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CAP MR-340D
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Summary of Analysis and Recommended Yellow Light Intervals

Summarized below are the recommended yellow light intervals as compiled from 6 different sources, each using generally accepted practices. It can be readily observed that there are three methods that, contrary to most industry recommendations, do not avoid the dilemma zone.

Method 1

Caltrans Traffic Engineering Handbook. 9-04.5 *Yellow Change Intervals*. Method 1 is based on the effect of speed on stopping time and distance and is shown in the following table:

Table I
Caltrans Suggested Yellow Light Time

Approach Speed, mph	Yellow Interval, seconds
28	3.1
31	3.3
34	3.5
37	3.7
40	3.9
43	4.2
47	4.4
50	4.7

Some investigators have concluded that the driver response time should allow for 1 second to decide whether to stop or proceed and 1.5 seconds to prepare to stop. The value of 2.5 seconds includes driver perception and response time as shown in page 12 of *Traffic Engineering Handbook*. It is not clear whether or not CalTrans data includes an allowance for driver perception and reaction time, PRT. The values shown suggest that they do not contain PRT allowance and, as such, do not avoid the dilemma zone.

Method 2

San Diego Police Department stopping distance chart, converted to stopping time using average velocity. Method 2 is based on the published stopping distance data from the San Diego Police Department. Recommended yellow light intervals were selected here to be equal to the stopping time as follows:

$?t_{yellow} = ?t_{stopping}$
= stopping distance ? $V_{approach}$? 2

yellow interval for 25 mph
= 85 ? 36.7/2
= 85 ? 18.35
= 4.63 sec @ 25 mph

Table II
Stopping Time for San Diego Police Department Published Stopping Distance

MPH	Distance, Ft	Time, Sec, SDPD
15	44	4.00
20	64	4.36
25	85	4.63
30	109	4.95
35	135	5.26
40	164	5.59
45	197	5.97
50	229	6.24

Method 3

Traffic Engineers Handbook, 5th edition, Institute of Traffic Engineers, 1999, pg. 481. Method 3 is based on formula 13.2 in the Traffic Engineers Handbook, 5th edition. Method 3B is the same as Method 3 but with the clearance interval moved from yellow to red, a questionable procedure but apparently allowed as an option. Method 5 is the same as Method 3 but uses acceleration of 15 ft/sec^2 vs. 10 ft/sec^2.

$?t_{yellow} = 1 + V/2a + V/20(64.4)g + W+L/V$

ITE 1976, a = 15 ft/sec^2, ITE 1985, a = 10 ft/sec^2

$?t_{yellow}$ = 2.83 seconds @ 25 mph with dilemma zone
= 5.28 seconds @ 25 mph with no dilemma zone

Table III
From ITE Traffic Engineers Handbook, 3rd & 5th Editions

Approach Speed 85th Percentile	1 + V/2a Yellow Interval		Roadway Width Adjustment for Clearing Intersection	Total Yellow Duration, No Dilemma Zone	
	1976	1985		1976	1985
20	1.97	2.46	3.07	5.04	5.53
25	2.22	2.83	2.45	4.67	5.28
30	2.46	3.20	2.05	4.18	5.25
35	2.71	3.57	1.75	4.13	5.32
40	2.95	3.93	1.53	4.51	5.46
45	3.20	4.30	1.35	4.55	5.65
50	3.44	4.67	0.8	4.24	5.47
55	3.69	5.04	0.7	4.39	5.74
60	3.93	5.40	0.7	4.53	6.11
65	4.17	5.76	0.6	4.77	6.36

Method 4

Clean Air Partners simplified analysis, yellow interval equal to stopping time using 1 second delay and 10 ft/sec^2 average deceleration, no dilemma zone.

Clean Air Partners simplified analysis uses 1 second delay for driver response time and 10 ft/sec^2 average deceleration. Both values are generally accepted in the industry. An example for calculation is that for 15 miles per hour, this is 22 feet per second and the vehicle will travel 22 feet during the driver response time. The average velocity after that and to the stopping point will be 11 feet per second and will take 2.2 seconds, thereby traveling another 24.2 feet, total yellow interval, 1.0 to 2.2 or 3.2 seconds. At approach speeds great than 30 miles per hour this simplified procedure generates yellow intervals longer than 6 seconds and should be, according to industry practice, capped at 6.0 seconds as shown in the table.

