Disputed Red Light Accidents: A Primer on Signal Control

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Intersection Accident Statistics

Intersection accidents occur on a daily basis. Some situations involve a disputed traffic signal. The National Highway Traffic Safety Administration tracks fatal accidents via the Fatality Analysis Reporting System (FARS). According to the data from FARS for the years 2000 to 2007, approximately 800 to 1,000 deaths per year occurred in the United States as a result of "red-light running crashes". Considerably more people are injured in "red-light running crashes", with numbers ranging from 100,000 to 125,000 injuries per year from 2000 to 2007.

Accidents of this type involve all varieties of vehicular traffic, including automobiles, trucks, buses, motorcycles, bicycles and pedestrians. Often in a broadside collision, both drivers will claim to have entered the intersection on a green light. If litigation develops, it can be beneficial to understand how the intersection signal control system operates. Then information can be gathered which is then combined with accident reconstruction determine who ran the red light.

This is an overview of the process for investigating the traffic signal aspect of intersection accidents, and an explanation of some of the key concepts. It is not intended to represent a complete method for analyzing intersection accidents. The details of the entire evaluation process are beyond the scope of this article.

Discovery- Information Needed

In the initial stage of the investigation, information can be obtained that will aid in the analysis of the disputed traffic signal accident. Depending on the nature of the accident, there are several pieces of information that may be needed. Keep in mind that it can take anywhere from a few days to several months to obtain this information, so it is best to start gathering the information as early as possible.

All information requests should specify timing data and/or drawings that were in affect on the date of the accident. In a basic investigation, it is helpful to obtain the following items:

1. Signal timing chart.
2. As-built plans.
3. Lane striping drawing (may be the same as as-buiilts)
4. Signal maintenance history (obtain data before/after accident date)

If there is a potential claim involving a government entity, then additional data may be needed, such as:

1. Accident history
2. Prior design drawings and signal timing data of the intersection
3. City, County and/or State standards on intersection and signal design
4. Engineering studies, notes, etc. on the design of the intersection

The information requests will need to be made with the appropriate agency at either the city, county or state level (depending on who has control of the intersection in question). In some cities, one can simply call the traffic engineering department and request the information- it may be delivered by mail or email, etc. The Los Angeles Department of Transportation Traffic Control Records has a form to request documents for intersection timing and/or drawings. One only needs to fill out the form and send it in with a check to obtain the needed information.

Discovery- Witness Testimony

While there are several tools used to analyze intersection accidents, witness testimony can be helpful in the analysis. There are various areas to go over with witnesses, so only a few will be highlighted here. The location of the witness should be established, as well as what he could see and what she did see (there is a difference). Witnesses can help to establish traffic patterns- light or heavy in a particular direction, backed up into the intersection, etc., as well as the presence of other vehicles or pedestrians, and the direction of travel of any other traffic. The goal is to find out the location of all vehicles and pedestrians and how they would have influenced the operation of the traffic signals.

The more detailed the information, the better. For example, Figure 1 shows a witness stopped in the northbound through lane, next to a left turn lane. For this example, assume that the left turn phase is a "protected" left turn controlled by a left turn arrow. If there was a vehicle in the northbound left turn pocket next to our hypothetical witness, the presence of that vehicle could call up the left turn arrow. However, if the left turning vehicle rolled up within a few seconds of the northbound through light phasing to green, the left turn arrow may not activate because of the late arrival of the left turning vehicle. The left turning vehicle would have to wait until the signal lights cycled through the other phases before the left turn arrow would turn green again. This example illustrates the benefit of obtaining detailed information from witnesses. In this case, we would like to know:

1. How long the witness had been stopped there?
2. What was the condition of "ALL" of the traffic signals when the witness arrived at the intersection (through, left turns, pedestrian phases)?
3. When did the left-turning vehicle arrive?
4. What was the condition of the traffic signals when the left-turning vehicle arrived?
5. What happened when the northbound lights changed?
6. Did the through (green ball) light and left turn lights change together?

There are many questions that would need to be incorporated into this examination. It is best to be organized and go through the traffic movements separately, looking to establish vehicular traffic, pedestrians, and signal condition. It may be helpful to inquire about traffic at nearby intersections in case the subject intersection is "coordinated" with other intersections. It should be clear that familiarizing oneself with the operation of the intersection before taking depositions will significantly improve the quality of the depositions.

