Red Light Camera Study - Chillicothe, Ohio

Purpose of the Yellow Light

Consider the traditional purpose of the yellow traffic light. As a motorist approaches an intersection, the yellow indication warns that the signal is about to turn red. Prior to the intersection and before the traffic signal, a stop bar is typically found. The stop bar is a wide, painted white strip located before the signal and all crosswalk markings that may be present. The critical point is the point located at a critical distance before the stop bar. Consider the critical point as the point of decision. It is at this point that the motorist must make a choice to either stop or go. When a motorist approaches the critical point as the signal turns yellow, the driver must determine whether they can safely bring the vehicle to a stop behind the stop bar. If the motorist determines that they do not have sufficient time to stop safely, the motorist will choose to continue through the intersection. The yellow light, if long enough, allows the motorist to fully proceed through the intersection before the light turns red. A properly timed yellow light ensures that motorists who first observe the yellow before the critical point are able to stop safely, and that those who first observe the yellow beyond the critical point are able to safely proceed through the intersection. See Figure 1 below.

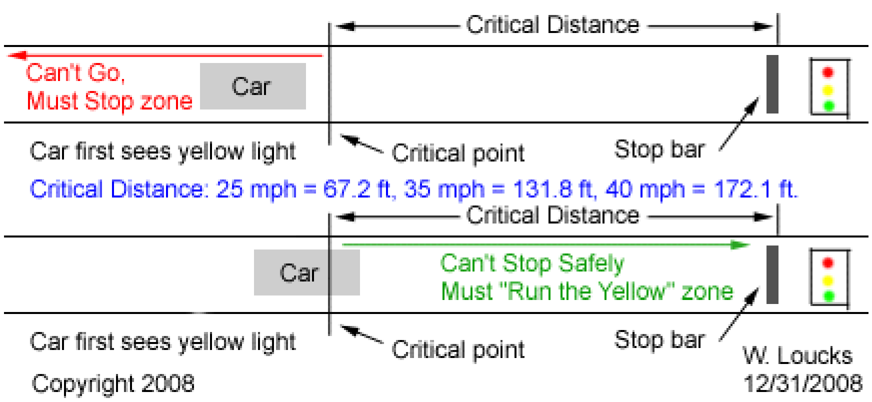

Figure 1

- Critical point, expressed as either a time or distance before stop bar, is the reference point at which the motorist must make the correct choice: stop or “run the yellow”. It is an imaginary line crossing the pavement.

The all red (AR) interval, when all four directions are red, is used to clear the intersection. Therefore, the all red interval timing is dependent upon the intersection's geometry.

- All red durations, when long enough, can be properly set to clear the intersection and avoid T-bone accidents.

Dilemma Zones Place Motorists in Harm's Way

Drivers who are in the "Can't Go, Must Stop" zone as the light turns yellow should know they are too far away from the intersection to clear it safely. To heed the yellow warning and avoid running a red light, these drivers must be able to come to a safe stop. Drivers who are in the "Can't Stop Safely, Must Run the Yellow" zone should realize that they are too close to the intersection to stop safely. They must be able to proceed safely through the intersection. When the yellow time is inadequate, or too short, there exists a space between the "Can't Go, Must Stop" and the "Can't Stop Safely, Run the Yellow" zones. In this space, the driver can neither proceed safely, nor stop safely. Engineers call this the "Dilemma Zone."

- Dilemma zones do not provide a reasonable choice and should not exist.

An inadequate yellow time may prevent motorists from coming to a safe stop, thereby increasing the risk of rear-end collisions. In the alternative, an inadequate yellow time may force drivers to enter an intersection on a red light. Both options are unacceptable.

- Dilemma zones prevent motorists from coming to a safe stop, increase the risk of rear-end collisions, or force drivers to run the red light.
- Dilemma zones are the most likely reason for an increased rate of rear end collisions at camera intersections (2004 North Carolina A&T University Study & Texas Transportation Institute study).

A properly timed signal with a sufficient display of yellow ensures that drivers will not be faced with the impossible choice presented by the dilemma zone. By determining the stopping and clearing distances for a given approach speed, one can calculate a sufficient yellow time that offers drivers a safe option, by design, every time.

- Yellow durations should be set properly to eliminate dilemma zones.