? t_{yellow} = delay + V/a
= 1.0 + V/10
= 1.0 + 36.7/10
= 4.67 @ 25 mph

Table IV
Vehicle Stopping Time with One Second Driver Response Time and Deceleration (@ 10 ft/sec^2)

Speed MPH		Stopping Distance, Ft			Stopping Time (sec)
	Ft/sec	Coast	Decel	Total	( ) max
15	22.00	22.0	24.2	46.2	3.20
20	29.33	29.3	43.0	72.3	3.93
25	36.67	36.7	67.3	104.0	4.67
30	44.00	44.0	96.8	140.8	5.40
35	51.33	51.3	131.6	182.3	(6.00) 6.13
40	58.67	58.7	172.3	231.0	(6.00) 6.87
45	66.00	66.0	217.8	283.8	(6.00) 7.60

Method 5

Traffic Engineers Handbook, Institute of Traffic Engineers, 1976, see Method 3 and Table III.

"Yellow vehicle change intervals should have a range of approximately 3 to 6 seconds. Generally, the longer intervals are appropriate to higher approach speed." [Manual on Uniform Control Devices (MUTCD), 1988 Edition, pages 4B-15].

"Approaches experiencing speeds of 35 mph or higher are considered high speed approaches." [Traffic Control Devices Handbook, subsection titled "High Speed Approaches", pages 4-29, FHWA, 1983].

The intervals selected by San Diego Traffic Engineering, particularly left turn signals, are not compatible with these regulations and do not comply with those in ITE 1985 by using the approach velocity as the velocity in the turn instead of the velocity in the approach.

Summary

The summary of the six methods (seven options) for establishing reasonable yellow light intervals for speeds of 25 and 40 miles per hour approach speeds are as follows:

Table V

Method	Yellow Light Duration	
	25 mph	40 mph
0, SDTE, dz	3.00	4.30
1, CalTrans, dz	3.00	3.90
2, SDPD, ndz	4.63	5.59
3, ITE-85, ndz	5.28	5.46
3B, ITE-85, dz	3.00	3.90
4, CAP 2001, ndz	4.67	6.87
5, ITE-76 ndz	5.30	5.00

The general conclusion is that three out of the seven recommended yellow intervals are considerably shorter than the other four. ITE references suggest that this difference is caused by the dilemma zone. Most authorities recommend avoidance of the dilemma zone in the interest of fair practice and traffic safety.

It can be shown that for a 3 second yellow light duration and speeds of 25 miles per hour or greater, a large fraction of the vehicles will be in the "dilemma" or "impossible to stop" range.

- Reasonable yellow interval 5.0 sec
- Unreasonable yellow interval 3.0 sec

Increasing yellow light time, from 3.0 to 5.0 seconds should improve traffic safety by allowing an extra 2.0 seconds for the intersection to clear before activating the green signal for opposing traffic and also discouraging panic stops and the consequent rear end collisions.

Conclusions and Recommendations

After a comprehensive review of the background data and literature, it is concluded that the traffic signals at the major intersections can be modified to enhance traffic flow and improve traffic safety by following recognized industry standards and adopting a more uniform timing for the yellow interval and avoid the dilemma zone.

This conclusion and recommendation is particularly applicable to intersections equipped with red light enforcement cameras where the yellow light duration has been adjusted to be shorter than that recommended by respected industry authorities such as the Institute of Transportation Engineers.

Advantages

- Improve traffic safety by adopting industry standard and consistent yellow duration, thereby reducing the driver confusing aspects of variable yellow light time.

- Improve traffic flow by allowing additional time to clear active traffic lanes.

- Improve traffic safety by reducing tendency toward rear end collisions caused by yellow intervals which are too short such as the 3 seconds used at most of the RLC intersections.

- Eliminate unreasonable citations issued to vehicle drivers who are innocently caught in the "dilemma" or "impossible to stop" zone as a result of unreasonably short yellow intervals.