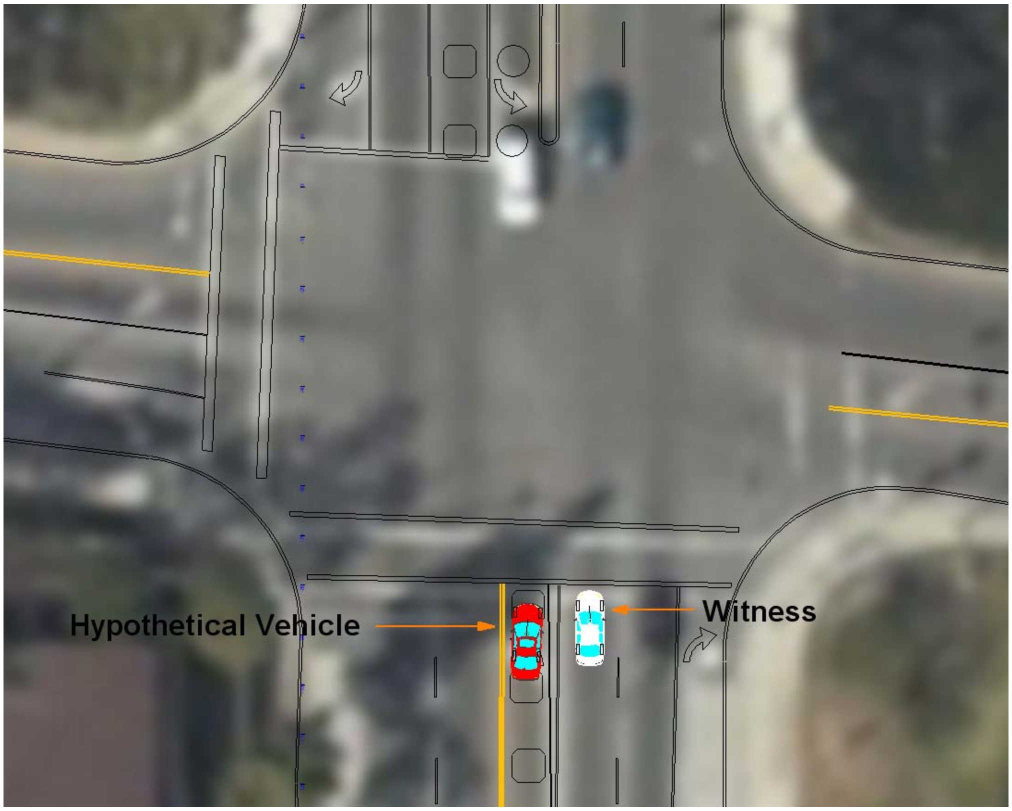


Figure 1

Intersection Defined

It is helpful to have an understanding of the meaning of a few technical terms. In California Vehice Code (CVC) 365, "intersection" is defined as "the area embraced within the prolongations of the lateral curb lines, or, if none, then the lateral boundary lines of the roadways, of two highways which join one another at approximately right angles or the area within which vehicles traveling upon different highways joining at any other angle may come in conflict". Hence, by extending each curbline back through the intersection, we define the entrance points into the intersection. These imaginary lines are used to define the point where each vehicle entered the intersection. Figure 2 below shows a sample aerial with the curbline extensions shown as orange lines. As can be seen, the crosswalk lines do not necessarily line up with the intersection entrance lines.

Figure 2

Signal Timing Definitions

The following terms are important to understanding signal timing issues:

Movement- a direction of the traffic pattern, such as the northbound through (straight) movement, the southbound left turn movement, etc.

Phase- a number given to a particular movement on signal timing charts or phase diagrams.

Interval- The amount of time assigned to a particular signal color, such as the northbound yellow interval. There may also be minimum times assigned, such as the minimum green interval, where the actual green time varies depending on traffic conditions.

Cycle- All of the phases served by the controller at an intersection (i.e. all of the movements) constitutes the cycle.

A few additional terms are listed here (see reference 1):

Average daily traffic (ADT)- The total volume of traffic passing a point or segment of a highway facility in both directions.

Call- A term used to describe the presence of vehicle, bicycle, or pedestrian demand in an actuated detection controller system. The "call" is placed to the controller, which then causes a phase change based on the timing plan.

Controller- The controller is the unit that controls the operation of the traffic signals at an intersection or series of intersections.

> **Local Controller-** The device used to operate and control the signal displays at the local intersection using signal timing provided by the user, master controller, or central signal system.
>
> **Master Controller-** An optional component of a signal system that facilitates coordination of a signal system with the local controller. Use of a master controller allows coordination of a major intersection with nearby smaller intersections.

