Bike Detection in California

California Department of Transportation

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Caltrans

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Bike Detection in California (Caltrans)
Overview

California Legislation à Caltrans Policy à Caltrans Traffic Operations Policy Directive 09-06 à Implementation Memo

Inductive Loops: Type D for bike detection compliance: 1D; 1D +3A; shunt option; proper windings direction; sizing (6’x6’ vs. 12’x6’) and (3’x3’ vs. 3’x6’)

Other Technologies: *Radar* (testing in Chico); FLIR

VideoSync: Quantify vehicle/bike detection analysis

Consider: *Intersection Conflict Zone detection*

Factors Contributing to Pedestrian and Bicycle Crashes on Rural Highways

Publication Number: FHWA-HRT-10-052, June 2010

Approximately 25 % of nationwide pedestrian and bicycle fatal and injury accidents occur on rural highways.

In contrast to urban highways, rural highways have certain characteristics that can be more hazardous to pedestrians and bicyclists, such as higher average vehicle speeds and a lack of sidewalk provisions.

Limited research has been conducted on rural highways, where crash types have been defined with more detailed coding than exists on standard police forms and where crash data could be linked with roadway characteristics and traffic counts. *In California, approximately 70% of state highways are in rural areas.*

The most common crash types for bicyclists differed in rural and urban areas. **The most common rural crashes included bicyclists turning/merging into the path of the driver and drivers overtaking the bicyclist.**

Both rural and urban areas had the same *Top 4 most common pedestrian crash types:* (1) peds walking along the roadway, (2) pedestrians failing to yield, (3) misc., and (4) peds darting/dashing midblock.

Similar to the comparison of bicycle crash types, the most common rural ped crash type (peds walking along the roadway) was more common at midblock segments, whereas the most common urban crash type (peds failing to yield) was mostly found at intersections.

Crash Factors	Type of Crash	Percent of Crashes	
		Rural	***Urban***
Resulted in fatality	Pedestrian	18	10
	Bicyclist	6	2
Pedestrian or bicyclist alcohol involvement	Pedestrian	24	19
	Bicyclist	8	6
Vehicle speed 41–60 mi/h	Pedestrian	46	20
	Bicyclist	47	9
Road speed limit 50 mi/h or higher	Pedestrian	57	11
	Bicyclist	54	3

Factors Contributing to Pedestrian and Bicycle Crashes on Rural Highways
Publication Number: FHWA-HRT-10-052 (June 2010)

California Vehicle Code 21450.5 (2008)

Traffic-Actuated Signals: Detection of Motorcycles and Bicycles

(a) A traffic-actuated signal is an official traffic control signal, as specified in Section 445, that displays one or more of its indications in response to the presence of traffic detected by mechanical, visual, electrical, or other means.

(b) **Upon the first placement of a traffic-actuated signal or replacement of the loop detector of a traffic-actuated signal, the traffic-actuated signal shall, to the extent feasible and in conformance with professional traffic engineering practice, be installed and maintained so as to detect lawful bicycle or motorcycle traffic on the roadway.**

(c) Cities, counties, and cities and counties shall not be required to comply with the provisions contained in subdivision (b) until the Department of Transportation, in consultation with these entities, has established uniform standards, specifications, and guidelines for the detection of bicycles and motorcycles by traffic-actuated signals and related signal timing.

(d) This section shall remain in effect only until January 1, 2018, and as of that date is repealed, unless a later enacted statute, that is enacted before January 1, 2018, deletes or extends that date.

Added and repealed Sec. 2, Ch. 337, Stats. 2007. Effective January 1, 2008. Repeal operative January 1, 2018.

California Traffic Control Devices Committee (CTCDC) ***requirements for Bike Detection***

Minimum bicycle timing: phase length [min green + yellow + red clearance],

based on intersection width: distance from limit line to far side of last conflicting lane

Reference Bicycle-Rider: minimum 4ft. tall person, weighing minimum 90lbs, riding on an unmodified minimum **16-inch** wheel bicycle

with non-ferromagnetic frame, non-ferromagnetic fork & cranks, aluminum rims, stainless steel spokes & headlight

Traffic Operations Policy Directive 09-06 (Sept. 10, 2009)

- specifies that "*All new limit line detector installations and modifications to the existing limit line detection on a public or private road or driveway intersecting a public road shall either provide a* ***Limit Line Detection Zone*** *in which the Reference Bicycle-Rider is detected* ***or*** *be placed on a* ***permanent recall or fixed time operation****.*"
- Detection Zone is defined by **6'x6' zone** immediately behind limit line
- The policy directive was incorporated in the 2012 California Manual on Uniform Traffic Control Devices (Calif. MUTCD).

Table 4D-109(CA) Signal Operations - Minimum Bicycle Timing (English Units)

$G_{min} + Y + R_{clear} \geq 6$ sec + (w+6 ft)/14.7 ft/sec, where
G_{min} = Length of minimum green interval (sec)
Y = Length of yellow interval (sec)
R_{clear} = Length of red clearance interval (sec)
W = Distance from limit line to far side of last conflicting lane (ft)

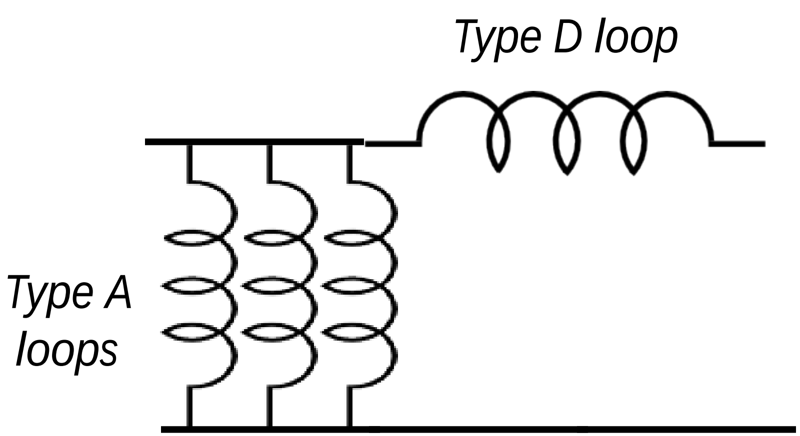
California MUTCD

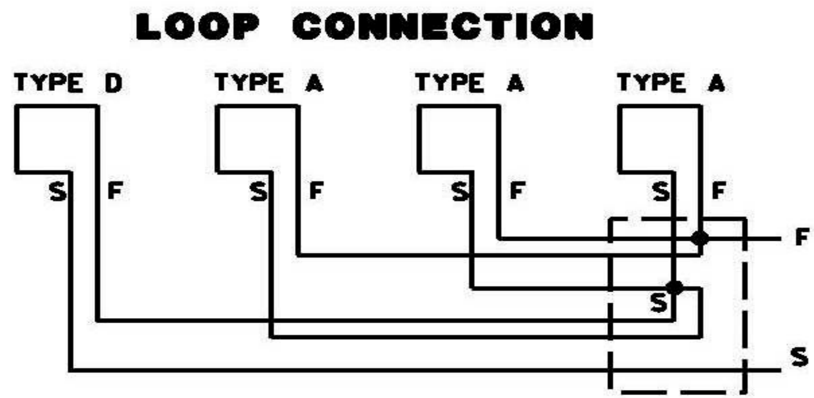
Distance from limit line to far side of last conflicting lane	Minimum phase length (minimum green plus yellow plus red clearance)
Feet	Seconds
40	9.1
50	9.8
60	10.5
70	11.2
80	11.9
90	12.5
100	13.2
110	13.9
120	14.6
130	15.3
140	15.9
150	16.6
160	17.3
170	18.0
180	18.7

