Clean Air Partners
5066 Santa Fe Street, San Diego, CA 92109
Phone: (858) 581-5600
Fax: (858) 581-5626
Email: info@cleanairpartners.com

CAP MR-356C
N. John Beck
July 25, 2001

Effect of Yellow Light Interval on the Frequency of Apparent Red Light Running Violations for the Red Light Camera Enforcement System as Used in San Diego

I. Background

Automated control of separation of the rights of way for opposing traffic at intersections was developed and used very early in the automotive industry. In the early 1930s, some of the signals were mechanical and were merely metal flags which alternately displayed the words STOP and GO. The equivalent of the yellow interval was the time required to move the metal signs which rotated on a pivot point. The determination of a violation was solely by the judgement of the police officer, if there was one. This was followed by the current practice using incandescent electric lights with green, yellow and red colored lenses. The addition of the yellow light interval was intended to allow the motorist warning time to safely continue through and clear the intersection or stop at the stop bar. The yellow light interval was intended solely for the purpose of enhanced safety and was never intended as a means for generating revenue. Following the introduction of red light camera enforcement systems, there apparently began a crusade to reduce yellow light intervals to enhance revenue from violation citations. The crusade to justify reduction in yellow light intervals remains as an objective in some circles.

II. Introduction

The City of San Diego has installed electronically controlled red light enforcement cameras at 20 intersections as a pilot program. The stated goal of the pilot program was to improve traffic safety by reducing vehicle collisions. To accomplish this goal, the San Diego City Council required that the intersections chosen for photo-enforcement would be locations where an accident analysis has shown that a significant number of accidents were caused by red light violations. Instead, the intersections chosen were not among the city's high accident intersections during the years immediately prior to and after installation. The locations chosen were intersections with high traffic volume, relatively high speeds, steep downhill grades or sharp right turns, and short yellow light times – all factors that can create a "dilemma" or "impossible to stop" zone. The yellow interval for these intersections have been set at various values from a minimum of 3.0 seconds to a maximum of 5.0 seconds. Initially, starting in September 1998, 12 of the 19 systems were set with a yellow interval of 3 seconds (see Appendix). By the end of 2000, yellow light intervals at 11 of the remaining 19 were set at 3.0 seconds . The remainder were timed with a yellow light interval of 3.5 to 4.9 seconds. Data recorded and maintained by the red light camera (RLC) operator and the City of San Diego include monthly summaries of the yellow light intervals, number of violations recorded by the RLC equipment and citations issued for each of the remaining 19 intersections. City records indicated that at least three intersections had their yellow lights shortened prior to the installation of a red light camera. City records also indicate that yellow light intervals were changed at least 8 times since the inception of the RLC system. Records of the before and after violation/citation results for four separate intersections with significant yellow light changes were thoroughly

reviewed. The records from these four intersections were analyzed for the effect of the yellow change interval on the frequency of apparent red light running. The data were correlated mathematically to determine the average effect of the length of the yellow interval on violation frequency. The correlation was found to be consistent and reasonable.

III. Summary

The apparent red light running data was compared for various intersections with different yellow light intervals using the correlation formula derived from the data provided by the city. Using a selected nominal reference value for yellow interval of 5.4 seconds and a minimum yellow interval of 3.0 seconds, the correlation formula showed that the rate of increase of apparent red light running increased an average of 13% for each one-tenth of a second that the yellow intervals were reduced below the baseline of 5.4 seconds. When applied to the yellow interval at the RLC system at the intersection of Mission Bay Drive and Grand Ave., the correlation predicts that the apparent violations would drop from 2262 per month to 283 apparent violations per month if the yellow light interval were to be increased from 3.0 seconds to 4.7 seconds. Actual data, for 2 months before the change to two months after the change at this intersection, showed the actual change to be a reduction from 2262 to 205 apparent violations per month which indicates excellent correlation between yellow interval and recorded violation. This correlation predicts for the intersection at North Harbor Drive and Grape St. that if the yellow interval were to be increased from the current 3.0 seconds to 5.4 seconds, the apparent red light running violations would decrease from the current reported value of 103 per day to 5 per day. For reference, the city records also show that during the time period of 5 years before and 2 years after the installation of the RLC systems, there were no collisions attributed to red light running at this same intersection; consequently, it was concluded that apparent red light running had no discernable effect on safety or accidents over this time period since there were no collisions attributed to red light running in either case. This data is shown in the tabulation below.

