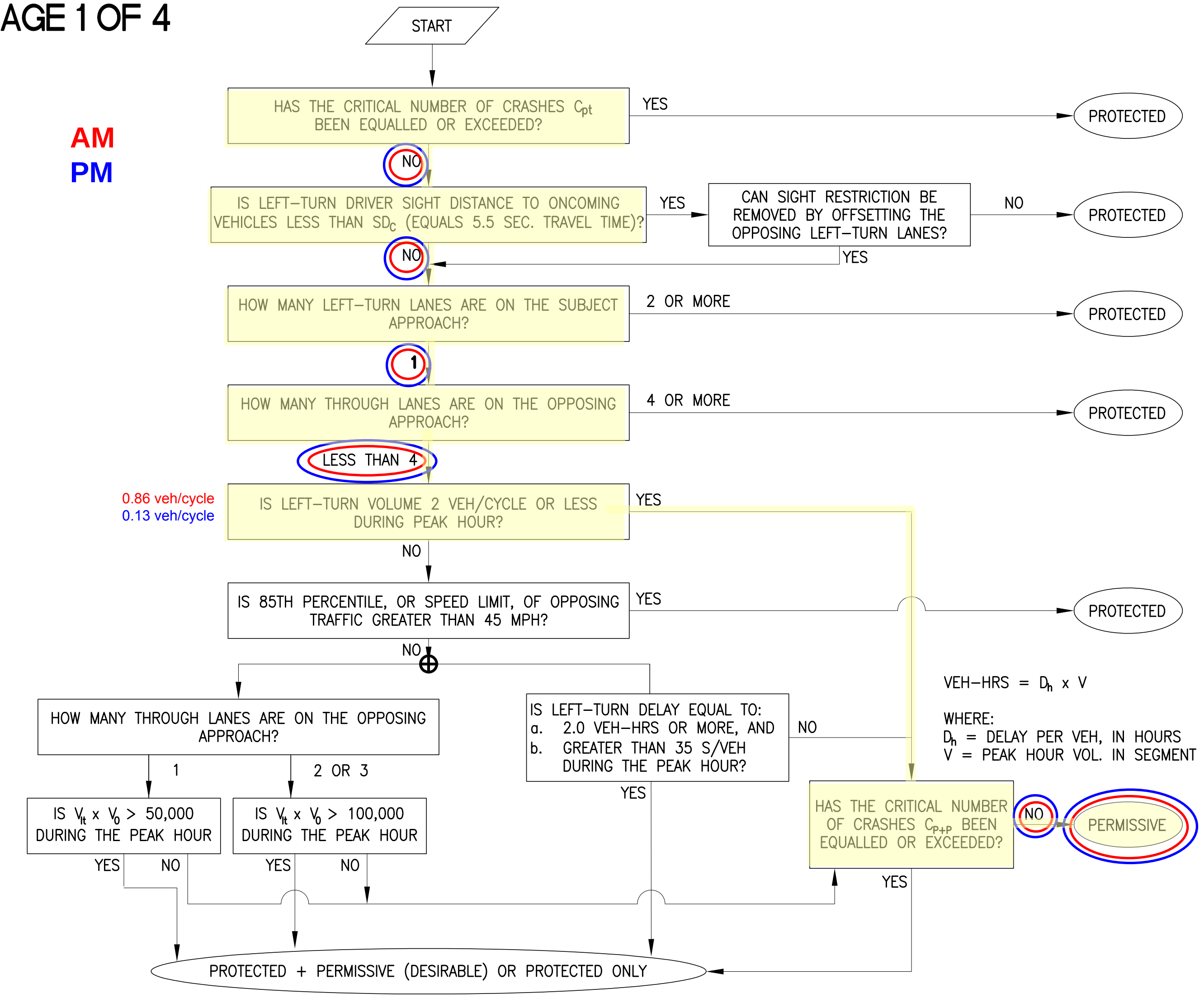
AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE
1