Challenges Encountered with Proper Type D loop Installation

Type D + 3 Type A Loops

One Type D loop in series with the parallel combination of 3 Type A loops (if not on its own DLC):





Change of Inductance Measured (ΔL): Ref. Bike over Type D loop

Total DLC length	*Inductance*	*Detector Card & sensitivity setting*	Ref. Bike: Inductance change *(least sensitive region of loop, ~8-9" from curb-side edge)*	Ref. Bike: Inductance change *(through center of loop)*
340 ft (1D +3A)	297 µH	(formerly Canoga) GTT C924: 6	82 nH	240 nH
		GTT C924: 6 *(max for presence)*	110 nH (6" from edge)	
		GTT C924: 6	85 nH	
		GTT C924: 6	93 nH	
		GTT C924: 6	76 nH	
340 ft (1D +3A)	297µH	GTT C924: 6	62 nH	229 nH
		GTT C924: 5	65 nH	231 nH
		GTT C924: 5	70 nH	246 nH
240 ft (1D +3A)	273 µH	GTT C924: 5	55 nH	249 nH
		GTT C924: 5	71 nH	201 nH
		GTT C924: 5	55 nH	233 nH
240 ft (1D +1A) *w/ 8" 14 gauge nickel chromium resistive wire*	247 µH	GTT C924: 5	62 nH	209 nH
		GTT C924: 5	72 nH	237 nH
		GTT C924: 5	64 nH	221 nH
		GTT C924: 5	58 nH	

If you have only 1 loop behind Type D loop:

Shunt Proposal

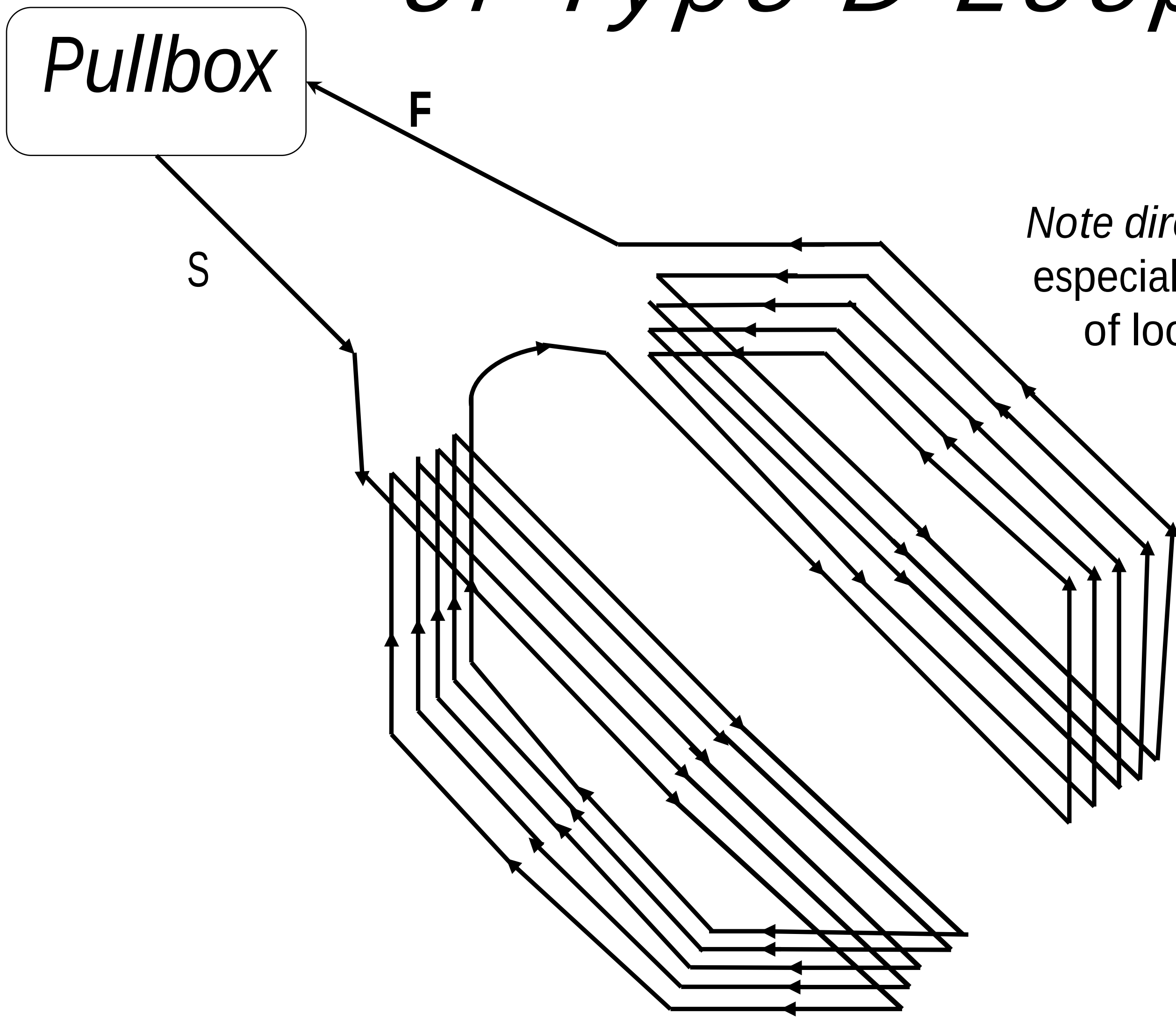
Resistive wire“shunt:” proposal of using a 8” 14 gauge nickel chromium to emulate a 2 parallel combination of Type A loops was inserted in parallel to the Type A loop.

Specifically for those districts that use only one Type A loop directly behind the limit line Type D loops.

Tested by connecting shunt **in series to the Type D loop (and shunt in parallel to one (1) Type A loop)**.

The test showed that the resulting ΔL when the bike was ridden over the Type D loop showed the results similar to 1D +3A configuration. The short (8”) length of ***0.165ohms/foot*** 14-gauge nickel chromium resistive wire was used as a shunt.

Direction of Windings of Type D Loop



Note direction of loop current:
especially in center segments of loop *(same direction)*

How to Determine Whether Type D Windings Installed Properly

Using DC power supply and ordinary compass: simple procedure to verify whether the direction of windings of Type D loop have been installed correctly.