Table I
Summary of Collision Data at North Harbor Drive and Grape

Year	Collisions Caused from Red Light Running	
	Original	With RLC
1994	0	
1995	0	
1996	0	
1997	0	
1998		0
1999		0
2000		0

IV. Description of Data and Method of Correlation

The basic data used for this correlation are shown in Table II in the Appendix. This data is from that collected and recorded by the City of San Diego and is summarized below for the four intersections with the most significant changes in yellow intervals and which had the apparent red light violations recorded before and after the change in yellow interval. Although review of the citations indicate possible discrepancies in the RLC equipment and data, for the purpose of this analysis it was assumed that the RLC equipment was functioning properly.

Table II
Summary of Data Two Months Before and After Change in Yellow Light Interval

Intersection Location	Yellow Interval	Actual Violations/Mo Before/After	Before/After Ratio	Equation Exponent	Normalized To 3 Second Yellow Light Interval
Harbor Dr. and 32nd St.	4.0/4.5	47/35	1.34	1.06 1.13	84/47/35 2%/0.0012 159/47/26/23
16th St. and F St.	4.0/4.9	131/35	3.74	1.16 1.13	490/131/35/ 14.5%/0.0043 444/131/35/24
Mira Mesa Blvd. & Scranton	3.9/4.3	403/234	1.72	1.14 1.13	1310/403/234 30.6%/0.0428 1210/403/247/64
Mission Bay Blvd. and Grand Ave.	3.0/4.7	2262/205	11.0	1.15 1.13	2262/205 52.9%/0.079 2262/283/120
Weighted Average of four intersections, normalized to 3 seconds				1.13	
Harbor Dr. & Grape St. (Reference only – projected from above)	3.0/4.0/5.4/60	3085/164/78	18.8	1.13	3085/909/164/78

The basic equation for correlation is as follows:

$V_2/V_1 = (1+r)^t$

V_1 = apparent violation rate, incidents per month at yellow interval time, T_1, seconds
V_2 = apparent violation rate, incidents per month at yellow interval time, T_2, seconds
r = rate of change in V per 0.1 second change in T
t = $(T_2 – T_1)(10)$
Tn = Yellow time normalized to 3.0 sec and V in incidents per month
HF = Hazard factor, probability of collision (based on distance traveled by vehicle accelerating from stop bar at 10 ft/sec^2 ? one half of roadway width)

V. Analysis and Presentation of Data

The data from the traffic records of the City of San Diego, when plotted in a chart showing the relationship between apparent violations and yellow interval, are shown in Figure 1. The comparison of actual data with that correlated by the formula is also shown. The correlation of calculated values to actual data is quite close for the intersections with high violation rates. The resolution of data becomes less precise at the lower violation frequencies; however, the trend of increasing violation rates with decreasing yellow intervals is unmistakable.

Using the correlation formula, derived from the trends of the actual data, permits projections of the effects of change of yellow interval on apparent violations which is shown by the curves in Figure 1. It is obvious that the yellow interval has a very strong effect on the frequency of apparent violations. As noted previously, increasing the yellow interval from 3.0 seconds to 5.4 seconds at the intersection of North Harbor Drive and Grape St. is projected to reduce daily violations from 103 per day to 5 per day.

It should be noted that the red light running violations can be classified into two categories, namely: harmless and harmful. According to the analysis used in this report, red light violations in the time period of less than six seconds after the start of yellow can be classed as harmless because, with normal traffic flow, there is insufficient time for the vehicles to travel to the point of potential contact. Violations in the time period 6 seconds beyond the start of the yellow light become increasingly harmful as the probability of collision increases. This effect on hazard factor is shown graphically by the projections in Figure 2. It should be noted that the red light camera enforcement system as employed by the City of San Diego addresses almost exclusively the harmless, but revenue producing, portion of the apparent violation period.