Coordination- The ability to synchronize multiple intersections to enhance the operation of one or more directional movements in a system.

Delay- A detector parameter typically used with presence detection for turn movements from exclusive lanes. For example, right turn detectors often have a 5-second delay, where the vehicle must remain on the detector for 5 seconds before the call is locked into the controller. Hence, a right turning vehicle that turns right without having to wait more than 5 seconds for cross-traffic will not cause an unnecessary phase change.

Flash Mode- If the signals lose power and electrical power is then restored, they will start up in a pre-timed flash mode that typically lasts 5-10 seconds. The main street through movement will usually flash in yellow phase, while the minor street and other movements will flash in red. After a short time, the signals resume normal operation with the main street through movement changing from flashing yellow to green, and the other movements changing from flashing red to solid red.

The signals can also go into “conflict flash” if a conflict is detected by the conflict monitor. For example, if the controller sends an electrical signal for simultaneous green lights for conflicting movements (i.e. north/south vs. east/west), the conflict monitor would detect the error and send the intersection into flash mode.

Lead-Lag Left-Turn Phasing- A left-turn phase sequence where one left-turn movement begins with the adjacent through movement and the opposing left-turn movement begins at the end of the conflicting through movement. This option may create a “yellow trap” with some permissive signal displays.

Preemption- Traffic signal preemption is the transfer of normal operation of a traffic control signal to a special control mode of operation. This can be used for train crossings, emergency vehicles, etc.

Intersection Controller Designs- Pre-timed, actuated, semi-actuated

While there many different intersection designs for signal control, the 3 basic types cover the most common situations. The first is the pre-timed signal actuation. In a pre-timed intersection control design, the controller has certain phases that are activated, usually a north/south movement followed by the east/west movement. If activated, the pedestrian phase will usually coincide with the appropriate through movement. If the cycle length was 60 seconds, it may be that the north/south phase is 30 seconds, and the east/west phase is 30 seconds. The controller would simply alternate back and forth between the phases and would not adjust the phase lengths to accommodate traffic conditions. Pre-timed controllers are effective where traffic patterns are very predictable. Newer electronic controllers have additional capabilities, allow for quick timing changes and can be easily incorporated into coordinated systems.

A semi-actuated intersection controller involves actuating a smaller street when it intersects with a larger or major road. Detectors are placed on the smaller street to determine when cross-traffic is present. When the vehicle travels over the detectors, a call is placed into the controller for that phase. Timers or delays may be used before the call is locked into the controller. Once the timing conditions have been satisfied, a red light will be displayed for movements on the major street, and a green light will be called up for the vehicle waiting on the small street. After the traffic on the smaller street has been served, the controller will "recall" to a green light for the major road. It will often remain green for the major street until a conflicting call is received again.

In a fully actuated design, all movements are controlled based on sensor inputs, so detectors must be implemented on all approaches. This would be common at an intersection of two major streets. The complexity of this type of intersection control increases significantly. Fully actuated designs may be coordinated with nearby intersections to better improve the flow of traffic (i.e. on approach to a major freeway on-ramp, etc.). Typically, each phase will have a minimum green interval (or time) to allow stopped vehicles near the intersection to move through on a green phase. The green light is "extended" for an additional preset number of seconds as other vehicles travel over the detectors for that movement. If the controller determines that no vehicles have moved over the detectors for a preset gap (usually 2-3 seconds), the green phase will extinguish. The amount of time that extensions can occur for is limited by a preset "max extension time". Once the max extension time is reached, the light will phase to yellow then red.

Detectors & Cameras

The most common type of sensor is the magnetic loop detector. These sensors can usually be seen in the road. They may be grouped with two or three detectors in a row to monitor traffic flow and gaps in traffic. Magnetic loop detectors will usually have a wire headed back towards the curb and eventually over to the controller cabinet. Figure 3 shows a photograph of typical magnetic loop detectors:

Figure 3

Some recent designs have begun to use cameras as the detection sensor. These cameras are usually placed atop the signal arm in the intersection. They will cover certain areas of the approach to the intersection. Programming within the control system analyzes the graphic image captured by the camera. The presence of a vehicle is detected by pre-set programming algorithms that detect changes in the pixel patterns. Figure 4 depicts a camera detector at an intersection.