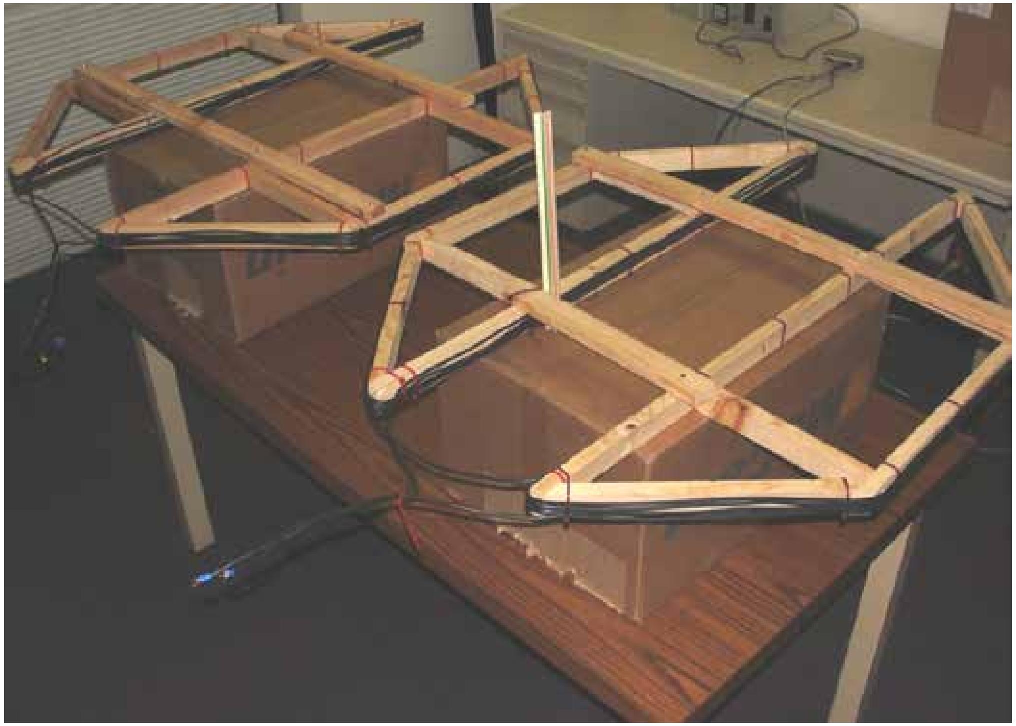
If direction of compass needle points in the *same direction* when placed over each of the center segments of the Type D loop, then direction of the windings is *correct*.

Method indicates whether the magnetic field is in opposing or same direction.

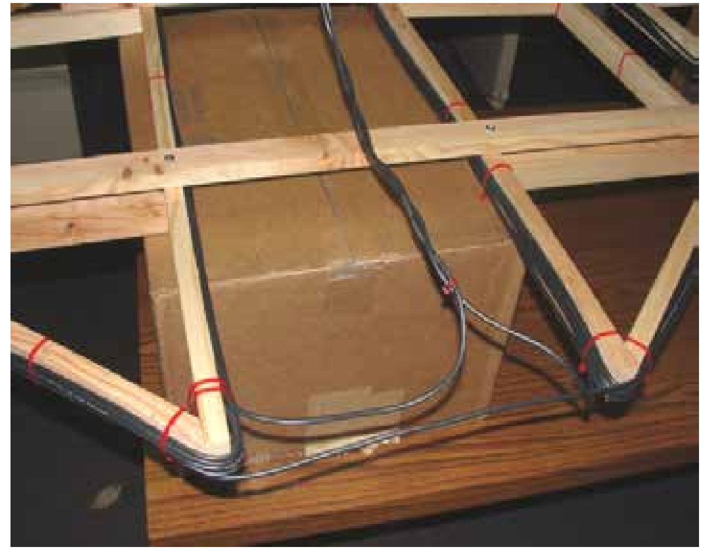
May use procedure during construction validate proper installation.

Testing Type D Loop Winding Direction

Proved 1st in Office



Correctly (R side) and incorrectly (L side) wound 3’x3’ Type D loops



Incorrectly wound 3’x3’ Type D loop – Note direction of windings in the center, that go in opposite directions, and closeup of right-half of the Type D loop.

Test Set-up for Detecting Reference Bicycle Wheel (16” diameter) over the Type D detector

*Using the Reno Model C 1101-SS detector card: measures ΔL/L, and outputs an **audible signal** when sufficient change of inductance detected, the bicycle wheel was passed over each of the loops*

Results Testing Wheel over 3’x3’ Type D loops

	Loop Inductance	Bike Detected?	ΔL/L % when bike wheel detected
Incorrectly wound Type D *(Loop A)*	87 µH	Only over edges of loop wire (outside edges of Type D loop)	0 in center of loop, but 0.018 -0.26% *at left-most and right-most edges*
Correctly wound Type D *(Loop B)*	84 µH	Yes, over all of Type D loop	0.08 – 0.111% (0.160% in center)

Magnetic Field and Using an Ordinary Compass

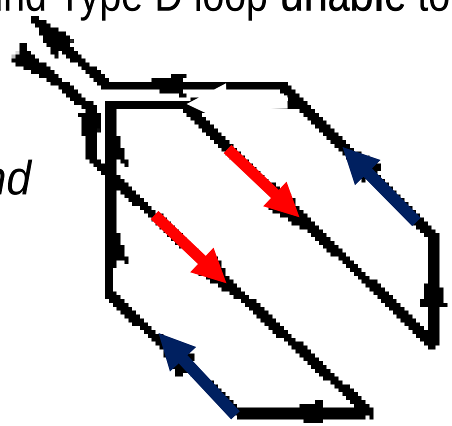
Electrical direct current (dc) generates a constant magnetic field around the wire (like a magnet generates a magnetic field): If magnetic field around wire stronger than earth's magnetic field, then compass placed near magnetic field will cause compass needle to point in the loop-current-generated magnetic field direction *instead of* pointing towards the earth's magnetic field (north).

Electromagnetism: Can determine ***direction of current flow*** within the Type D loop. **Correctly** wound Type D loop: both of the center segments of the loop will cause the compass needle to point in the ***same* direction**. The outer segments of the loop will cause the needle of the compass to point in the *opposite* direction to that of the center segments. If direction of the current flows in the same direction in the center segments of the Type D loop, the reference bicycle would be detected.

For the **incorrectly** wound Type D loop, each of the center segments of the loop cause the needle of the compass to point in the ***opposite*** direction. Currents in the center of the Type D loop in opposing directions: resulting magnetic fields around these segments counteract, resulting in an overall smaller magnetic field, which therefore ***results in less sensitivity*** of the Type D loop.

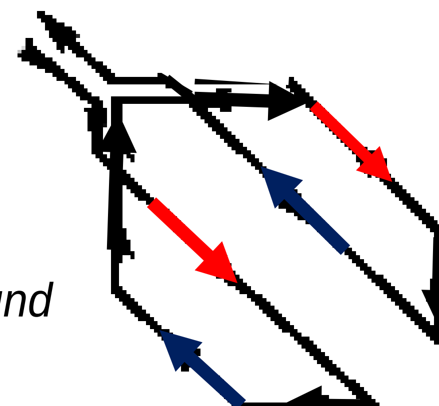
à à Incorrectly wound Type D loop **unable** to detect the reference bicycle wheel.

Correctly wound



Shows only 1 winding,
but must be 5 windings
for bike detection.

Incorrectly wound



Detection Ability With Respect to Height: vertical distance above loop wire

To determine how high above the Type D loop wire the 16” bicycle wheel could be detected, same compass used.

Compass needle was observed while lying directly on the wooden-framed loop segment. Compass moved (lifted) up at various increments, from 2-10” inches above Type D loop. A 12” ruler was attached for test and compass held at different heights.

Consistent results were found at each of the loops for **> 4**” **of height** above wooden-framed loop (due to 8 Amps current used).

à à The magnetic permeability through the air & concrete is practically the same, so o*verlay of pavement should not impede detection of a bicycle wheel.*

D3 field demo of both 3'x3' Type Loops with DC power (8 Amps)

Compass placed over each center segment of *incorrectly* wound Type D loop. Needles (red) are pointing in opposite direction.