For example, prior to November 14, 2008, the traffic light at the intersection of Paint Street and Main Street had a yellow light duration below 3.0 seconds. This created a dilemma zone greater than 30 feet. Within this zone, it was unsafe to stop, yet the distance from the intersection was too great to "run the yellow" before the light turned red. Since running red lights is dangerous, this dilemma zone <u>placed motorists in harm's way</u>, as they had no acceptable choice.

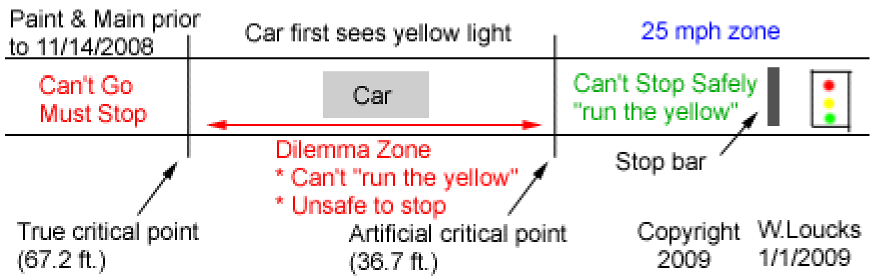

Figure 2

Paint & Main Streets' dilemma zone calculations are based on the following:
3 sec. yellow minus 1 second reaction time minus 1 sec. for the camera = 1 sec. to clear the stop bar.

A time of 1.83 sec. is actually required to clear this stop bar. Falling 0.83 sec. too short at the posted speed limit of 25 mph, the resulting dilemma zone created measures 30.5 feet. In order for the motorist to clear the yellow light before the red light appears, the motorist's approach speed would have to be 45.8 mph, which exceeds the posted speed limit by more than 20mph.

Using the Chillicothe Engineering Department's own data, dated November 19, 2008, the Paint & Main yellow was extended from 3 seconds to 4 seconds in this 25 mph zone. However, the traffic light at Bridge Street & Main Street is a 35 mph zone, yet it also has a 4 second yellow duration. This, too, is documented within the Chillicothe Engineering Department's report. Therefore, the Bridge & Main traffic light also has a dilemma zone, also around 30 feet in length. See Figure 3 below.

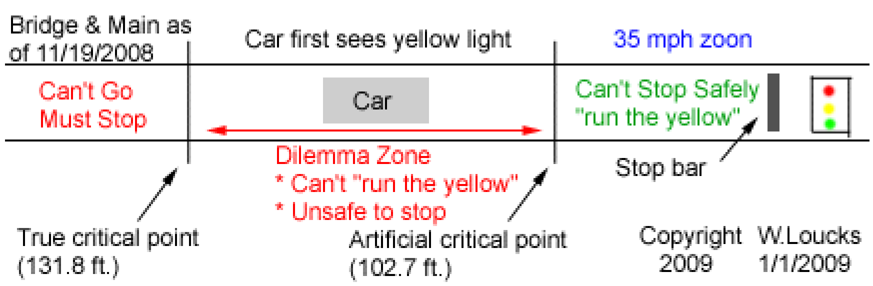

Figure 3

Bridge & Main Streets' dilemma zone calculations are based on the following:
4 sec. yellow minus 1 second reaction time minus 1 sec. for the camera = 2 sec. to clear the stop bar.

2.57 sec. are actually required to clear this stop bar. As this is 0.57 sec. too short at 35 mph, the resultant dilemma zone measures 29.1 feet.

Most likely, traffic camera intersections experience an increase in rear-end collisions due to existing dilemma zones.

- Dilemma zones will either prevent motorists from coming to a safe stop, thereby increasing the risk of rear-end collisions, or force drivers to enter the intersection on a red light.
- Dilemma zones are the most likely reason for an increased rate of rear-end collisions at camera intersections (2004 North Carolina A&T University Study).
- Properly timed traffic signals eliminate dilemma zones.

Dilemma Zones Generate Tickets

It is easy to understand how dilemma zones place motorists in harm's way, but these zones are also a way to generate tickets. Red Light Incidents data was obtained from the Chillicothe Police Department. Figure 4, below, a bar graph, plots the "Ticket Count," or number of tickets issued due to Red Light Incidents, <u>versus</u> "Date Range," 7 day periods. The data below pertains only to the Paint & Main intersection. The data collected reveals the number of tickets generated both before and after the yellow light duration was changed from 3 sec. (dilemma zone) to 4 sec. (no dilemma zone) on November 14, 2008. It clearly indicates a vast difference in the number of Red Light Incidents when the yellow light duration was changed. On a per day basis, when the yellow was 3 sec., the average ticket count was 18.3 times greater than after the yellow was changed to 4 sec. (6.548 vs. 0.357 per day). See Figure 4 below.