Figure 4

Signal Timing Basics

A cycle is defined as the total time that a controller takes to provide green, yellow, and red signals to all of the movements. A cycle can be further broken down into phases, and each phase can be broken down into intervals. An interval is the smallest signal timing segment. Intervals are generally referred to as green, yellow, and red. The interval indicates the time that each color is illuminated.

Interval Timing

Traffic engineers will conduct studies of the traffic patterns in order to determine whether signals are needed at an intersection, and how the signals should be timed. When signals are used to control the intersection, the study will typically involve a "traffic count" to determine how many vehicles are turning left, going straight, or turning right at an intersection. Since traffic patterns vary throughout the day, the traffic count will involve monitoring traffic over a pre-determined time period. The movements with the largest number of vehicles in their respective direction will receive more green time in the cycle in order to accommodate the traffic pattern. Timing data can be changed at different times of day in order to accommodate heavy traffic flow in particular movements.

Signal Timing- Yellow Clearance Phase

The duration of the yellow change interval will vary depending on the road and intersection design, as well as local and state guidelines for signal timing. Generally speaking, the time allocated for the yellow change interval will account for the speed limit of each approach, grade on approach, visibility of the signal, and traffic volumes.

Signal Timing- Red Clearance Phase

Since it is legal to enter the intersection on the yellow phase, a potential conflict can develop when a driver enters the intersection on the latter portion of the yellow phase. Traffic engineers may use an "ALL RED" clearance time to allow the late-entry vehicle to clear the intersection before cross traffic starts up and moves into the intersection. All of the signals are red during the "ALL-RED" phase. Depending on the width of the intersection and the speed of the vehicles, collisions can occur when the cross-traffic enters the intersection.

Signal Timing- Left Turn Phases

Control of the interval times for a left turn phase in an actuated controller is handled in a manner similar to the through movements. Generally speaking, the minimum green time will be shorter on a left turn phase- typically 3-7 seconds. The minimum gap is usually set at 0-2 seconds. The controller is constantly analyzing where vehicles are being detected by the loop detectors or cameras. After the minimum green time has expired, the controller is looking for a gap in the left turning traffic. If the controller detects that no vehicles are present on the sensors for a time equal to the minimum gap, the green arrow will phase to a yellow arrow. Remember that these are general parameters- refer to the specific timing data to see how a controller is functioning at an intersection.

Signal Timing- Pedestrian Phases

The pedestrian "WALK" and flashing "DON"T WALK" times are also calculated in the design of the controller timing parameters. Seven seconds is a typical time used for the walk interval, which allows enough time for the pedestrian to move off of the sidewalk and into the crosswalk. This time may be increased to accommodate heavy pedestrian traffic situations.

The flashing "DON'T WALK" phase is calculated to allow the pedestrians to finish crossing the street once they have entered the crosswalk. Generally speaking, the standard walking speed used for the timing calculation is 4 feet per second. Hence, for a crossing distance of 60 feet, the time allocated to the flashing "DON'T WALK" phase would be approximately 15 seconds (60 feet divided by 4 feet/sec). Again, modifications can be made to accommodate unique intersection requirements, so check the timing data.

The solid "DON'T WALK" phase may come on concurrent with the yellow phase for through traffic. In an actuated controller with heavy vehicular traffic on the through movement, the solid "DON'T WALK" could be shown during the green phase. The signal timing charts typically indicate when this interval illuminates.

Phase Diagrams

A phase diagram lists the phases that are active at the intersection. A common type of phase diagram in shown in Figure 5 below:

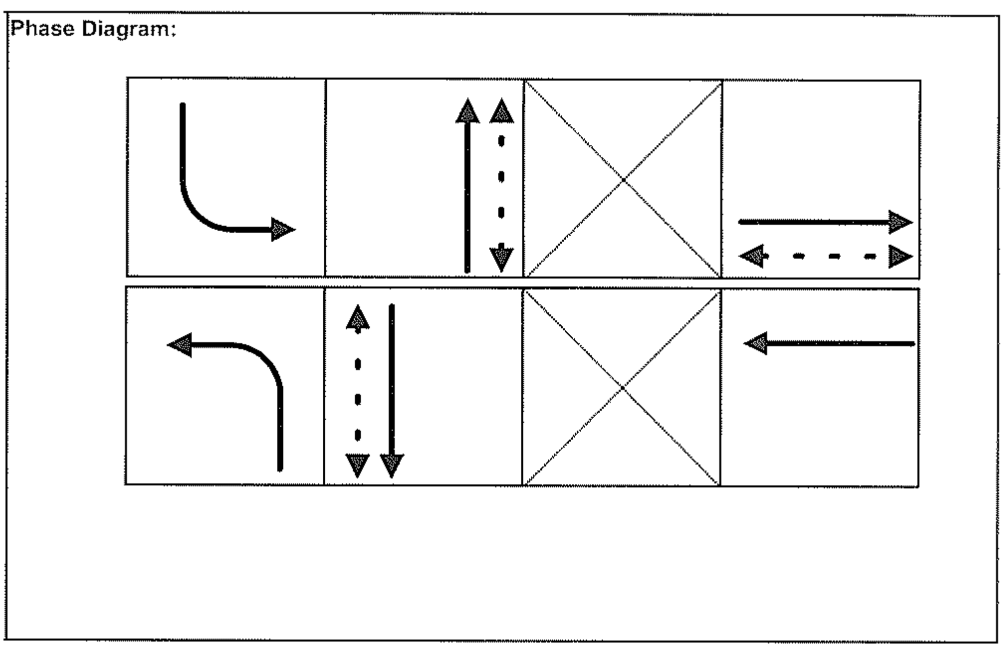


Figure 5

In a phase diagram, north is always up. Phase 1 is in the upper left box (southbound left-turn), and the numbering increases left to right on the top row. Hence, phase 4 is at the upper right corner (eastbound through). Phase 5 (northbound left-turn) is at the lower left position, while phase 8 (westbound through) is at the lower right position. Phases 3 and 7 are not active in this controller. The dashed lines indicate pedestrian phases that are concurrent with the through phases.

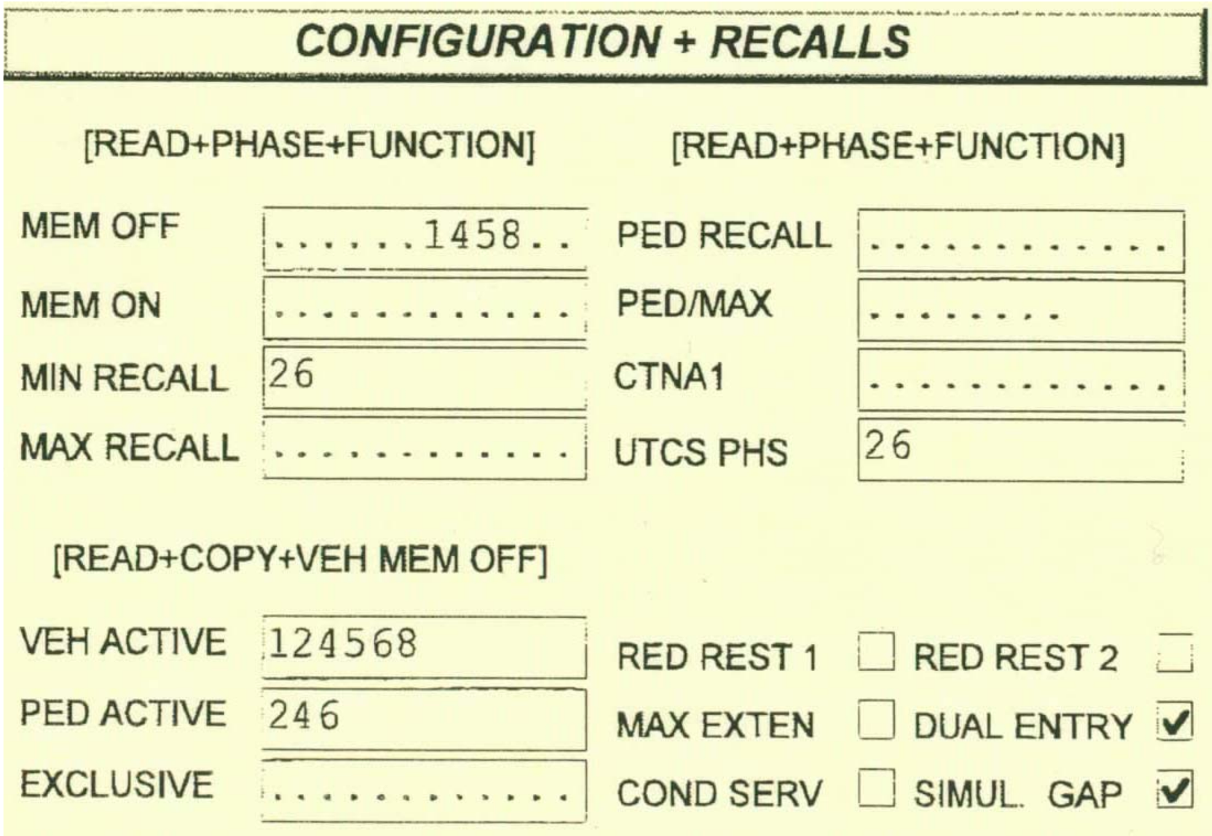
In a pre-timed signal controller, the cycle length is fixed and remains the same. Usually the duration of the green, yellow and red phases does not vary, though newer digital controllers can run different plans at different times of day to accommodate changes in traffic flow.