VI. Computation of Optimum Baseline

In the selection of yellow light intervals by professionals in the field of traffic engineering and traffic control, there is almost universal agreement on the following boundary conditions:

- Driver perception/response time, PRT, should be treated as a minimum of one second.
- Yellow light interval should be long enough for a driver to either cross the stop bar and continue through the intersection before the light turns red or safely execute a normal stop without running the red light. There should be no “dilemma” or “impossible to stop” zone.
- It is generally agreed, in the traffic engineering profession, that yellow light intervals should be no less than 3 seconds nor more than 6 seconds.
- It is generally agreed and preferred that a reasonable deceleration rate to use for calculations and projections is 10 feet per second per second.
- If the calculation exceeds 6 seconds, the specific situation can be aided by capping the yellow light at the intersection at industry recommended practice of 6 seconds and then adding early warning flashing yellow lights upstream of the intersection as is done at many high speed highways.

The author has concluded that a reasonable baseline yellow light interval can be calculated by using the design approach speed and requiring that the yellow interval be at least equal to normal, non-panic, stopping time, with 10 feet per second per second deceleration rate. Taking a design approach speed of 30 miles per hour, baseline yellow interval is computed as follows:

?? Vehicle physical stopping time from 30 miles per hour, 44 feet per second ? 10 = 4.4 seconds.

?? Driver PRT, 1.0 second.

?? Baseline yellow interval for 30 miles per hour becomes 5.4 seconds.

?? Further refinement for grade, pavement condition, roadway width, etc. can be made as an adjustment to the baseline.

VII. Conclusions and Recommendations

After a comprehensive review of pertinent literature, records and sworn testimony, it has been concluded that in San Diego the yellow light intervals for RLC intersections were selected to shorter than recommended levels solely to enhance revenue. There is no record that these ultra short yellow intervals were ever intended to improve traffic safety.

There is unrefutable evidence that the length of the yellow light interval has a strong and consistent effect on the frequency of apparent red light running violations. This conclusion applies to both human and electronic enforcement techniques. There is no evidence that shortening the yellow light duration improves traffic safety by reducing collisions or any other benefit. On the contrary, there are sources in the literature that report that reductions in yellow light intervals increase the frequency of rear end collisions.

The current yellow light intervals for the 19 existing RLC intersections in San Diego were intended (by the traffic engineers) to be compliant with the 1985 recommended practice of the ITE. Detailed examination indicates that there is a question as to whether the recommended practices were followed specifically as defined by ITE. The selection of the fixed value of 3.0 second yellow interval in 11 of the intersections is not compliant with the recommended 85th percentile approach speed measured 100 to 400 feet ahead of the intersection. The ITE calculations for yellow interval apparently suggest the option of not including the clearance interval as part of the yellow interval; hence forcing the system into the dilemma range. In addition, there is strong evidence that the current recommended practices of ITE, CalTrans, IIHS and others are seriously flawed and recommend yellow light intervals which are too short and create a large and undesirable dilemma zone. It is curious that the current recommendations, 1985 ITE, can be interpreted by some to allow the option to select either of two yellow intervals; one short – the other long (one with a dilemma zone and the other without, ITE is not clear on this matter). RLC operators invariably select the first option.

There is a strong indication that if the yellow light intervals at the 19 RLC intersections in San Diego were increased to a uniform 5.4 seconds, red light running would be reduced by more than 10 fold and traffic safety would be improved.

VIII. Overview

This report addresses specifically the effect of yellow light intervals on indicated red light violations and concludes that the intervals, as currently used, are much too short. It is also concluded that this deficiency can be fully mitigated by increasing yellow intervals to avoid the dilemma zone at all 19 RLC intersections.

Safety improvement is not treated in this report because there was no evidence of such attributed to the red light camera enforcement system in San Diego. Conclusions were made on how the efficacy of the RLC system might be adjusted to improve safety, but that issue is not addressed in this report. The only proven effects of shortening yellow light intervals is increased revenue from computer generated red light violations and decreased safety from increased rear end collisions.