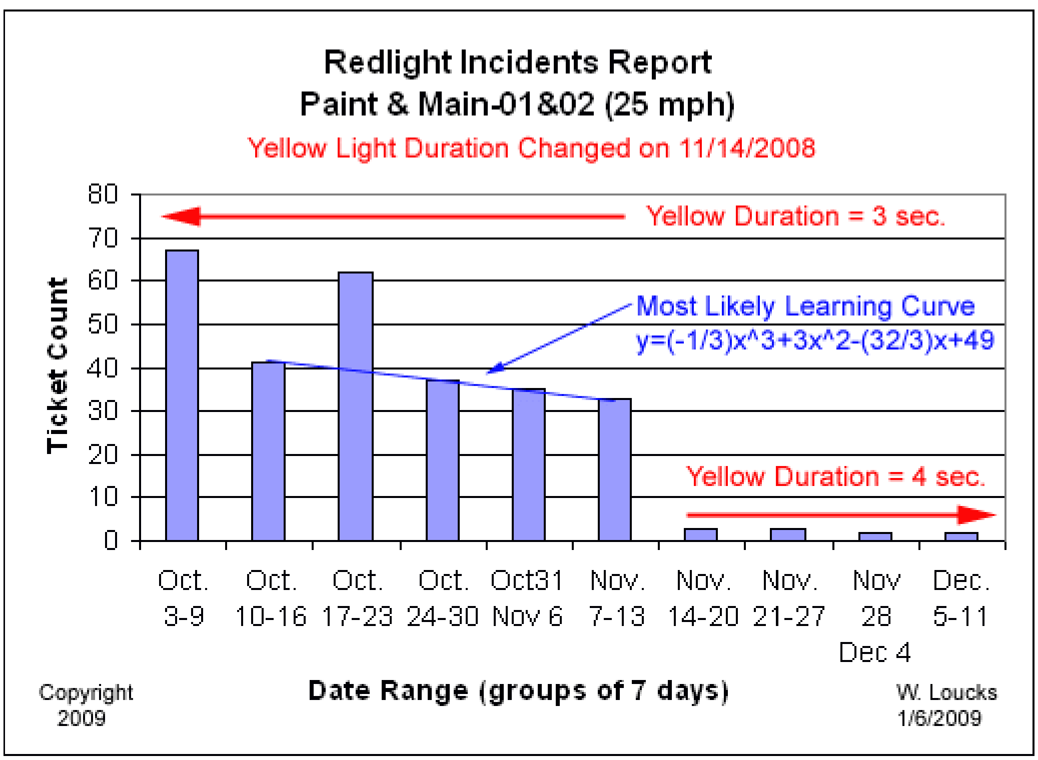

Figure 4

- This establishes that, if a yellow light duration is changed, a considerable difference in the number of Red Light Incidents will occur following the change.

Figure 5, below, graphs “Ticket Count” of the Red Light Incidents <u>versus</u> “Date Range" at N. Bridge & Marietta, both before and after the yellow light duration was changed from an unknown duration (long dilemma zone) to 4.9 sec. (0.03 sec. dilemma zone) on October 22, 2008. It clearly indicates a significant difference in the number of Red Light Incidents following the yellow light duration change. On a per day basis, when the yellow was unknown, prior to the change, the average ticket count was 36.5 times higher than after the yellow was increased to 4.9 sec. (29.782 vs. 0.816 per day). See Figure 5 below.

- Properly timed traffic signals nearly eliminate “Red Light Running."