Testing District 3 (Wilson Rd at Hwy 99) Type D loops

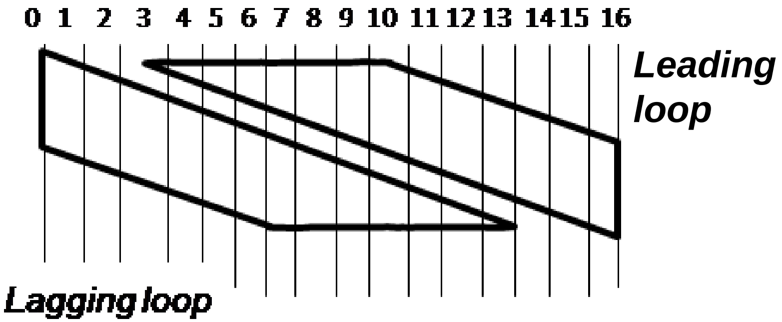
Using Loop Finder to confirm exact location of Type D loop and indicate on pavement using chalk.

Verifying direction of magnetic field (perpendicular to direction of current flow).
This Type D limit-line loop, WB Wilson Road at Hwy 99, proved to have been installed incorrectly.
Note direction of magnetic field of center segments are pointing in opposite directions.

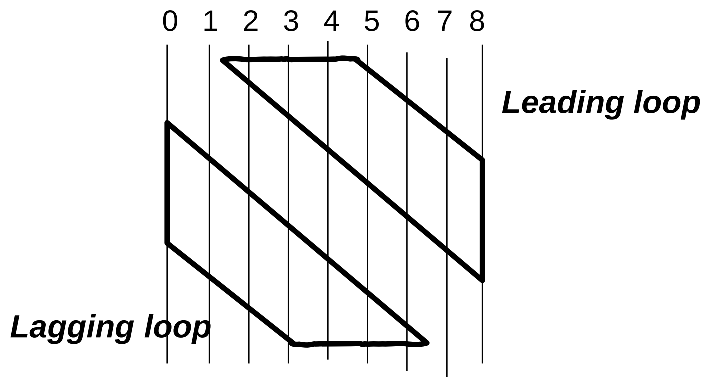
Similar results in District 10 (Hwy 26 (E. Fremont St.) and Cardinal Ave).

Improper Sizing of the Type D Loop

- Caltrans District 10 expanded the specified 6'x6' Type D loop to 12'x 6' because of wide single-lane
- Reference bicycle used to ride along each of the evenly spaced lines (9" spacing) to determine if the bicycle could be detected. Lines drawn & numbered on the pavement, and the ref. bicycle (16" wheel) used to ride along each of drawn lines



12' x 6' Type D loop



6' x 6' Type D loop

Testing the 12’x6’ loop

Loops tested using both the standard Diablo 222 and the Reno 1101SS detector cards: Reno card has the feature of measuring and displaying ΔL/L percentage.
Bike ridden over each of 16 lines. If the bike was not detected, the cyclist repeated riding over the line, a total of 3 or 4 times, to confirm lack of detection.

The inductance was recorded for just the loop alone and % change of inductance, with the bike over the loop (if detected). Overall, the elongated Type D loop was able to detect the bicycle ~70% of the loop. ***Note that Line 0 and Line 16 typically have the highest ΔL/L***. This is not true with the 6’x6’ Type A loops, when riding directly over (parallel to) the loop cable. The reason is the ANGLE OF ATTACK of the bicycle rim and the loop wire.

In Summary:

The 45 degree angle is *very* important for the Type D loop, for optimal bike detection.

The 6’x6’ Type D loop is more sensitive for bike detection than the 12’x6’ Type D loop. The reason is the angle of attack: the 6’x6’ results in a 45 degree angle, but the 12’x6’ results in a larger angle (90 degrees is least sensitive).

Detector sensitivity was set at 6 (max setting= 7). Besides increasing sensitivity to 7, there are more detector cards available with much more sensitivity settings; so if a standard Type 222 card is inadequate for bike detection (due to degradation over time), *a solution could be to replace with a more sensitive detector card.*

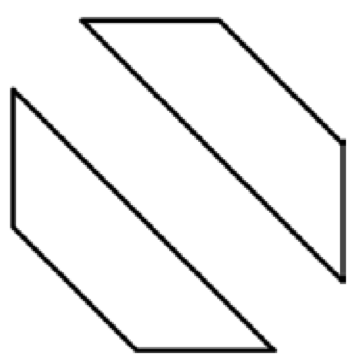
It is best to connect only 1 Type D loop per detector channel. Connecting 2 Type D loops in series would require consideration of DLC length and careful detection card selection (sensitivity based on L/ΔL vs. L). Two Type D loops should never be connected in parallel for bike detection.

Bike Lane Type D loops (3’ wide)

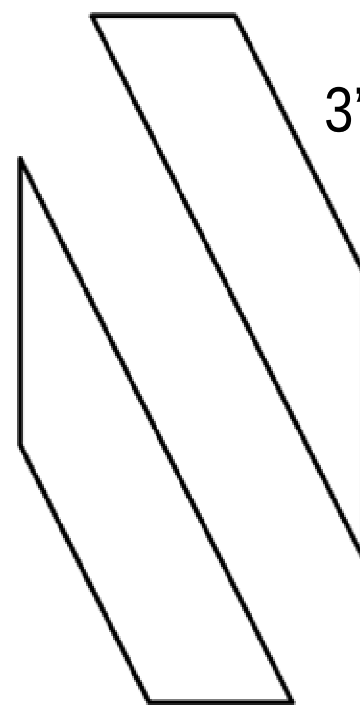
District 12 requested approval to reduce Type D loops to 3’ width for bike lane.

Question: Which is better: 3’x3’ Type D or longer length 3’x6’ Type D loop?

3’x3’ Type D loop



3’x6’ Type D loop



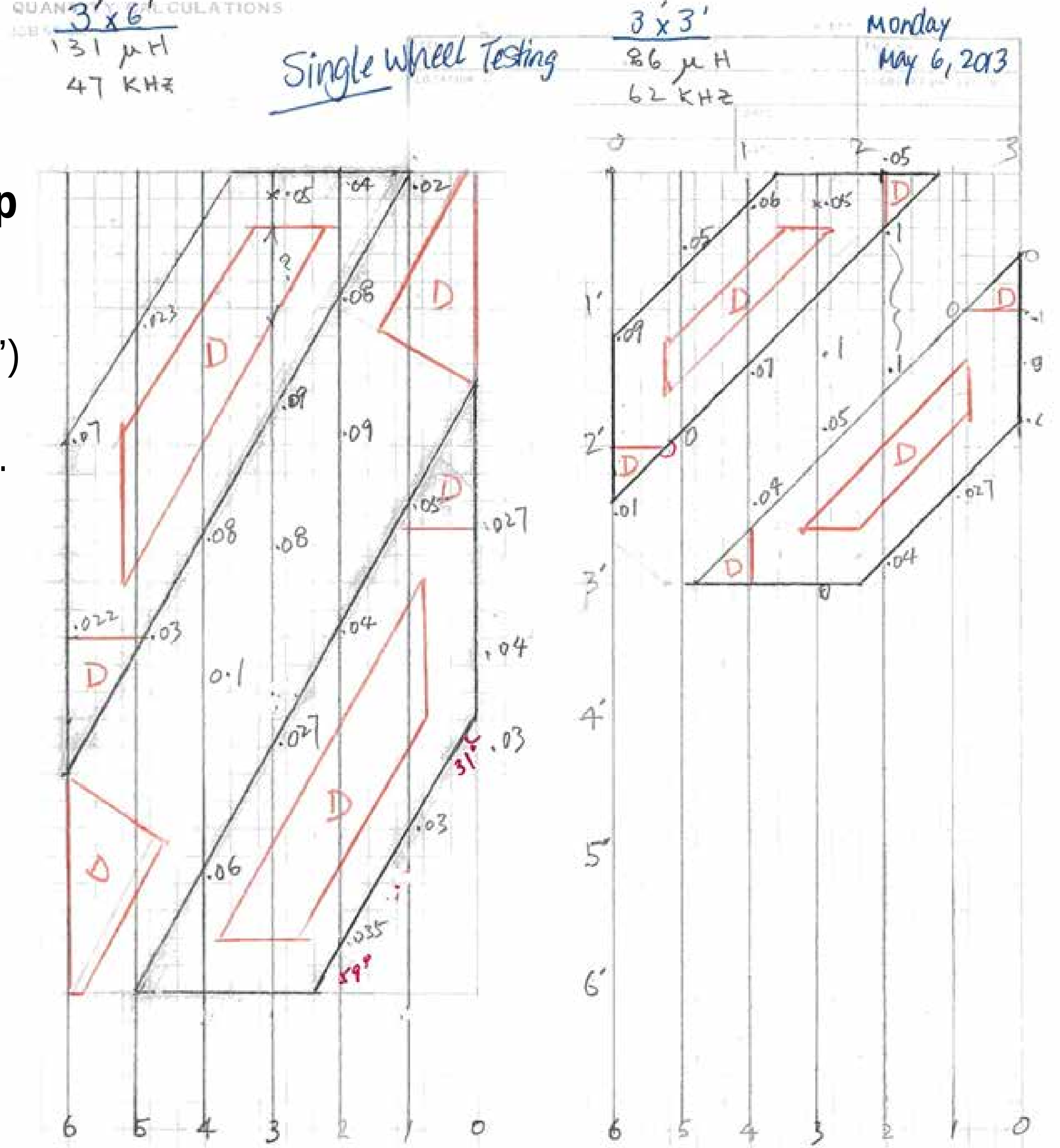
Measurements of Percent Change of Inductance ($\Delta L/L$ %) 3’ width Type D loop