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

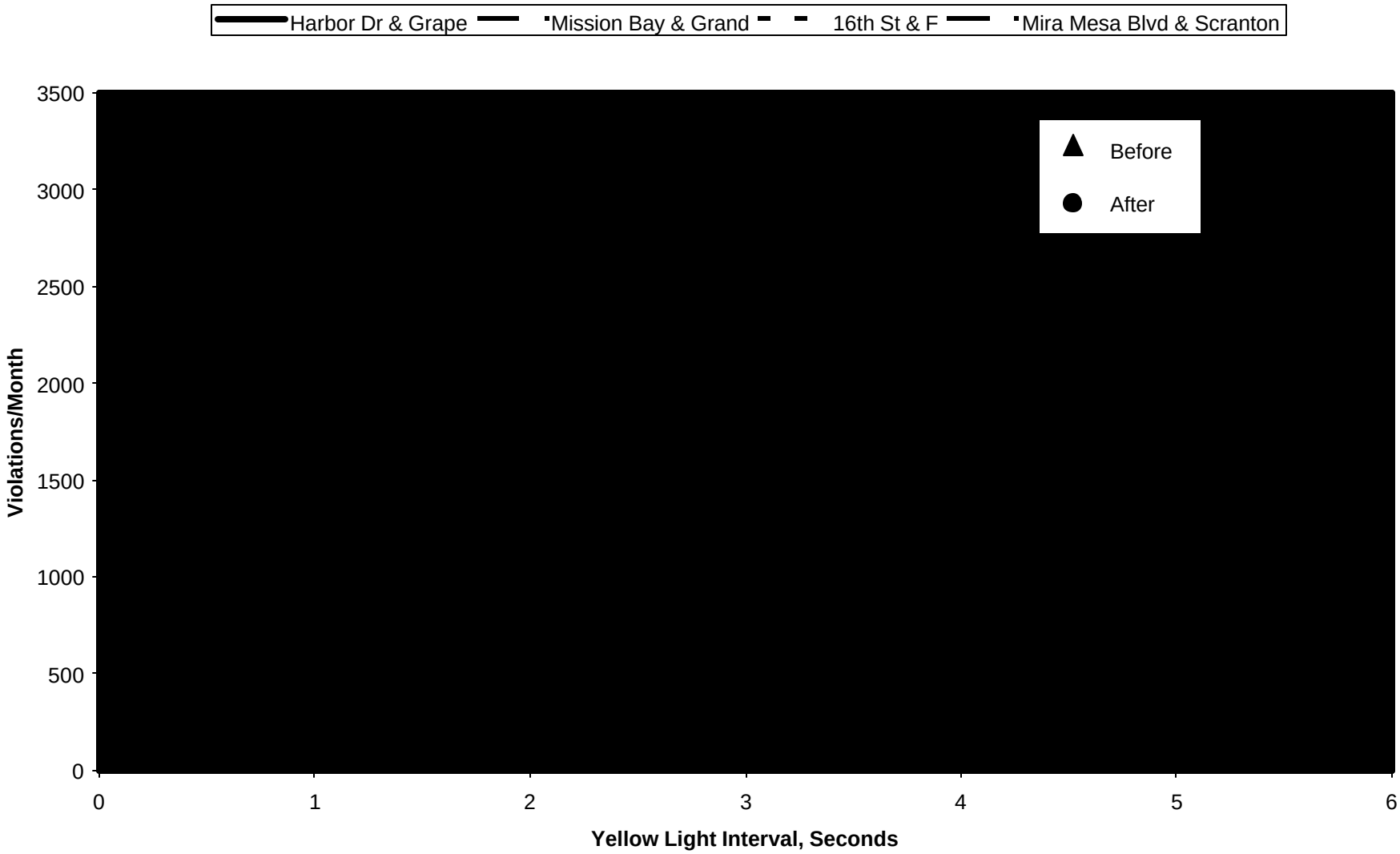

Figure 1