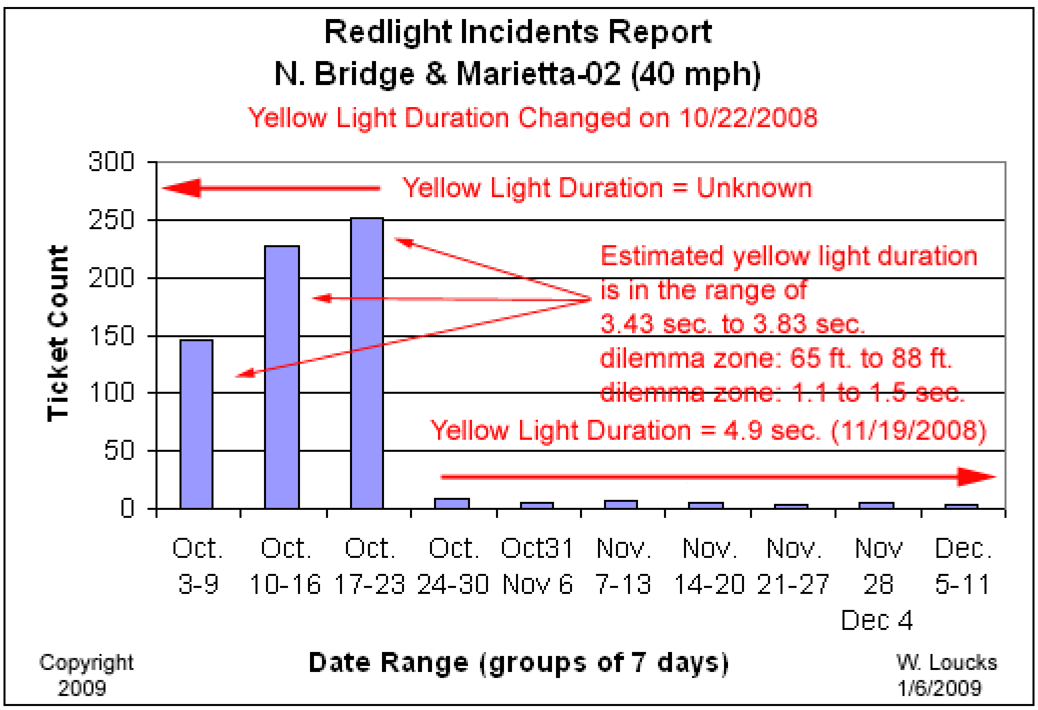

Figure 5

Figure 6, below, shows “Ticket Count” of the Red Light Incidents <u>versus</u> “Date Range (7 day periods)” at Bridge & Main, both before and after the yellow light duration was changed from an unknown duration (long dilemma zone) to 4.0 sec. (0.57 sec. dilemma zone) on October 10, 2008. It also indicates a large difference in the number of Red Light Incidents following the yellow light duration change. On a per day basis, when the yellow was unknown, prior to the change, the average ticket count was 7.8 times greater than after the yellow was changed to 4.0 sec. (25.286 vs. 3.254 per day). See Figure 6 below.