Single wheel used, passed over each wooden-framed reduced sized Type D loops (3’x3’ and 3’x6’)

Measurements of % change as noted. Red zones depict “dead zones” of no change (approx. size).

Measurement of Inductance for 3’x3’ was 131µH and for 3’x6’ was 86µH.

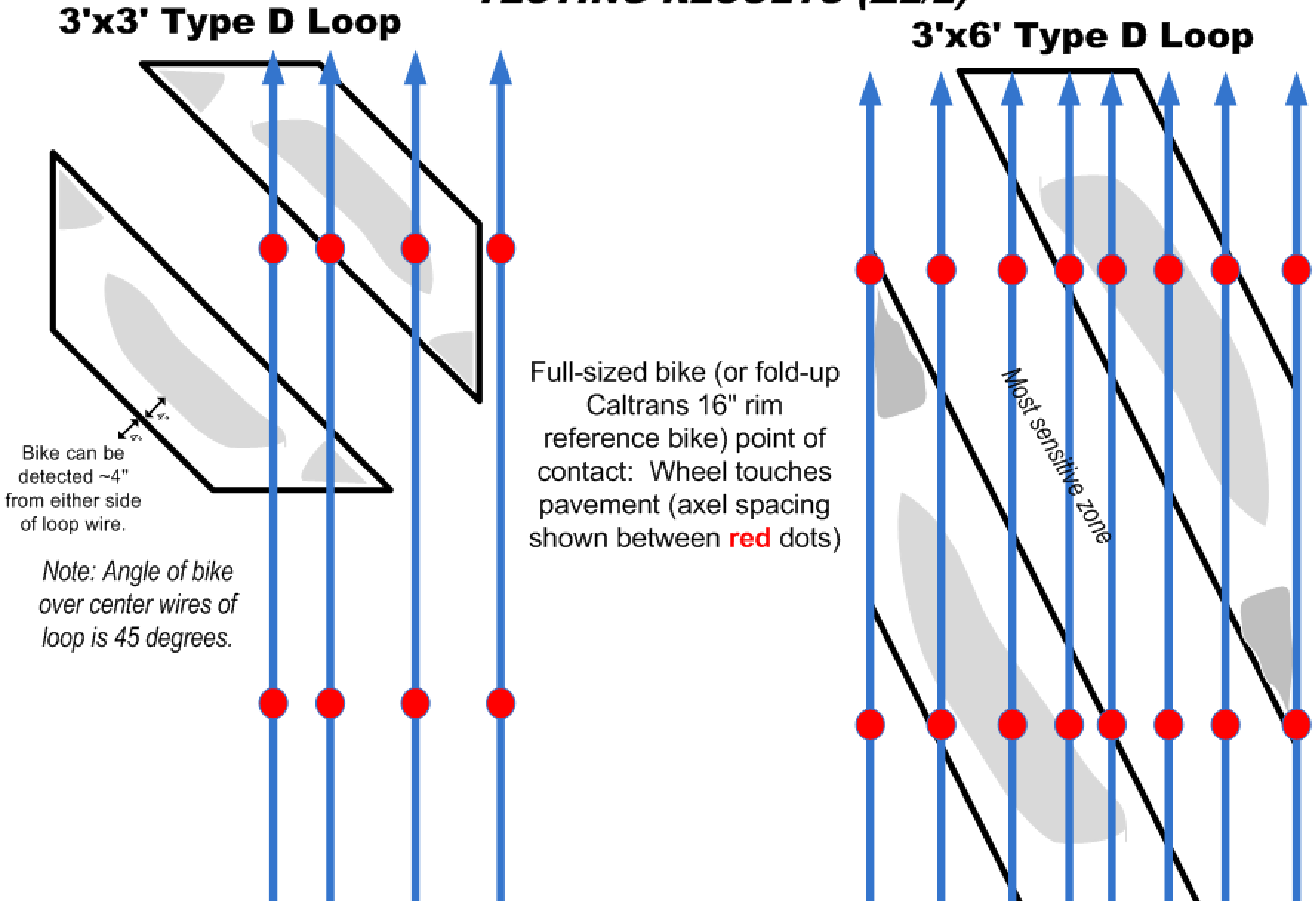
Note “middle diagonal region” is consistently sensitive (does detect wheel).



D: Dead Zone à no detection

Measurements of % Change of Inductance: **$\Delta L/L$ %**

TESTING RESULTS (ΔL/L)



Arrow represents bike. Note that only about half of bike can be in 3'x3' Type D loop. Shaded areas represent "***dead zones***" where bike can not be detected. Highest sensitivity for bike is on the parallel loop line (close to 0 Degrees). No sensitivity when perpendicular to loop wire.

Note: Angle of bike over center wires of loop is 30 degrees.