The cycle length can vary in an actuated controller because the time allocated to each phase will vary with traffic conditions. If a particular direction of travel has heavy traffic flow, then that phase may extend until the maximum green time is expended. Conversely, if cross traffic is light, the controller will only allocate minimal time to that movement. The controller may skip the phase if it detects no vehicles are present to serve. Figure 6 depicts the timing data for a fully actuated intersection. (The phase diagram is shown in Figure 7). In looking at the northbound phase 2 timing, we see that the initial green time is 10 seconds (INIT GREEN). After the initial green expires, the green light will extend for 2 seconds for each vehicle that rolls over the sensors (GREEN EXT). Note that since the north-south movements are dual entry, a vehicle in either the northbound or southbound directions can trigger an extension. The maximum extension time is 40 seconds (MAXIMUM 1). The yellow phase is 4 seconds, followed by an all red of 1 second. As previously explained, all signal lights at the intersection are red during the all red interval. Note that the pedestrian phase, when activated, goes concurrently with the green phase. There is a 7-second interval allocated to the “walk” phase, and a 16 second interval allocated to the flashing “don’t walk” phase. In this case, the solid “don’t walk” phase comes on concurrently with the yellow light, unless multiple vehicle extensions extend the green beyond the 23 seconds for the WALK and PED CLEAR intervals. There is a 1-second all red interval as well. Although not listed, the minimum gap is equal to the time for the green extension. Hence, if the sensors detected a gap in traffic equal to 2 seconds for the north/south movements, the signal would phase from green to yellow.

	PHS 1	PHS 2	PHS 3	PHS 4	PHS 5	PHS 6	PHS 7	PHS 8
				PHASE TIMING (READ+PHASE+FUNCTION)				
INIT GREEN	4	10		4	4	10		4
GREEN EXT	1.5	2		2	1.5	2		2
MAX 1	15	40		25	15	4		25
MAX 2	25			25	25	25		25
YELLOW	3	4		4	3	4		4
ALL-RED	1	1		1	1	1		1
WALK		7		7		7		
PED CLEAR		16		22		16		
TIME/ACT								
MAX INIT								
TBR								
TTR								
MIN GAP								
RED REVERT	5.0	5.0		5.0	5.0	5.0		5.0
PED REVERT								

Figure 6

Other configuration parameters are typically given in the signal timing charts. In Figure 7 below, we note that "MIN RECALL" is set to Phase 2 and 6. This means that the controller reverts back to north-south green when there are no conflicting calls from the sensors (i.e. no other cars around). In other words, the signals will return to a green phase for the north/south directions, which is the main road for this intersection. We also see that no phases are called out for "PED RECALL", indicating the pedestrian phase requires activation to be called up. "PED ACTIVE" indicates that there is a pedestrian phase with the northbound (2), eastbound (4) and southbound (6) phases.



CONFIGURATION + RECALLS

[READ+PHASE+FUNCTION]

MEM OFF	......1458..
MEM ON	....
MIN RECALL	26
MAX RECALL	....

[READ+PHASE+FUNCTION]

PED RECALL	....
PED/MAX	....
CTNA1	....
UTCS PHS	26

[READ+COPY+VEH MEM OFF]

VEH ACTIVE	124568
PED ACTIVE	246
EXCLUSIVE	....

RED REST 1	☐	RED REST 2	☐
MAX EXTEN	☐	DUAL ENTRY	☑
COND SERV	☐	SIMUL. GAP	☑

Figure 7

As seen in Figure 7, the box for dual entry is checked. This means that if a westbound vehicle arrives at the intersection and a call is placed to the controller to give westbound a green, the controller will also give eastbound a green, even if there is no eastbound traffic. Since the east/west movements can each have a green without a conflict, the controller gives both movements a green light. The north/south movements would operate in a similar manner.