Waialae Avenue & 6th Avenue Intersection - Westbound Approach
(With Left-turn Lane Installed)

PAGE 1 OF 4



CRASH DATA

Not Met

NUMBER OF LEFT–TURN MOVEMENTS ON SUBJECT ROAD	PERIOD DURING WHICH CRASHES ARE CONSIDERED (YEARS)	CRITICAL LEFT–TURN–RELATED CRASH COUNT WHEN CONSIDERING PROTECTED–ONLY, C_{pt} (CRASHES/PERIOD)	 WHEN CONSIDERING PROT.+PERM, C_{P+P} (CRASHES/PERIOD)	
ONE	1	6	4	0
ONE	2	11	6	0
ONE	3	14	7	0
BOTH	1	11	6	
BOTH	2	18	9	
BOTH	3	26	13	

SIGHT DISTANCE

ONCOMING TRAFFIC SPEED LIMIT (MPH)	MINIMUM SIGHT DISTANCE TO ONCOMING VEHICLES, SD_C (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

VARIABLES

V_{lt} = LEFT–TURN VOLUME ON THE SUBJECT APPROACH, VEH/H

V_0 = THROUGH PLUS RIGHT–TURN VOLUME ON THE APPROACH OPPOSING THE SUBJECT LEFT–TURN MOVEMENT, VEH/H

NOTE:

THIS FLOW–CHART HAS BEEN ADAPTED FROM THE LEFT–TURN WARRANT GUIDELINES PROVIDED IN THE TRAFFIC SIGNAL TIMING MANUAL (2008), FHWA. **DARKENED TEXT DENOTES MODIFIED VALUES.** THESE GUIDELINES SHOULD NOT BE USED AS THE SOLE MEANS OF WARRANTING A PARTICULAR LEFT–TURN PHASING SCHEME; ENGINEERING JUDGMENT SHOULD ALWAYS BE APPLIED IN MAKING THE DETERMINATION. REFER TO FIGURE 3 AND FIGURE 4 FOR FURTHER DISCUSSION.

⊕ **WHERE DATA IS AVAILABLE, THE YIELD RECOMMENDATION FROM THE LEFT–TURN DELAY ASSESSMENT SHOULD BE USED. OTHERWISE, USE YIELDING RECOMMENDATION FROM THE VOLUME CROSS–PRODUCT.**

TRAFFIC ASSESSMENT FOR
LEFT–TURN SIGNAL PHASING
GUIDELINES

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS, SURVEYORS • HONOLULU, HAWAII