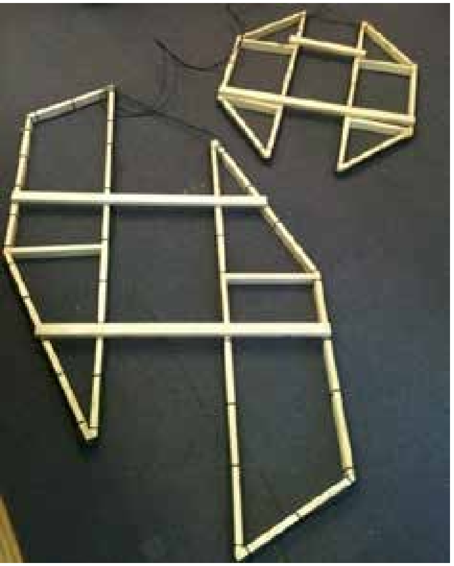
Wooden-Framed 3’ Wide Type D Loops

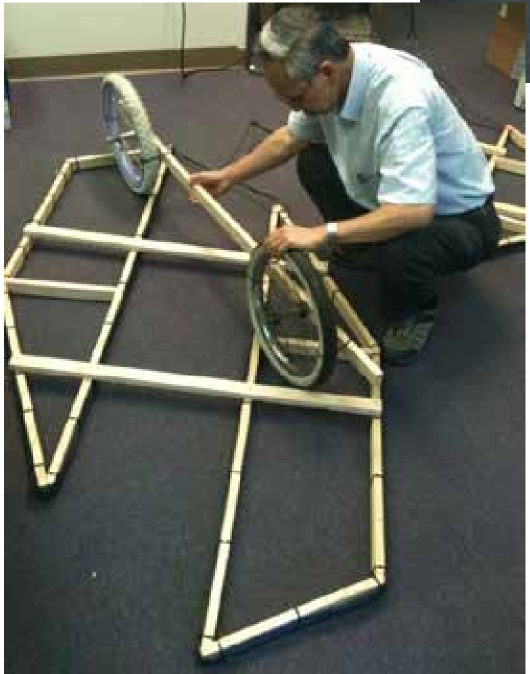
Wooden “axle” used to vary spacing between tires (24” and 40”). Note foldable adult “reference bike” which is 40” spacing between wheel centers.

24” spacing between center of tires ↑

Also, note tape measure across 3’ detector width: used to “ride” bike over loop at various distances from edge (6” spacing). Percent change of inductance measured and recorded at each spacing (0”, 6”, 12”, 18”, 24”, 30” and 36” from left-most edge).

Both 3’x6’ and 3’x3’ Type D loops





40” spacing between center of tires. *Note foldable adult “reference bike.”*

Photos by Hamid Z.

Reduced Width Type D Loop:
Comparing Change of Inductance Measurements (ΔL/L)%

Detector Card Used*: Reno 1101-SS Model C* à measured: ΔL/L (%) Sensitivity Level = 6
3'x3' Type D loop: Inductance= 84μH; Frequency 53.4kHz
3'x6' Type D loop: Inductance= 135μH; Frequency 50.8kHz

Spacing Varied: Distance between centers of front tire and back tire
40" (average for adult)s and 24" (to represent small child)

Bike Line Ridden (from left edge)	**3'x6'** ***40" spacing***	**3'x3'** ***40" spacing***	**3'x6'** ***24" spacing***	**3'x3'** ***24" spacing***
0"	0.040 -.094%	0.032- 0.040%	0.018-0.020%	0.046-0.051%
6"	0.098%	0.035- 0.041%	0.025%	0.060-0.072%
12"	0.042%	0.021-0.025%	0.023-0.025%	0.093-0.104%
18"	0.0140%	0.062-0.095%	0.018-0.021%	0.082-0.113%
24"	0.158%	0.058-0.080%	0.084% (*consistent*)	0.0106-0.101%
30"	0.037-.040%	0.032-0.04%	**Ø** – 0.084%	0.103-**0.121%**
36"	0.102-0.121%	Ø: none when front tire at stopbar; but at 2' behind stop bar: 0.05-0.125%	0.084% (*consistent*)	0.030-0.037%
Comments:	Complete detection: No Dead Zones	*Definite dead zone at Right-most side*	Sometimes both wheels in Dead Zones	Most sensitive (highest % **ΔL/L**)

Technology of Interest:

Microwave Radar

TC-CK1-SBE
Motion and Presence Sensor

Caltrans is testing a microwave radar detector that can *distinguish* between bikes and cars (MS Sedco INTERSECTOR).

The HQ Division of Traffic Operations received many letters from Calif. cities, counties and MPOs: objected to the mandated extended green bike timing. Complaints included traffic engineers' concerns with the *overall intersection efficiency, optimal coordinated traffic signal systems and the impact on additional unnecessary traffic delays to motorists and resultant negative air quality impacts for the public.*

Caltrans believes that a solution would be a vehicle detector that can distinguish between cars/trucks and bicycles, so required additional bike timing would only be necessary if a bike is present.

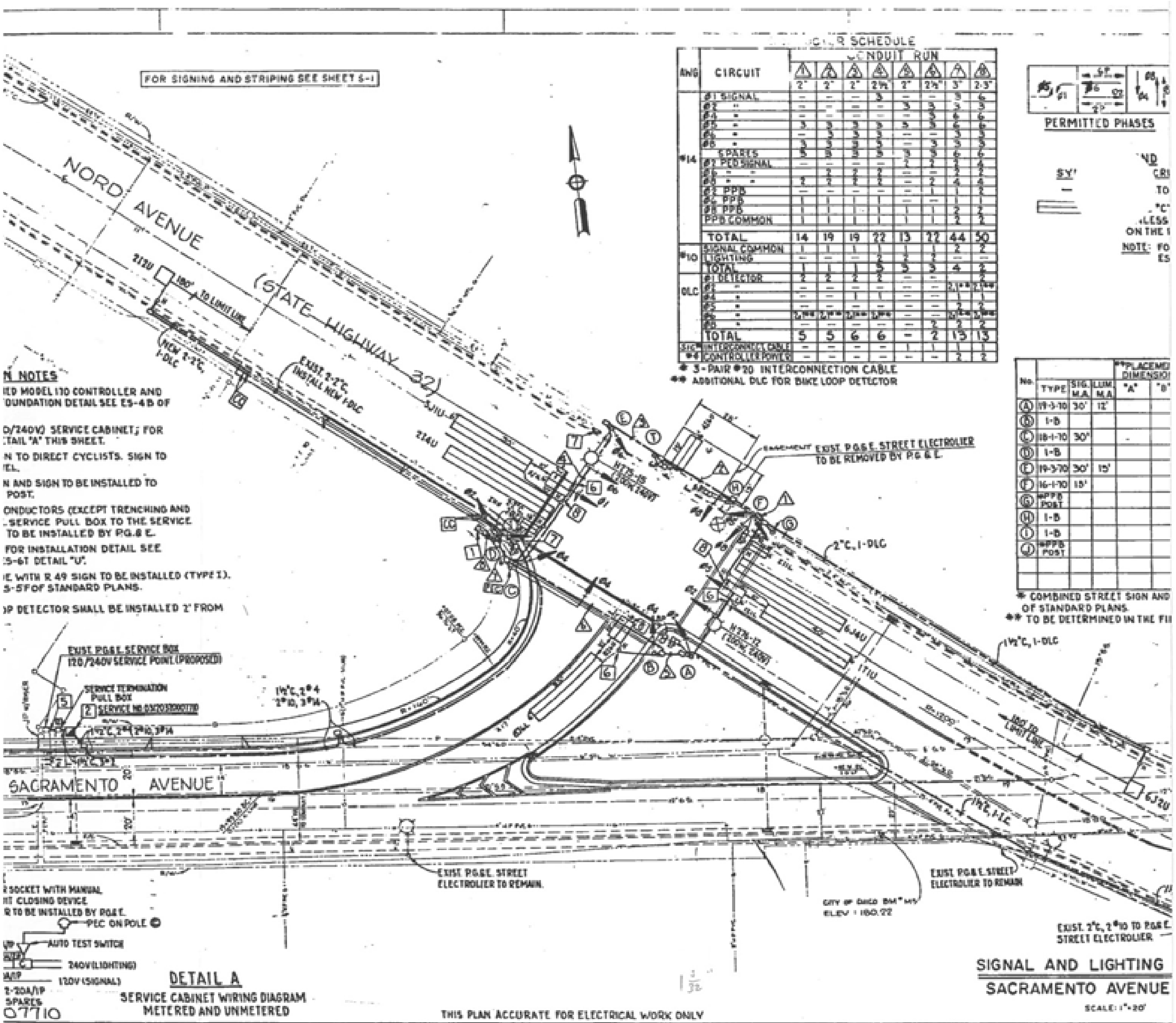
The **City of Pleasanton** has been operating their signals with this device for ~2years. They received the *ITS America's Smart Solution Spotlight award.*

Caltrans has been testing the device at location known for high bike volumes in the City of **Chico**. Results so far seem promising. Accurate detection system that can distinguish bikes from cars would allow Caltrans to extend the minimum green *if, and only if*, a bike is detected.