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Appendix

Figure 1, "Effect of Yellow Light Interval On Apparent Red Light Violations"
Figure 1A, "Effect of Yellow Light Interval on Apparent Red Light Violations and Collision Hazard Factor"
Figure 2, "Vehicle Stopping Distance vs. Speed, SDPD"
Figure 3, "Vehicle Stopping Time vs. Speed, SDPD"
Figure 4, "Percent of Vehicles in Impossible to Stop Zone"
Figure 5, ITE Handbook, 5th Edition, 1985-99, excerpts
Figure 6, "Perception Reaction Time"
Figure 7, ITE Handbook, 1976, excerpts
Figure 8, "Comparison of Yellow Intervals"
Figure 9, Red Light Camera Defense Team, "Appendix 'A'" dated 6/23/2001
Figure 10, "Yellow Time Table"
Figure 11, Office of the House Majority Leader (R. Armey), "Red Light Running Crisis *Is It Intentional*?", May 2001, selections of reports, Parts IV & V

Effect of Yellow Light Interval On Apparent Red Light Violations

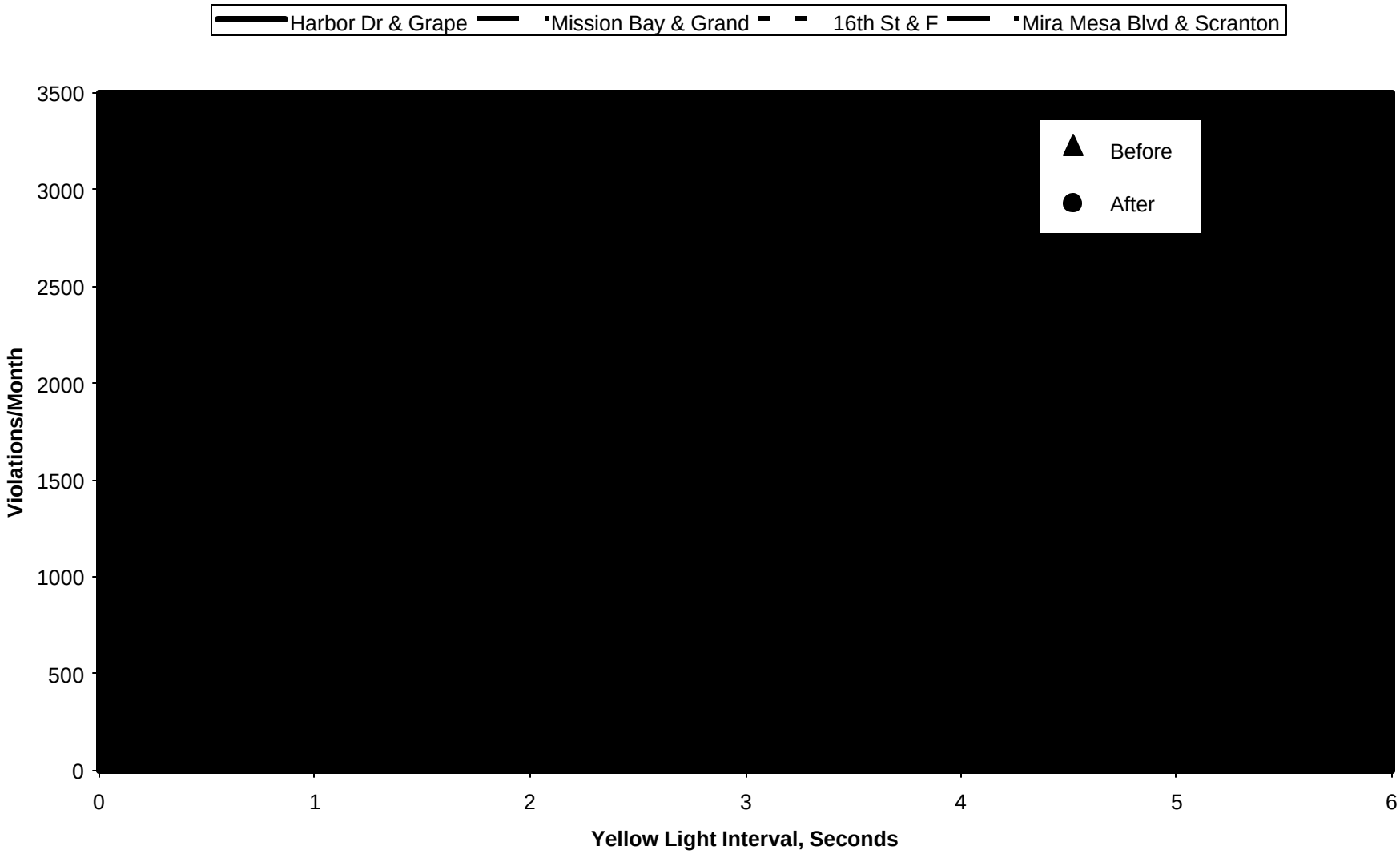

Figure 1

Effect of Yellow Light Interval On
Apparent Red Light Violations & Collision Hazard