FLOWCHART 1: GUIDELINES FOR DETERMINING THE POTENTIAL NEED FOR A LEFT–TURN PHASE

FIGURE

1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑↱		↰	↑↱			↰↑	↱
Traffic Volume (veh/h)	12	410	100	28	994	24	137	167	62	24	152	82
Future Volume (veh/h)	12	410	100	28	994	24	137	167	62	24	152	82
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.98	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88
Adj Sat Flow, veh/h/ln	1693	1660	1693	1710	1676	1710	1676	1676	1710	1701	1601	1601
Adj Flow Rate, veh/h	17	500	169	37	1198	33	163	190	105	30	192	112
Adj No. of Lanes	0	2	0	0	2	0	1	1	0	0	1	1
Peak Hour Factor	0.70	0.82	0.59	0.75	0.83	0.72	0.84	0.88	0.59	0.81	0.79	0.73
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	57	1393	462	71	1914	52	120	267	147	56	273	311
Arrive On Green	0.65	0.65	0.65	0.65	0.65	0.65	0.26	0.26	0.26	0.26	0.26	0.26
Sat Flow, veh/h	36	2158	716	57	2966	81	962	1012	559	70	1036	1180
Grp Volume(v), veh/h	365	0	321	653	0	615	163	0	295	222	0	112
Grp Sat Flow(s),veh/h/ln	1548	0	1362	1595	0	1509	962	0	1572	1106	0	1180
Q Serve(g_s), s	0.0	0.0	12.0	0.0	0.0	26.8	6.2	0.0	18.7	4.1	0.0	8.5
Cycle Q Clear(g_c), s	11.0	0.0	12.0	24.9	0.0	26.8	29.0	0.0	18.7	22.8	0.0	8.5
Prop In Lane	0.05		0.53	0.06		0.05	1.00		0.36	0.14		1.00
Lane Grp Cap(c), veh/h	1033	0	879	1064	0	974	120	0	414	329	0	311
V/C Ratio(X)	0.35	0.00	0.37	0.61	0.00	0.63	1.36	0.00	0.71	0.68	0.00	0.36
Avail Cap(c_a), veh/h	1033	0	879	1064	0	974	120	0	414	329	0	311
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	8.9	0.0	9.0	11.3	0.0	11.7	53.6	0.0	36.7	36.3	0.0	32.9
Incr Delay (d2), s/veh	0.9	0.0	1.2	2.7	0.0	3.1	207.9	0.0	5.6	5.4	0.0	0.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.2	0.0	4.8	12.2	0.0	11.9	10.5	0.0	8.8	6.8	0.0	2.8
LnGrp Delay(d),s/veh	9.8	0.0	10.2	14.0	0.0	14.8	261.5	0.0	42.4	41.7	0.0	33.7
LnGrp LOS	A		B	B		B	F		D	D		C
Approach Vol, veh/h		686			1268			458			334	
Approach Delay, s/veh		10.0			14.4			120.4			39.0	
Approach LOS		B			B			F			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		76.0		34.0		76.0		34.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		71.0		29.0		71.0		29.0
Max Q Clear Time (g_c+I1), s		14.0		31.0		28.8		24.8
Green Ext Time (p_c), s		44.1		0.0		34.7		1.8

Intersection Summary	
HCM 2010 Ctrl Delay	33.9
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑↱		↰	↑↱			↰↑	↱
Traffic Volume (veh/h)	31	664	21	4	544	22	151	318	80	26	59	39
Future Volume (veh/h)	31	664	21	4	544	22	151	318	80	26	59	39
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.96	1.00		0.96	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1693	1660	1693	1710	1676	1710	1676	1676	1710	1701	1601	1601
Adj Flow Rate, veh/h	35	685	45	11	573	30	186	361	98	36	79	56
Adj No. of Lanes	0	2	0	0	2	0	1	1	0	0	1	1
Peak Hour Factor	0.88	0.97	0.47	0.38	0.95	0.73	0.81	0.88	0.82	0.73	0.75	0.70
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	79	1394	90	42	1504	78	217	518	141	105	203	552
Arrive On Green	0.51	0.51	0.51	0.51	0.51	0.51	0.41	0.41	0.41	0.41	0.41	0.41
Sat Flow, veh/h	91	2743	178	21	2958	153	1124	1268	344	161	498	1351
Grp Volume(v), veh/h	393	0	372	322	0	292	186	0	459	115	0	56
Grp Sat Flow(s),veh/h/ln	1542	0	1469	1643	0	1490	1124	0	1613	659	0	1351
Q Serve(g_s), s	0.0	0.0	20.0	0.0	0.0	14.4	16.8	0.0	28.2	4.0	0.0	3.1
Cycle Q Clear(g_c), s	18.3	0.0	20.0	14.0	0.0	14.4	49.0	0.0	28.2	32.2	0.0	3.1
Prop In Lane	0.09		0.12	0.03		0.10	1.00		0.21	0.31		1.00
Lane Grp Cap(c), veh/h	816	0	747	866	0	758	217	0	659	309	0	552
V/C Ratio(X)	0.48	0.00	0.50	0.37	0.00	0.39	0.86	0.00	0.70	0.37	0.00	0.10
Avail Cap(c_a), veh/h	816	0	747	866	0	758	217	0	659	309	0	552
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	19.0	0.0	19.4	18.0	0.0	18.0	52.9	0.0	29.4	28.4	0.0	21.9
Incr Delay (d2), s/veh	2.0	0.0	2.4	1.2	0.0	1.5	27.0	0.0	3.2	0.7	0.0	0.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	8.8	0.0	8.6	6.7	0.0	6.2	7.8	0.0	13.1	3.4	0.0	1.2
LnGrp Delay(d),s/veh	21.0	0.0	21.8	19.2	0.0	19.5	79.9	0.0	32.6	29.2	0.0	22.0
LnGrp LOS	C		C	B		B	E		C	C		C
Approach Vol, veh/h		765			614			645			171	
Approach Delay, s/veh		21.4			19.3			46.2			26.8	
Approach LOS		C			B			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		66.0		54.0		66.0		54.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		61.0		49.0		61.0		49.0
Max Q Clear Time (g_c+I1), s		22.0		51.0		16.4		34.2
Green Ext Time (p_c), s		23.0		0.0		24.9		4.4