- 19 States currently using INTERSECTOR
- Almost 700 units deployed in USA
- Not affected by weather, nor sun glare

Weight: 5 lbs 24.75GHz 4 outputs (8 zones max)
Size: 11"x8.5"x7" (LxWxH)
Detection range: 50' min – 425' max
Cost: < $5Keach (~$19K for 4-leg intersection)

Caltrans Bike Detection Test Location



Chico, California, approx. ~1mile from Chico State University

Intersector radar units installed on the NB traffic signal mast arm (at 18'), and SB traffic signal pole shaft (at 16'6").

Video cameras also installed.

VideoSync

http://www.dot.ca.gov/newtech/operations/videosync/index.htm

Caltrans Division of Research & Innovation (DRI) developed VideoSync 10+ years ago.*

VideoSync is a **portable roadway detector evaluation system**.

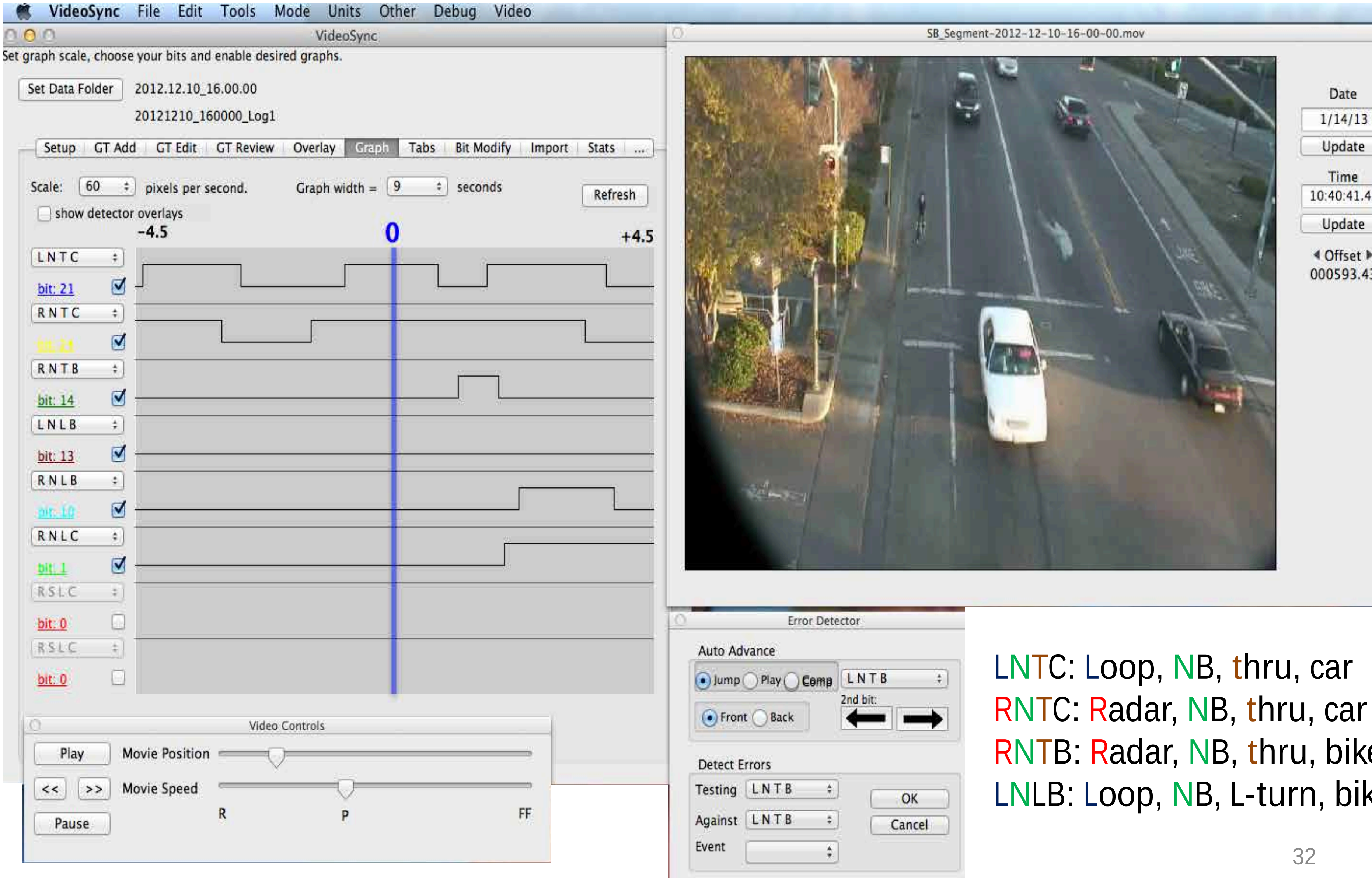
Consists of both hardware & software, each can be used independently.

The software ***synchronizes*** the inductive loop, radar, and/or other detector data with video and provides graphical and statistical tools for "*ground truthing*" the detector. Associated hardware aids in collecting field data and can be used as a stand-alone surveillance system.

Originally developed to address the lack of quality freeway data that is being automatically reported to PeMS (Performance Measurement System). VideoSync was a tool to assist with calibration and to "fix" roadway detectors. Common issues found were incorrect mapping of detectors to the proper traffic lane.

*Acknowledgements – appreciation for continued support from DRI Joe Palen & Dale Reed.

VideoSync Display



LNTC: Loop, NB, thru, car
RNTC: Radar, NB, thru, car
RNTB: Radar, NB, thru, bike
LNLB: Loop, NB, L-turn, bike

VideoSync Analysis of INTERSECTOR *Parameters & Criteria*

TP: Car/bike correctly identified/detected: *signal high & correct.*

FP: Car/bike detected but none present: *signal high but incorrect*.

TN: No car/bike detected and there is none present:

signal low & correct.

FN: Car/bike MISSED: *signal low, but incorrect*.

If a bike MISSED during a green phase: not considered a *“Radar Fail.”*

Policy limits detection to those waiting at the limit line during a red phase.

à à *Bike approaching intersection during green phase does not need to be detected*.

VideoSync Analysis of INTERSECTOR

Chico Results To-Date

- Detection data (loop & radar) and video recorded:
  December 2012 (2 weeks; 7 one-hour blocks analyzed in great detail),
  April 2013 (3 weeks; 5 one-hour blocks analyzed)
  May 2013 (1 week; a one-hour block analyzed)
  June 2013 (1 week; 2 one-hour blocks analyzed).

Analyzed hours of data chosen based on bike volumes or other characteristic (TOD).

Highest hourly bike volume: ~30.

- Based on conservative "ground truth" values of vehicle volumes (30' long Type C loops can not result in accurate vehicle volumes due to geometry of the loop), as denominator,
  vehicle presence **detection was found to be ~99-100% accurate.**
- **Detection of bikes ~95-100% accuracy.**
- There are issues of "signal instability" (predominantly Left-turn lane) that could be addressed with operator-selectable traffic controller options (locking signal).