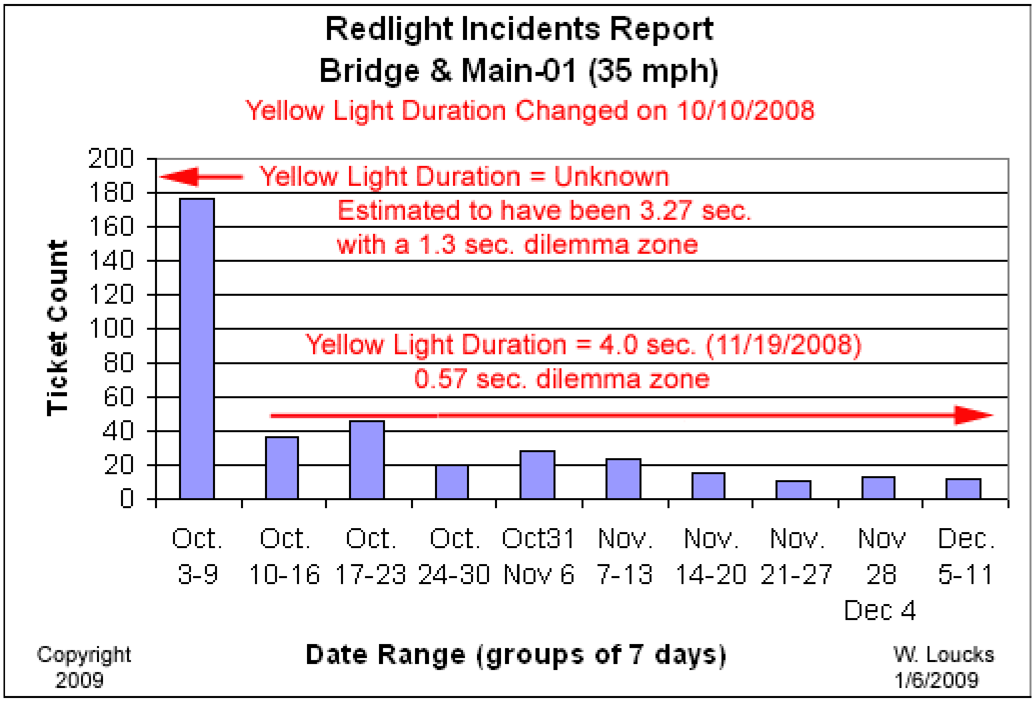

Figure 6

Figure 7, as follows, displays the plot of Yellow Light Duration vs. Speed Limit for a flat level surface. The red line is based on the Traffic Engineering Manual (TEM). It also shows how the traffic lights at Paint & Main, Bridge & Main, and N. Bridge & Marietta were not in compliance with the TEM prior to 11/14/2008. The blue line is a more reasonable yellow light timing based on a braking g of 0.3. The blue line adjusts driver reaction time from the TEM's standard of 1.0 sec. to 2.3 sec. According to a 2000 University of Iowa study, 2.3 sec. is the average driver reaction brake time.

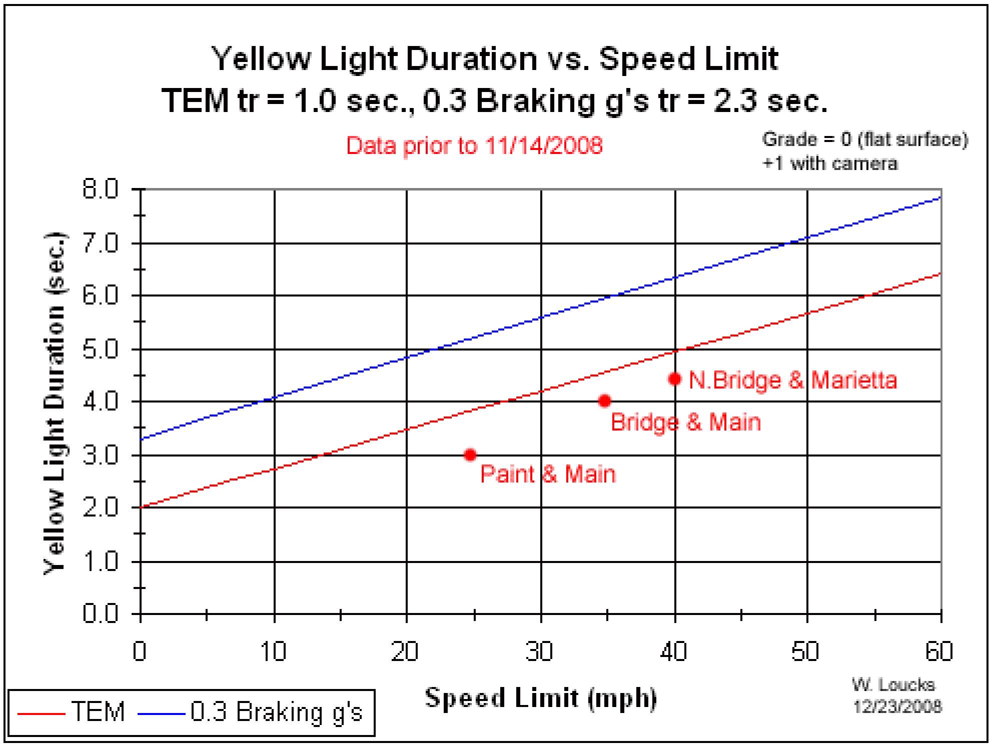

Figure 7

Figure 8, below, plots Yellow Light Duration vs. Speed Limit for a flat level surface. The red line is based on the TEM. It depicts how the traffic lights at Paint & Main, Bridge & Main, and N. Bridge & Marietta have changed since 11/14/2008. Note that two traffic lights are still not in compliance with the TEM. The blue line shows a more reasonable yellow light timing based on a braking g of 0.3, adjusting the reaction time from 1.0 sec. to 2.3 sec. See Figure 8.