Intersection Summary		
HCM 2010 Ctrl Delay		28.5
HCM 2010 LOS		C

HCM 2010 Signalized Intersection Summary
8: 6th Ave & Waialae Ave

9/1/2016

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑↱		↰	↑↱			↰↑	↱
Traffic Volume (veh/h)	12	410	100	28	994	24	137	167	62	24	152	82
Future Volume (veh/h)	12	410	100	28	994	24	137	167	62	24	152	82
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.96	0.99		0.96	0.99		0.97	0.98		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88
Adj Sat Flow, veh/h/ln	1693	1660	1693	1710	1676	1710	1676	1676	1710	1701	1601	1601
Adj Flow Rate, veh/h	17	500	169	37	1198	33	163	190	105	30	192	112
Adj No. of Lanes	0	2	0	0	2	0	1	1	0	0	1	1
Peak Hour Factor	0.70	0.82	0.59	0.75	0.83	0.72	0.84	0.88	0.59	0.81	0.79	0.73
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	55	1316	436	69	1814	50	220	299	165	63	282	240
Arrive On Green	0.61	0.61	0.61	0.61	0.61	0.61	0.05	0.30	0.30	0.21	0.21	0.21
Sat Flow, veh/h	34	2150	713	57	2963	81	1597	1005	555	127	1369	1163
Grp Volume(v), veh/h	367	0	319	653	0	615	163	0	295	222	0	112
Grp Sat Flow(s),veh/h/ln	1552	0	1346	1594	0	1507	1597	0	1560	1496	0	1163
Q Serve(g_s), s	0.0	0.0	13.3	4.1	0.0	29.4	6.0	0.0	18.0	6.9	0.0	9.3
Cycle Q Clear(g_c), s	12.1	0.0	13.3	27.8	0.0	29.4	6.0	0.0	18.0	15.0	0.0	9.3
Prop In Lane	0.05		0.53	0.06		0.05	1.00		0.36	0.14		1.00
Lane Grp Cap(c), veh/h	984	0	824	1010	0	922	220	0	464	346	0	240
V/C Ratio(X)	0.37	0.00	0.39	0.65	0.00	0.67	0.74	0.00	0.64	0.64	0.00	0.47
Avail Cap(c_a), veh/h	984	0	824	1010	0	922	220	0	511	389	0	275
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	10.6	0.0	10.9	13.6	0.0	14.0	38.6	0.0	33.5	40.4	0.0	38.4
Incr Delay (d2), s/veh	1.1	0.0	1.4	3.2	0.0	3.8	12.7	0.0	2.3	3.0	0.0	1.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.8	0.0	5.2	13.4	0.0	13.1	3.1	0.0	8.1	6.6	0.0	3.1
LnGrp Delay(d),s/veh	11.7	0.0	12.2	16.8	0.0	17.8	51.3	0.0	35.8	43.4	0.0	39.8
LnGrp LOS	B		B	B		B	D		D	D		D
Approach Vol, veh/h		686			1268			458			334	
Approach Delay, s/veh		12.0			17.3			41.3			42.2	
Approach LOS		B			B			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6	7	8
Phs Duration (G+Y+Rc), s		72.3		37.7		72.3	10.0	27.7
Change Period (Y+Rc), s		5.0		5.0		5.0	4.0	5.0
Max Green Setting (Gmax), s		64.0		36.0		64.0	6.0	26.0
Max Q Clear Time (g_c+I1), s		15.3		20.0		31.4	8.0	17.0
Green Ext Time (p_c), s		39.0		3.4		27.9	0.0	2.6