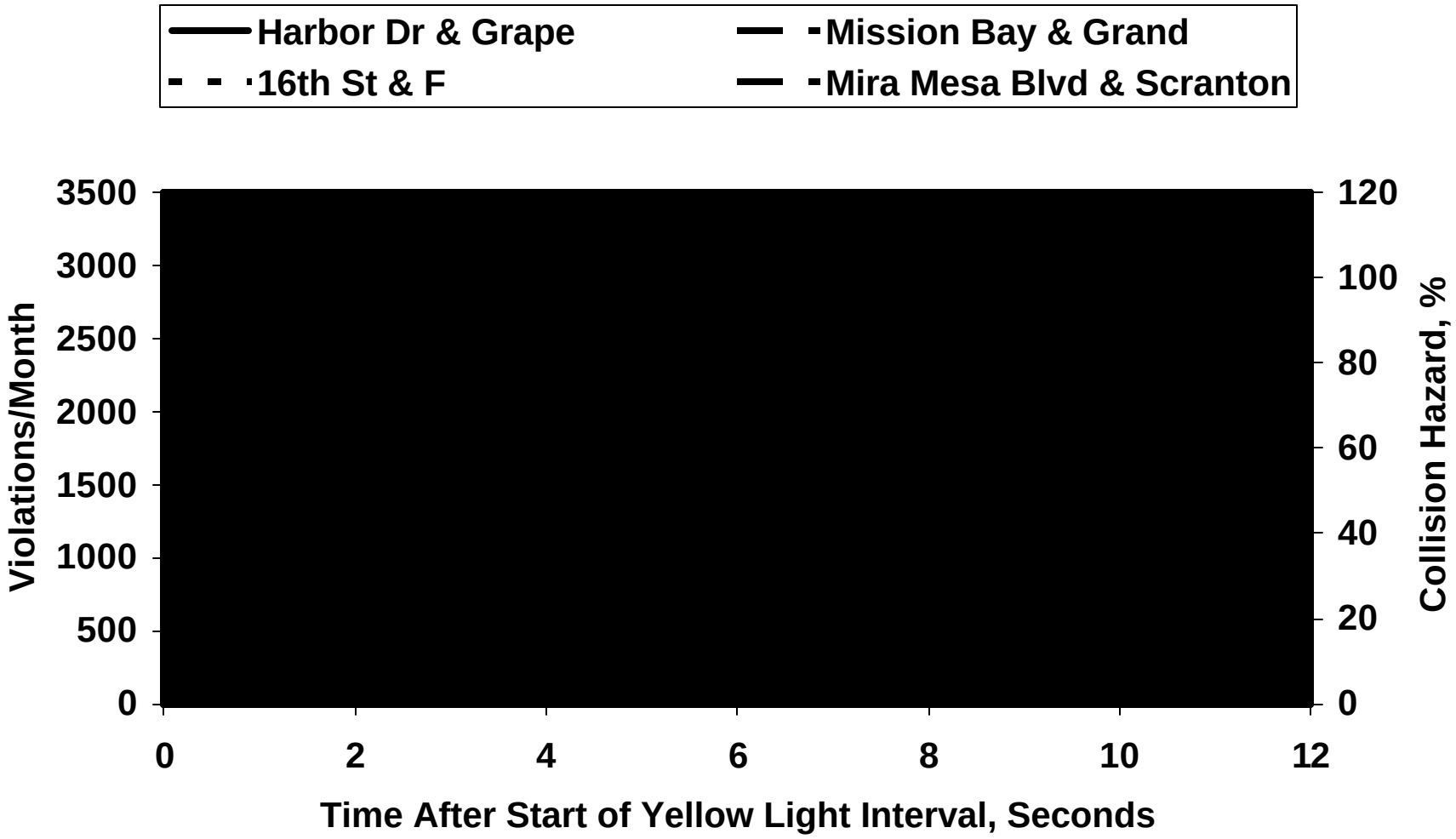

Figure 1A

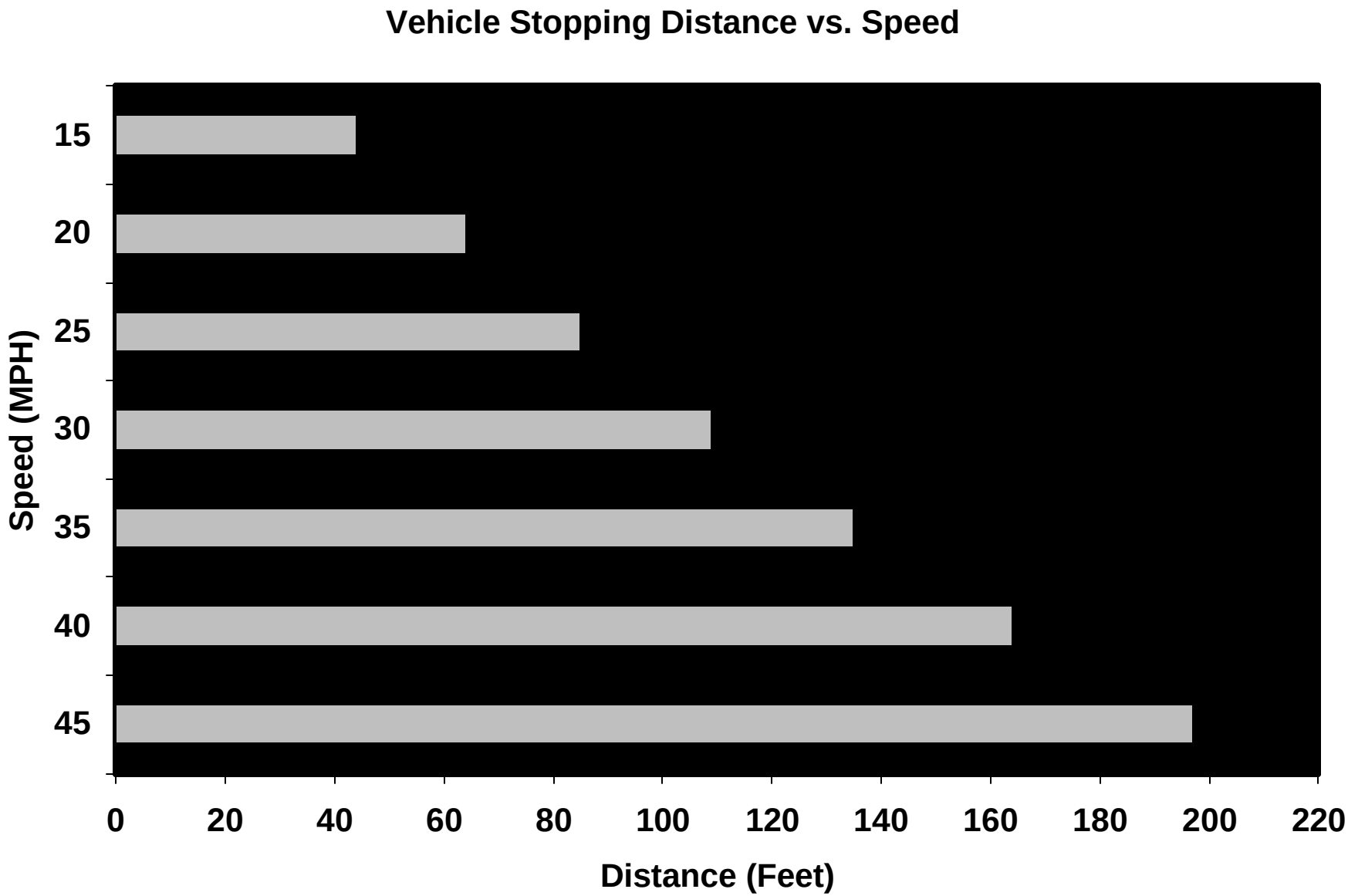
Vehicle Stopping Distance vs. Speed
Speed (MPH)
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160
180
200
220
Distance (Feet)