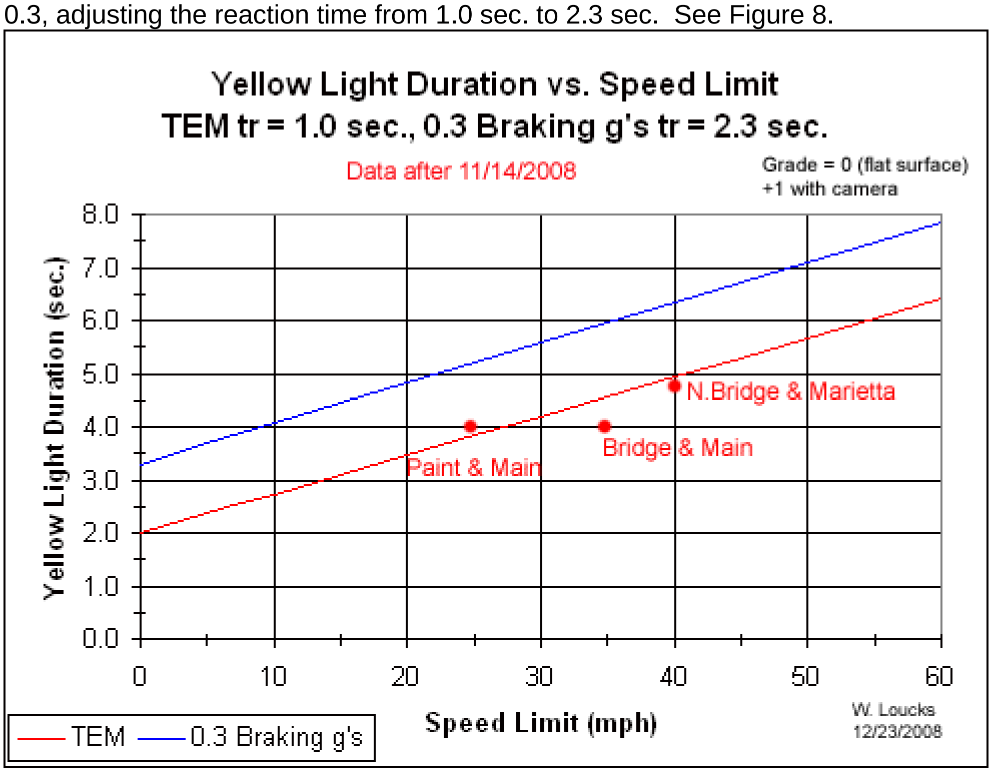

Figure 8

Chillicothe still has improperly timed traffic signals.

Chi-Square Goodness-of-fit Test

Given:

- Yellow light duration at Paint & Main (25 mph zone) was increased by 1 second on 11/14/2008.
- Time period studied before yellow light was extended by 1 second: 10/2/2008 to 11/13/2008 (43 days). The observed Red Light Incidents count was noted.
- Time period studied after yellow light was extended by 1 second: 11/14/2008 to 11/27/2008 (14 days). The observed Red Light Incidents count was noted.
- The study investigated the Red Light Incidents over the two time periods.
- Expected count was adjusted relative to the day count for each time period (apples to apples comparison on a per day count basis).

Assumptions:

- There is no significant difference in the weather conditions during the time periods investigated.
- There is no significant difference in the traffic flow during the before and after time periods investigated.
- Driver's “learning curve” was modeled to be: $y = -\frac{1}{3}x^3 + 3x^2 - \frac{32}{3}x + 49$,or approximately two per week on average; see Figure 4 above.

Observed frequencies:

- 10/02/2008 to 11/13/2008: 275 observed Red Light Incidents over 42 days; average of 6.548 per day
- 11/14/2008 to 11/27/2008, 10 observed Red Light Incidents over 28 days; average of 0.357 per day

	Observations	**Expected**	**Total**
Before (yellow = 3 sec.)	275 (42 days)	(42/70)(285) = 171	446
After (yellow = 4 sec.)	10 (28 days)	(28/70)(285) = 114	124
Total	285 (70 days)	285	570

Chi-Square Goodness-of-fit Test:

- The Chi-Square Goodness-of-Fit Test is used to determine whether sample data are consistent with a hypothesized distribution. In this case, the hypothesis states that there is a uniform distribution of Red Light

Incidents across the time periods both prior to and following the yellow light timing change.