FLIR Camera

Caltrans has several districts using ***video detection*** for signal operations.

District 11 (San Diego) no longer uses inductive loops, except for advance detection. Districts using video detection have reported problems in accurately detecting cars when there is sun glare, shadows and fog.

Two districts (D2 & D11) have been evaluating the FLIR camera. The FLIR (***Forward Looking Infra Red***) company uses CCD (charge-coupled device) cameras and doesn't need periodic lens maintenance since it doesn't use traditional optical lens. D11 has been pleased with the results so far.

The FLIR camera is a thermal-sensitive camera uses a germanium stone lens. This product does not have the problems glare, shadow, darkness, fog, rain, and dust, nor the reflection problem with radar. Long used by the military, such as for night-vision, the FLIR camera has recently entered the transportation industry. They purchased Traficon (USA) in 2012.

The FLIR can be used as a camera replacement for existing video detection systems. It is likely that a combination solution using both the infra red and radar system would provide the extremely high accuracy detection needed for intersection conflict zone detection (inside the intersection).

FLIR has not been evaluated by Caltrans HQ for bike detection. The County of Sacramento is currently preparing to evaluate the FLIR camera and is considering the use of VideoSync for the data analysis.

Consideration for Operating Signals Differently

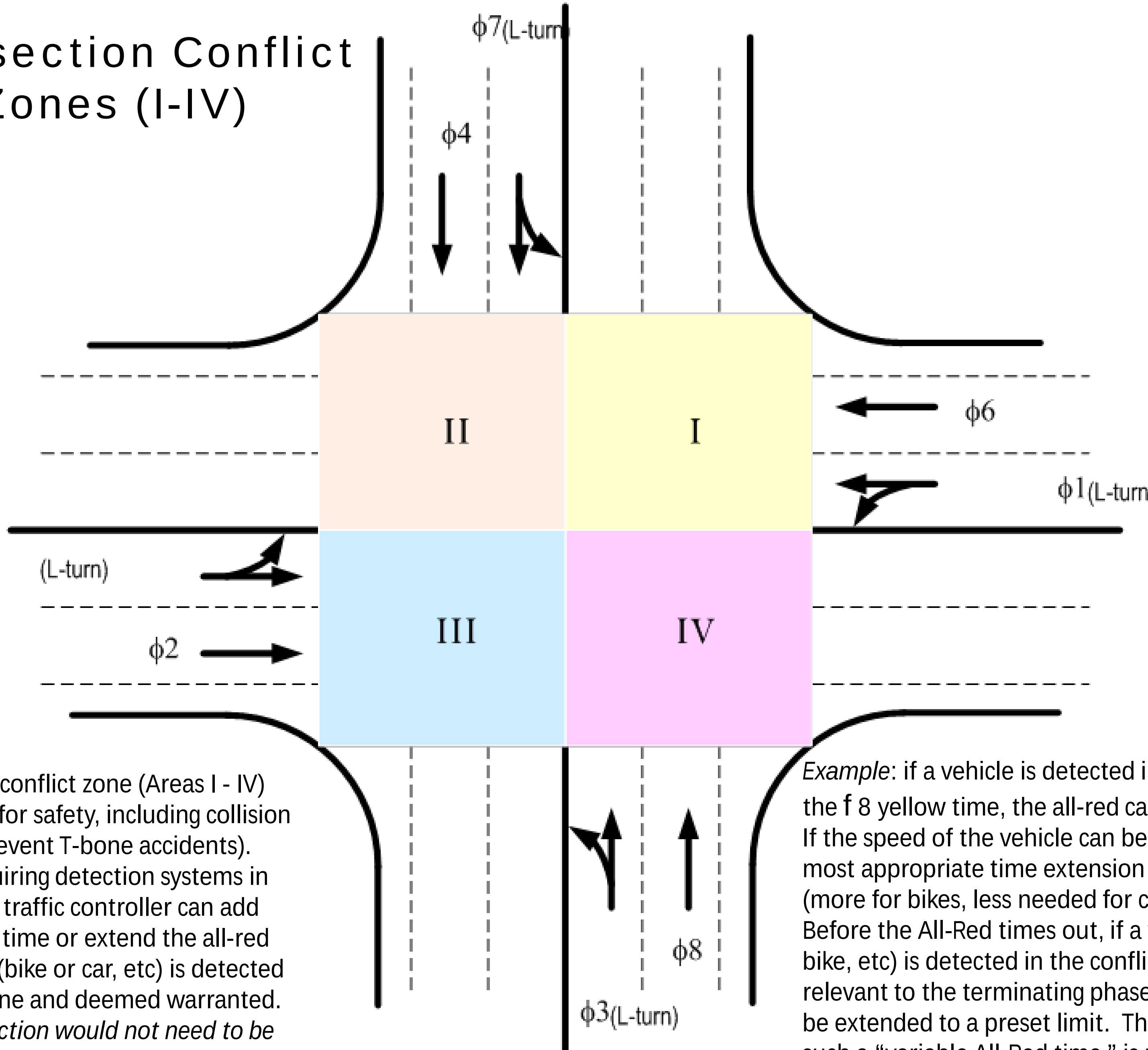
The ability to detect any bike or vehicle (or pedestrian) within the intersection would be very useful to prevent T-bone accidents. If we can accurately detect within the intersection, rather than just relying on detection of vehicles behind the limit line, there are options for signal operations.

An alternate approach is to extend the ***all-red*** time whenever an object (bicycle or vehicle) is detected inside the intersection, before the termination of the All-Red phase.

Such an approach would reduce the need for extremely high accuracy for bike/vehicle detectors and also help reduce red light running collisions. ***This approach would impact the rural intersections more than urban intersections, due to the sparse rural bicycle traffic and higher approach speeds.*** Because of emerging technologies, it is possible to detect any vehicle (whether a bike or a car) that is already inside the intersection, downstream of the limit line (stop bar). Operating a signal with this type of detection is of great interest to improve traveler safety.

On June 7, 2013 Caltrans adjusted the Chico radar units to POINT DOWN towards the intersection conflict zones. The current camera will be replaced with an omni (360^{o}) camera with a greater field of view. More data still needs to be analyzed, to determine whether supplemental detection systems are needed. For example, a side-fired radar unit could be added in addition to the frontal units. This could take care of the occlusion issue from large trucks.

Intersection Conflict Zones (I-IV)



Detection in the conflict zone (Areas I - IV) would be useful for safety, including collision avoidance (to prevent T-bone accidents). Rather than requiring detection systems in the vehicles, the traffic controller can add additional green time or extend the all-red time if a vehicle (bike or car, etc) is detected in the conflict zone and deemed warranted. *This type of detection would not need to be specific to type of vehicle (car or bike, etc).*

Example: if a vehicle is detected in Zone I during the f 8 yellow time, the all-red can be extended. If the speed of the vehicle can be measured, the most appropriate time extension could be added (more for bikes, less needed for cars).
Before the All-Red times out, if a vehicle (car or bike, etc) is detected in the conflict zone quadrant, relevant to the terminating phase, the All-Red may be extended to a preset limit. The advantage of such a “variable All-Red time,” is that drivers can’t count on a long All-Red and try to run the All-Red.

Final Comments

- Important to *quantify* accuracy of detection technologies
- Agreement of bike detection analysis parameters (TP, FP, TN, FN); ground truth (such as with VideoSync)
- Share results!
- Consider additional applications of available technology; potential to improve safety

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