Figure 2

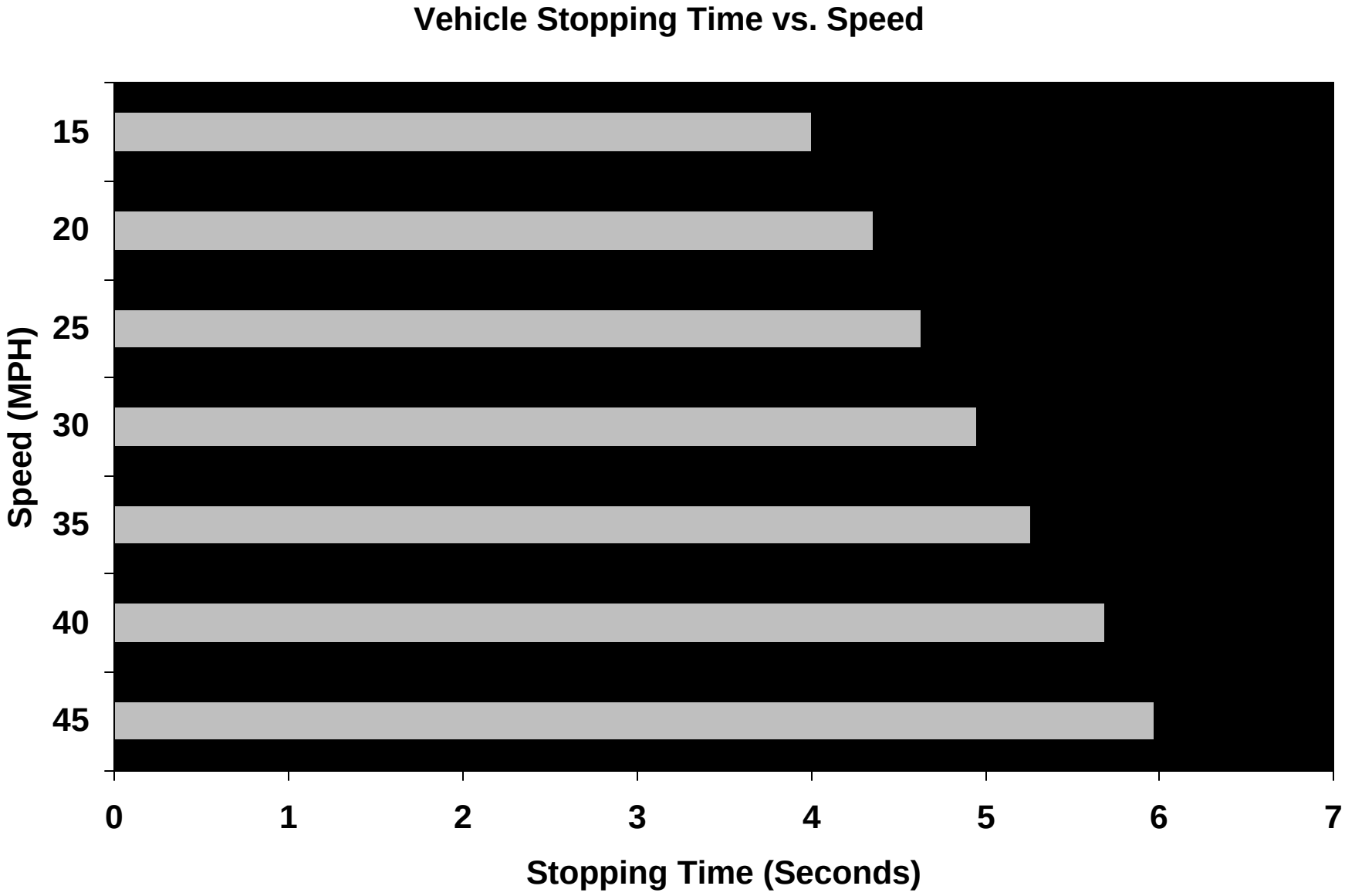
Vehicle Stopping Time vs. Speed
Speed (MPH)
15
20
25
30
35
40
45
0
1
2
3
4
5
6
7
Stopping Time (Seconds)