H_0 (null hypothesis): There is no difference in the observed frequencies of Red Light Incidents, on a per day basis, in the sample data obtained both before and after the yellow light duration was increased by 1 second at Paint & Main on 11/14/2008.

H_A (alternate hypothesis): There is a difference in the observed frequencies of Red Light Incidents, on a per day basis, in the sample data obtained both before and after the yellow light duration was increased by 1 second at Paint & Main on 11/14/2008.

Chi-square test results:

Let α (alpha) = 0.05 level of significance. This is the most commonly used value.
OR let α (alpha) = 0.01 level of significance, as is typically used in the health industry. If

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} = 158.129$$

. with 1 degree of freedom.

ρ-value = 0.0001

Since the ρ-value is less than α, reject the null hypothesis. The same result is accomplished by comparing the critical value of 6.6349 (a 0.01 level of significance) to χ^2. Since χ^2 is greater than the critical value, reject the null hypothesis (158.129 is greater than 6.6349). Note: the greater χ^2 is above the critical value, the more significant the test becomes. For more information, please see http://www.swogstat.org/stat/public/chisq_calculator.htm. By conventional criteria, this difference is considered to be extremely statistically significant.

The p-value is the probability (0.01% chance) of obtaining a result at least as extreme as the one that was observed, given that the null hypothesis is true. In this case, one would reject the null hypothesis and accept the alternate hypothesis; that is, the additional 1 second of yellow duration did make a difference. In other words, the null hypothesis has a 0.01% chance of explaining the results by chance if it is true. To illustrate, compare the Red Light Incidents data to watching someone flip a coin. The flipper states that the coin is fair. He proceeds to flip 196 times. The coin lands on heads 186 of those flips. Does one still accept that the coin being flipped is a fair coin? More likely, one would reject the fair coin hypothesis and accept an alternate hypothesis that the coin is not fair.

Chi-square Conclusion:

Extending the yellow light duration at Paint & Main by one second did make an extremely statistically significant difference in the number of Red Light Incidents. Since red light running is unsafe, and, at times, unavoidable with a three second yellow, the City of Chillicothe placed the traffic light at Paint & Main in an unsafe condition. By doing so, the city also placed motorists in harm's way without regard to their safety.

- Chi-square statistically proves a relationship exists between the length of the yellow light and the number of tickets produced. A shorter yellow produces more tickets, and a longer yellow produces very few tickets.

Figure 9, below, clearly indicates that a shorter yellow light duration resulted in a greater number of Red Light Incidents. Using the TEM as a reference point, Paint & Main, with a 3 sec. yellow (0.83 sec. below the TEM), yielded the greatest number Red Light Incidents. Bridge & Main with a 4.0 sec. yellow, 0.57 sec. below the TEM, had fewer Red Light Incidents. N. Bridge & Marietta, with a 4.9 sec. yellow, 0.03 sec. below the TEM, had even fewer Red Light Incidents. Finally, Paint & Main, with a 4 sec. yellow, 0.17 sec. above the TEM, had the fewest number of Red Light Incidents.