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

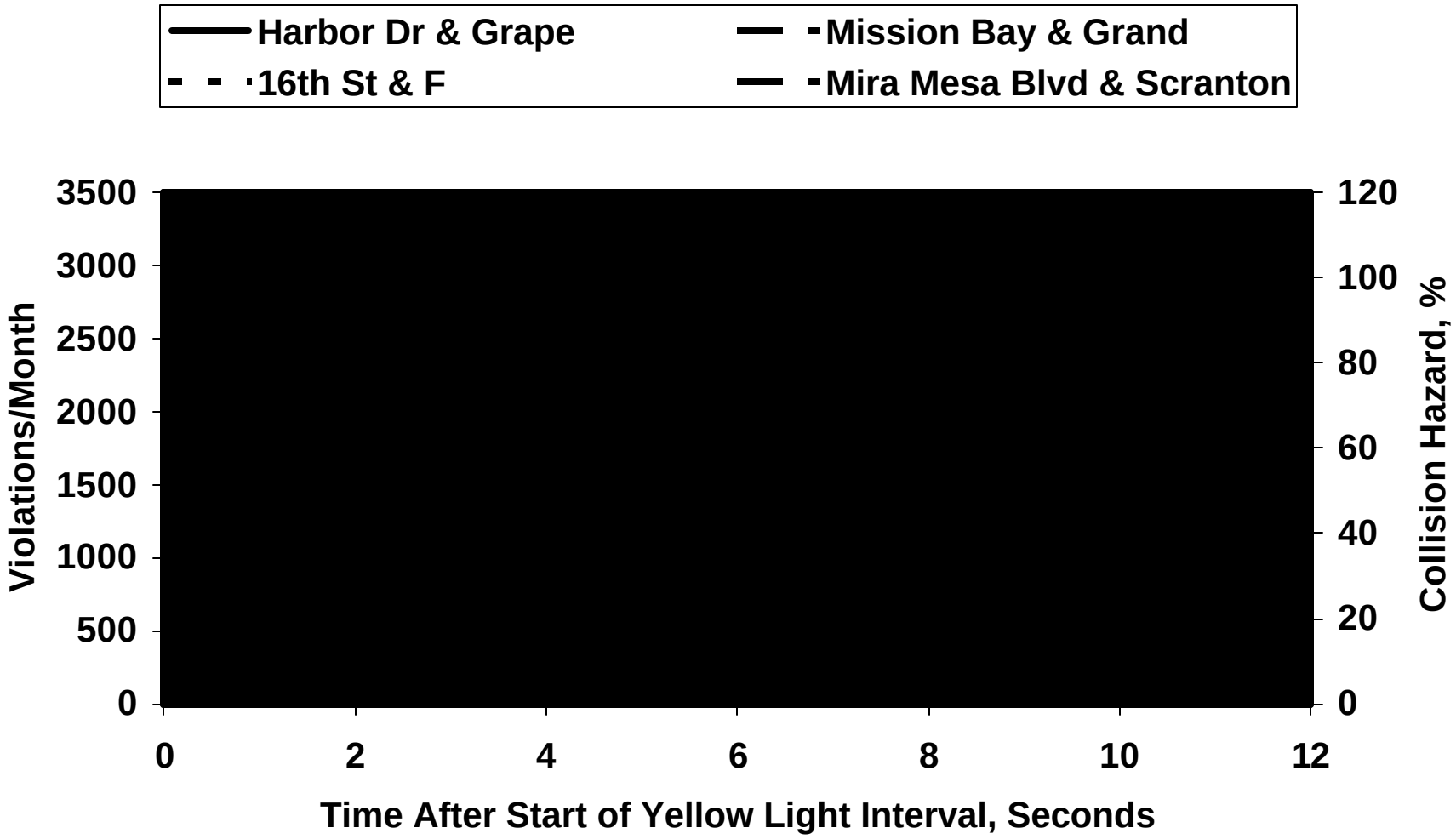

Figure 1A

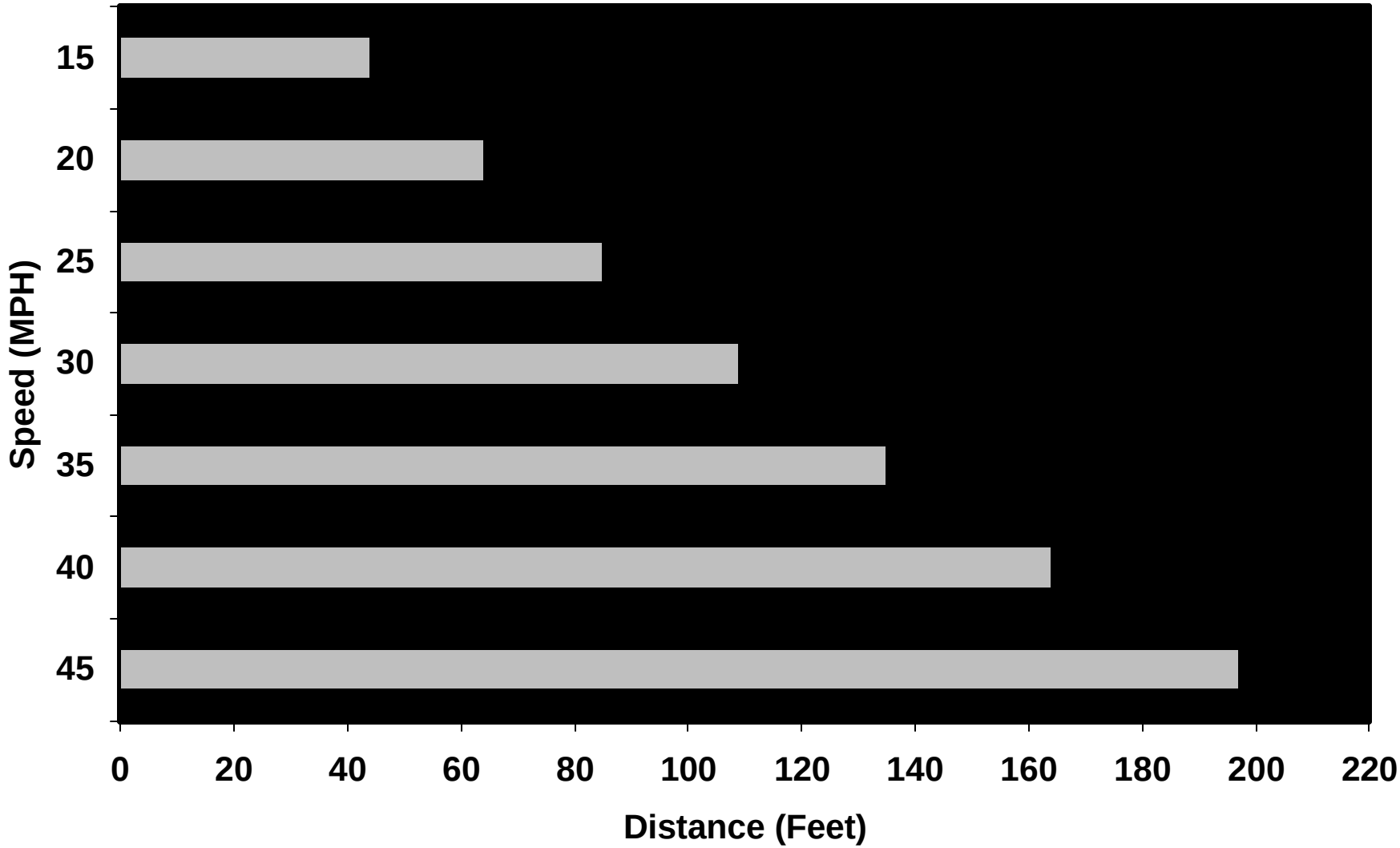
Vehicle Stopping Distance vs. Speed
Speed (MPH)
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160
180
200
220
Distance (Feet)