Figure 3

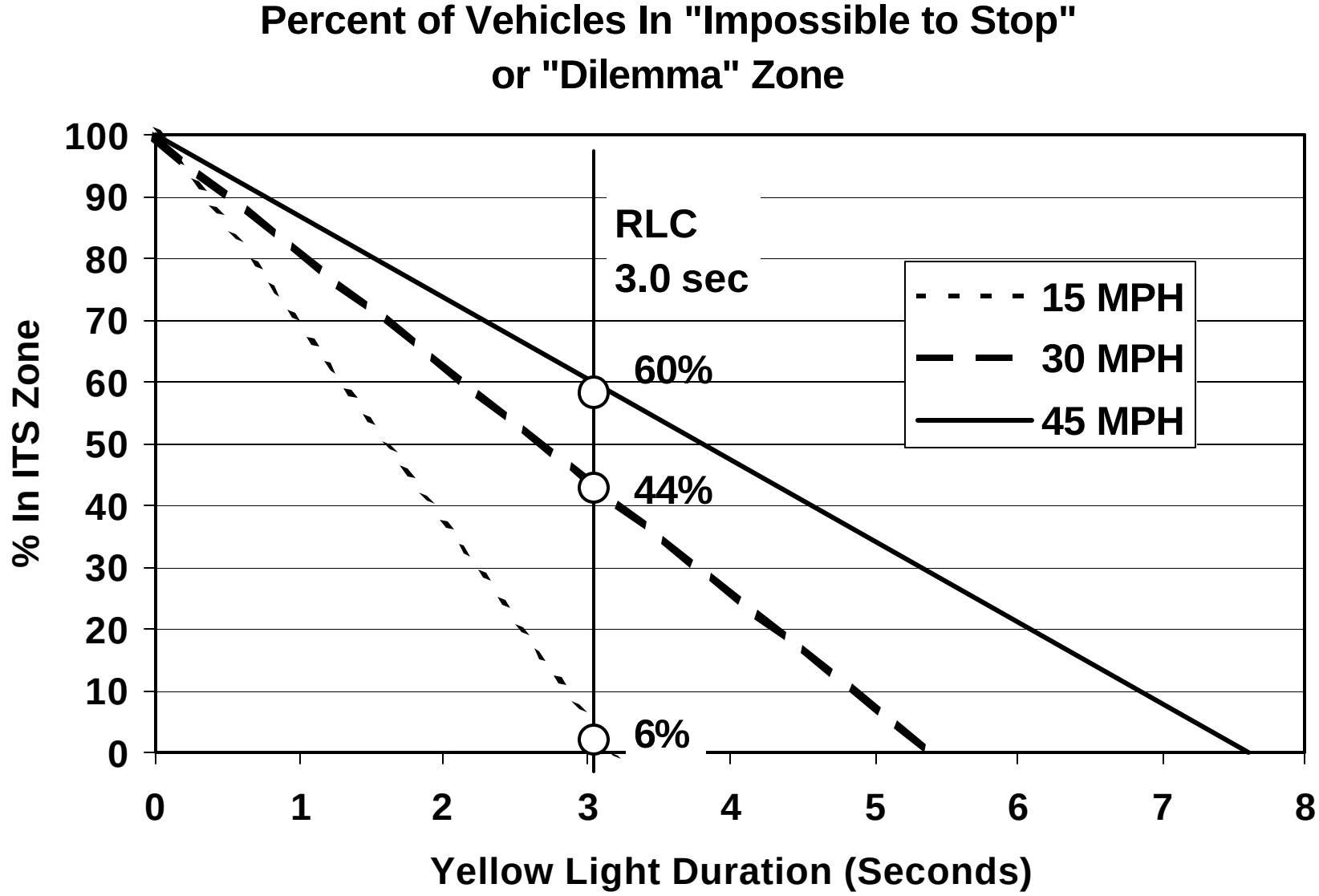
Percent of Vehicles In "Impossible to Stop"
or "Dilemma" Zone
% In ITS Zone
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
Yellow Light Duration (Seconds)
RLC
3.0 sec
60%
44%
6%
15 MPH
30 MPH
45 MPH