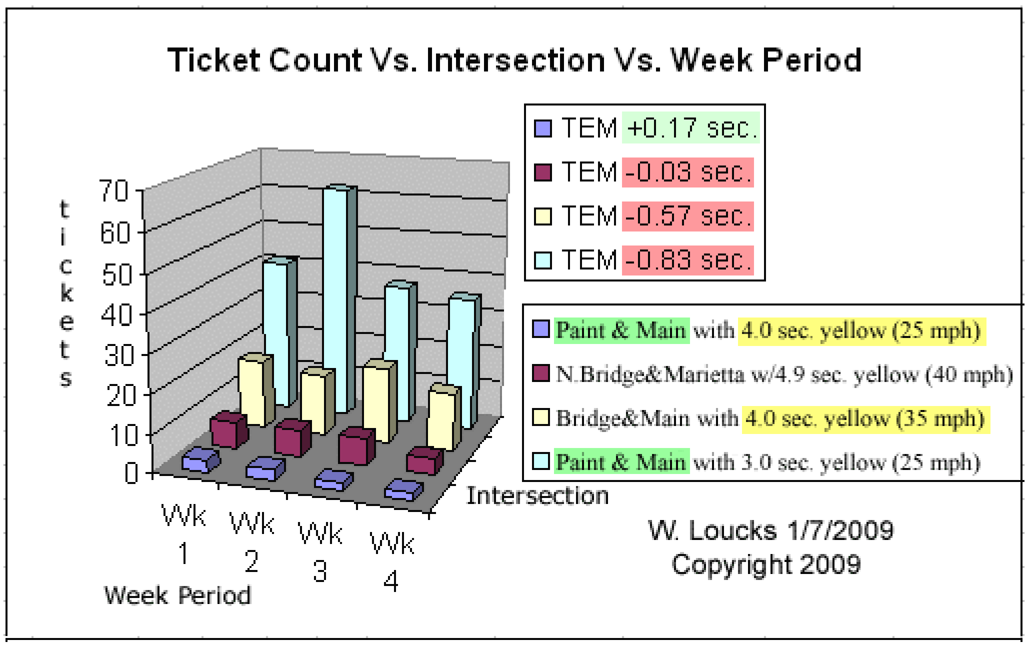

Figure 9

- Figure 9 illustrates how a shorter yellow light produces more red light tickets.

In Conclusion:

- Critical point, a distance before stop bar, is the reference point at which the motorist must make the correct choice: stop, or “run the yellow."
- All red durations, when long enough, can be properly set to clear the intersection and avoid T-bone accidents.
- Dilemma zones do not provide a reasonable choice and should not exist.
- Dilemma zones prevent motorists from coming to a safe stop, increase the risk of rear-end collisions, force them to “run the red light,” or force them to exceed the posted speed limit.
- Yellow durations should be properly set to eliminate dilemma zones.
- Dilemma zones are the most likely reason for an increased rate of rear end collisions at camera intersections.
- Properly timed traffic signals eliminate dilemma zones.
- Properly timed traffic signals nearly eliminate “Red Light Running."
- Chi-square statistically proves a relationship exist between the length of the yellow light and the number of tickets produced. A shorter yellow produces more tickets, and a longer yellow produces very few tickets.
- Chillicothe still has improperly timed traffic signals.
- Figure 9 illustrates how a shorter yellow light produces more red light tickets.
- In summary, dilemma zone provide motorists the following three choices: slam on the brakes and risk a rear-end accident, continue through the intersection and be issued a “red light” infraction, or speed up and be issued a speeding infraction. These options are neither safe nor acceptable, and they carry a financial consequence for the motorist as well.

W. Loucks - 1/5/2009 –

Reference:

400 TRAFFIC SIGNALS Traffic Engineering Manual
(October 17, 2008) **October 23, 2002 4-21**
403 TRAFFIC CONTROL SIGNAL FEATURES AND OPERATION

403-2 Vehicle Change Interval

The vehicle change interval (or phase change interval) described in **OMUTCD Section 4D.10** consists of the yellow change interval and the all-red clearance interval. The exclusive function of the yellow change interval is to warn traffic of an impending change in the right-of-way assignment. For **ODOT**-maintained signals, the yellow change interval should be followed by a red clearance interval (all-red phase) of sufficient duration to permit traffic to clear the intersection before conflicting traffic movements are released. For more efficient operations, start-up time for the conflicting movements may be considered when setting the length of the all-red.

The length of the phase change interval can be determined using the following equation, in which [(W+L)/ V] represents the all-red interval:

$Y + AR = t + V/(2a + 64.4g) + [(W + L) / V]$ (for English units)
$Y + AR = t + V/(2a + 19.6g) + [(W + L) / V]$ (for metric units)
Where: $Y + AR$ = Sum of the yellow and all-red
t = perception/reaction time of driver (typically assumed to be 1 second)
V = approach speed, ft/s (m/s)
a = deceleration rate, ft/s^2 (m/s^2) (typically assumed to be 10 ft/s^2 (3.0 m/s^2))
W = width of intersection, ft (m) (measured from the near side stop bar to the far edge of the conflicting traffic lane, along the actual vehicular path)
L = length of vehicle, ft (m) (typically assumed to be 20 feet (6.0 meters))
g = approach grade, percent of grade divided by 100 (plus for upgrade, minus for downgrade)
Yellow change intervals typically are in the range of three to six seconds, and the typical maximum all red interval is two seconds.