Intersection Summary	
HCM 2010 Ctrl Delay	23.0
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↰↑↱			↰↑↱		↰	↑↱			↰↑	↱
Traffic Volume (veh/h)	31	664	21	4	544	22	151	318	80	26	59	39
Future Volume (veh/h)	31	664	21	4	544	22	151	318	80	26	59	39
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.96	1.00		0.96	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1693	1660	1693	1710	1676	1710	1676	1676	1710	1701	1601	1601
Adj Flow Rate, veh/h	35	685	45	11	573	30	186	361	98	36	79	56
Adj No. of Lanes	0	2	0	0	2	0	1	1	0	0	1	1
Peak Hour Factor	0.88	0.97	0.47	0.38	0.95	0.73	0.81	0.88	0.82	0.73	0.75	0.70
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	87	1562	101	44	1688	87	253	438	119	72	129	296
Arrive On Green	0.57	0.57	0.57	0.57	0.57	0.57	0.09	0.35	0.35	0.22	0.22	0.22
Sat Flow, veh/h	95	2734	177	23	2955	153	1597	1268	344	146	585	1343
Grp Volume(v), veh/h	392	0	373	322	0	292	186	0	459	115	0	56
Grp Sat Flow(s),veh/h/ln	1536	0	1470	1640	0	1491	1597	0	1612	732	0	1343
Q Serve(g_s), s	0.0	0.0	17.5	0.0	0.0	12.5	10.6	0.0	31.3	5.1	0.0	4.1
Cycle Q Clear(g_c), s	15.9	0.0	17.5	12.2	0.0	12.5	10.6	0.0	31.3	21.4	0.0	4.1
Prop In Lane	0.09		0.12	0.03		0.10	1.00		0.21	0.31		1.00
Lane Grp Cap(c), veh/h	910	0	840	968	0	852	253	0	557	201	0	296
V/C Ratio(X)	0.43	0.00	0.44	0.33	0.00	0.34	0.73	0.00	0.82	0.57	0.00	0.19
Avail Cap(c_a), veh/h	910	0	840	968	0	852	253	0	658	277	0	380
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	14.4	0.0	14.8	13.6	0.0	13.7	33.3	0.0	35.9	44.2	0.0	38.1
Incr Delay (d2), s/veh	1.5	0.0	1.7	0.9	0.0	1.1	10.5	0.0	7.3	2.6	0.0	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	7.7	0.0	7.4	5.9	0.0	5.4	5.4	0.0	15.0	3.8	0.0	1.5
LnGrp Delay(d),s/veh	15.9	0.0	16.5	14.6	0.0	14.8	43.8	0.0	43.2	46.7	0.0	38.4
LnGrp LOS	B		B	B		B	D		D	D		D
Approach Vol, veh/h		765			614			645			171	
Approach Delay, s/veh		16.2			14.7			43.4			44.0	
Approach LOS		B			B			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6	7	8
Phs Duration (G+Y+Rc), s		73.6		46.4		73.6	15.0	31.4
Change Period (Y+Rc), s		5.0		5.0		5.0	4.0	5.0
Max Green Setting (Gmax), s		61.0		49.0		61.0	11.0	34.0
Max Q Clear Time (g_c+I1), s		19.5		33.3		14.5	12.6	23.4
Green Ext Time (p_c), s		23.9		3.7		25.4	0.0	3.0

Intersection Summary			
HCM 2010 Ctrl Delay			25.9
HCM 2010 LOS			C