As-built plans

As-built plans are drawings that show the road "as it was built". Intersection as-built's will typically show the road and lanes. They will show the placement of detectors, poles, signal heads, streetlights, electrical equipment, and more. They usually have accurate lane striping, but occasionally a second drawing, referred to as a "lane striping" diagram, will show the lane striping. They should be signed by, and stamped by, a licensed professional engineer (Civil Engineer). A sample as-built plan is shown in Figure 8 below.

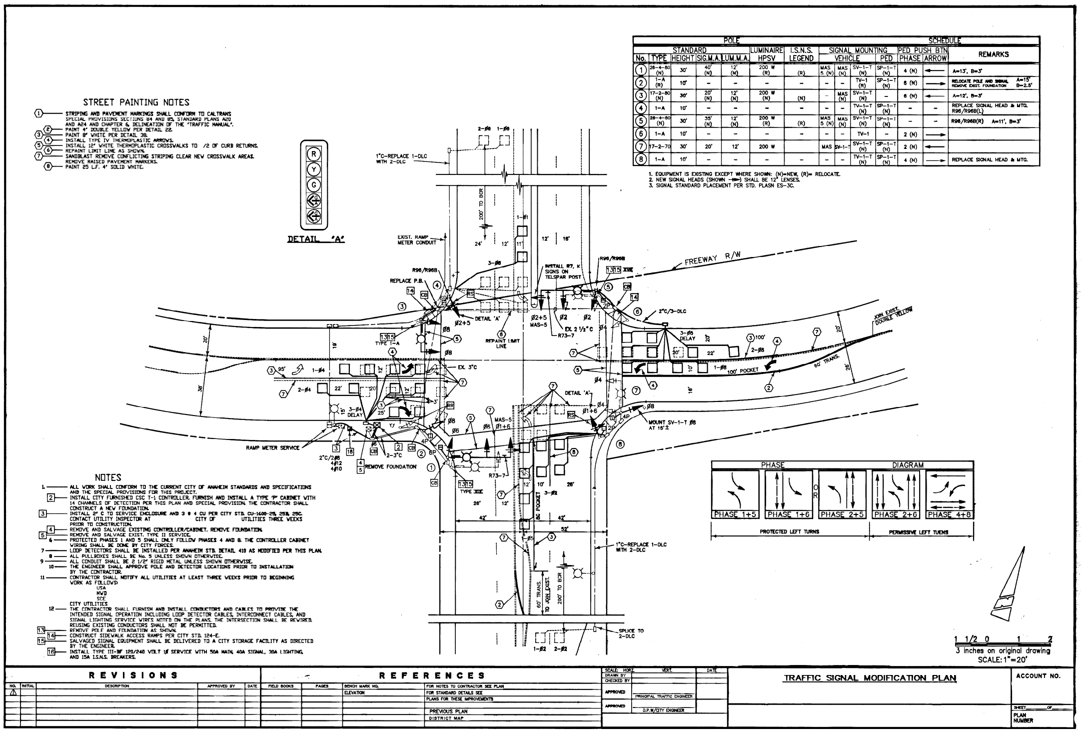


Figure 8

Conflict monitor

A conflict monitor analyzes the status of the signal control system. If a conflict occurs in the control system, the conflict monitor places the intersection in flash mode. The intersection will remain in flash until a technician opens the control box and resets the intersection controller. The conflict monitor prevents two conflicting phases from showing green at the same time (i.e. north-south and east-west). The conflict monitor can be set to monitor timing inputs as well, such as a minimum time for yellow phases.

Coordinated Intersection Control

In an attempt to improve traffic flow on roads with congestion problems, new systems are being installed that coordinate traffic signal control between multiple intersections. Typically, an interconnection (electrical connection line) is installed between the intersections that are to be coordinated. A central controller analyzes the overall traffic pattern, while localized controllers monitor traffic at each intersection. The central controller attempts to predict when traffic will arrive at the next intersection and coordinate control to minimize stop time and keep traffic moving. Signal timing can be continuously updated to improve the flow of traffic. Some of these systems also use video cameras allow traffic engineers to monitor traffic real time and make additional adjustments to the timing parameters.