Figure 4

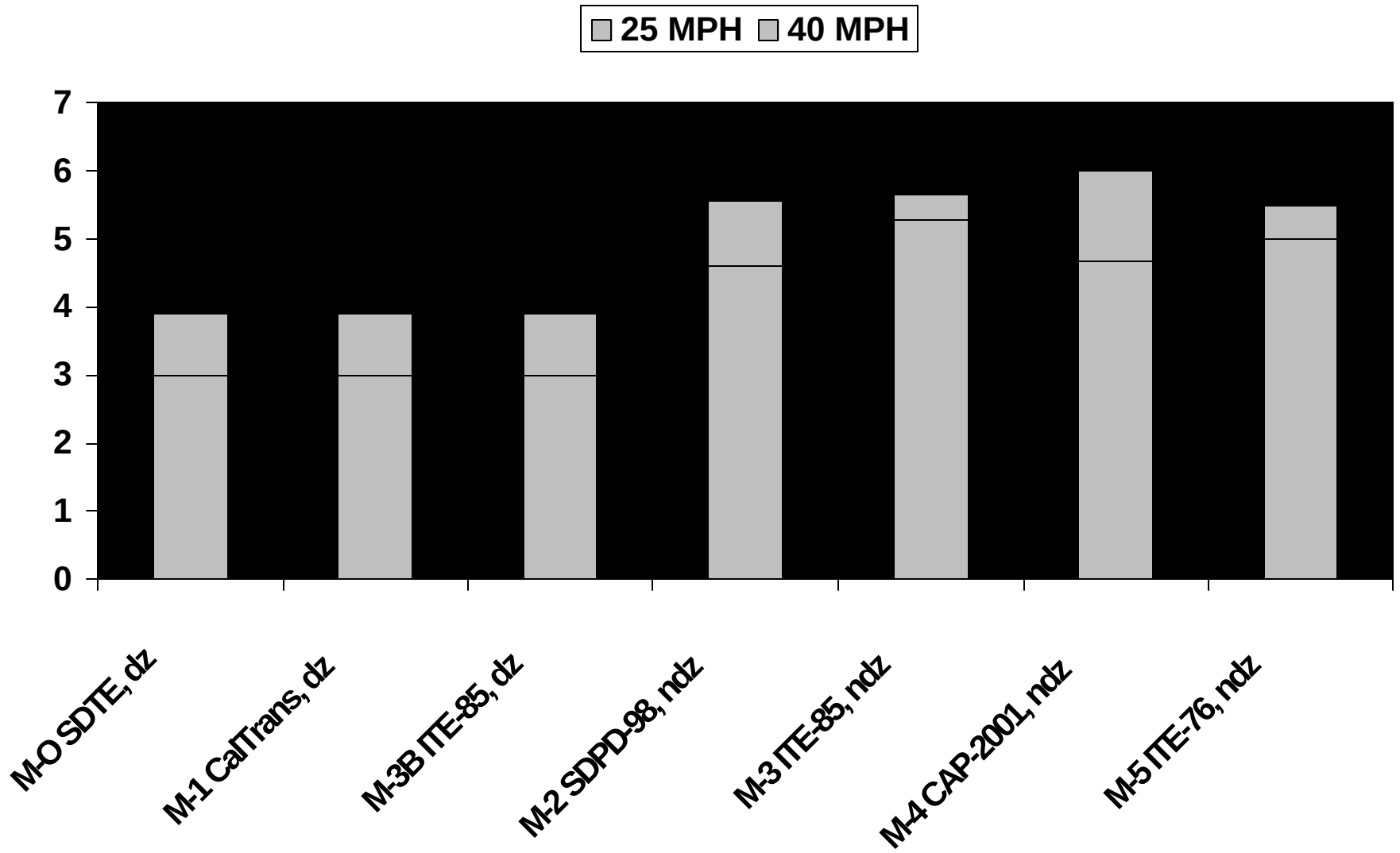
Comparison of Yellow Light Times
25 MPH
40 MPH
7
6
5
4
3
2
1
0
M-O SDTE, dz
M-1 CalTrans, dz
M-3B ITE-85, dz
M-2 SDPD-98, ndz
M-3 ITE-85, ndz
M-4 CAP-2001, ndz
M-5 ITE-76, ndz

Figure 8