Intersection Signage

Various signs are used at intersections. For example, a highway with a high speed limit without an intersection for some distance would typically have warning signs that indicate the presence of the upcoming intersection that is controlled by traffic signals, thereby giving motorists warning that they may need to stop at the intersection. Other signs may restrict usage of a lane to turning movements only, such as in a right turn only lane. There are requirements and guidelines on the placement of signs in sources such as the "Manual of Uniform Traffic Control Devices". Other manuals may be used depending on the agency responsible for the intersection (state, county or city).

Accident Reconstruction Analysis

Analysis of intersection accidents typically involves an accident reconstruction wherein vehicle positions on approach to impact are plotted on a scaled diagram. The location and movements of witnesses will also be incorporated into the analysis. Intersection control data, such as the location of detectors, lane stripes, signal heads, signs, etc., will also be incorporated. Then an analysis can be completed. Figure 9 below shows a "time-distance" analysis with the appropriate data included. This basic plot would then be used to evaluate testimony and other evidence in order to analyze who ran the red light.

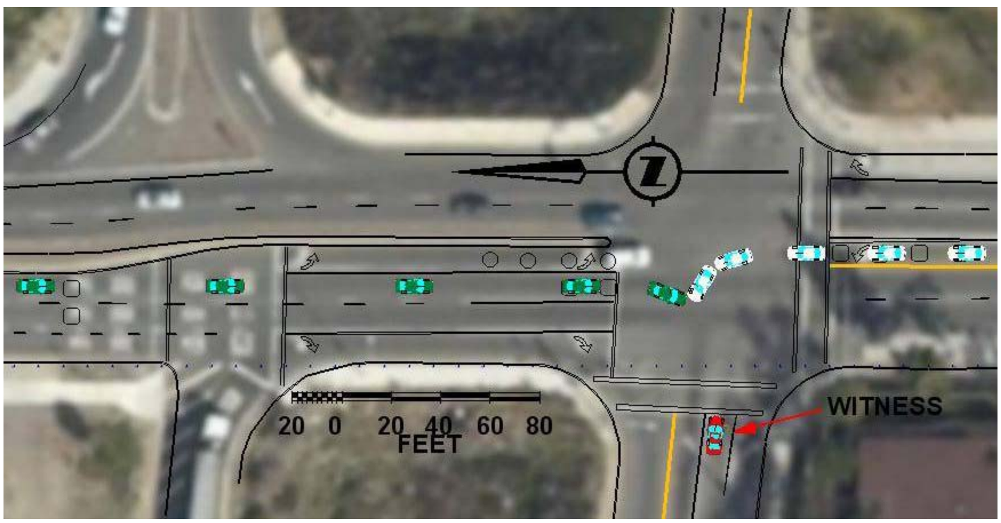


Figure 9

In the example discussed here, the accident occurred at approximately 2:00 A.M. A northbound vehicle approached and turned left to go west (not shown here). A second left-turning vehicle, that was behind the lead vehicle by a few seconds, then turned left. A southbound vehicle approached and a collision occurred between the southbound vehicle and the second left-turning vehicle. A witness had pulled up eastbound and stopped for the red light. The witness had been stopped at the intersection long enough to see the left turning vehicle approach and enter the intersection. No other traffic was reported to have been present.

The phase and timing charts are shown in Figures 5-7. We see that the north-south street was the main street. Also, the north-south street had "protected-permissive left turns", where left turns could be made on a green ball. At 2:00 A.M., light traffic would be expected, and the signals would recall to green for north-south traffic until a conflicting call was received by the controller (i.e. east-west traffic). The presence of the eastbound witness vehicle tells us that a conflicting call had been placed into the controller, such that the north-south phase would time out soon and then the east-west movement would receive a green light.

The left-turning vehicle claimed to have turned on a "green arrow". The southbound driver claimed to have had a green light the entire time he approached and as he entered the intersection. Since it was a "protected-permissive" left turn for the northbound vehicles, the northbound driver was permitted to turn left on the green ball, but would need to yield to approaching southbound traffic (note the sign next to the signals in Figure 3). The presence of the eastbound vehicle tells us that his direction would be served next. Hence, we would expect that the north-south signal would time out, then eastbound would then be served with a green light. Under these conditions, a green arrow would not be called up for the northbound left turning vehicle. Hence, it was concluded that they turned on a green ball and had failed to yield to the southbound vehicle.

Summary

The topic of traffic signal control, as it pertains to accident reconstruction of intersection accidents, has been discussed at an introductory level here. The intent was to give an overview and assist the reader with the process of investigating intersection accidents. As the complexity of traffic signals increases, the litigator will need additional information on these systems. A list of reference material is given below.

References

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