Figure 2

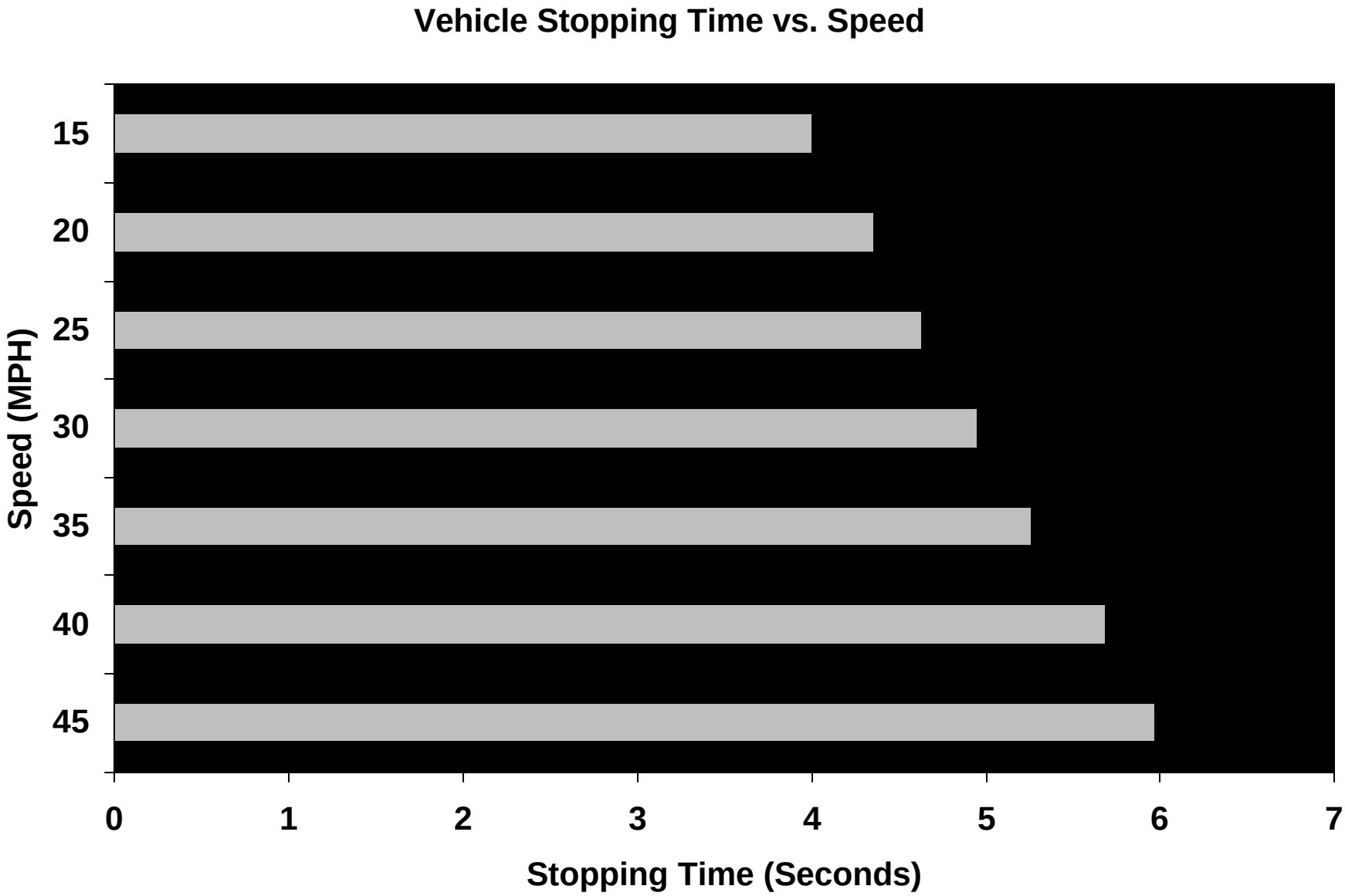
Vehicle Stopping Time vs. Speed
Speed (MPH)
15
20
25
30
35
40
45
0
1
2
3
4
5
6
7
Stopping Time (Seconds)

Figure 3

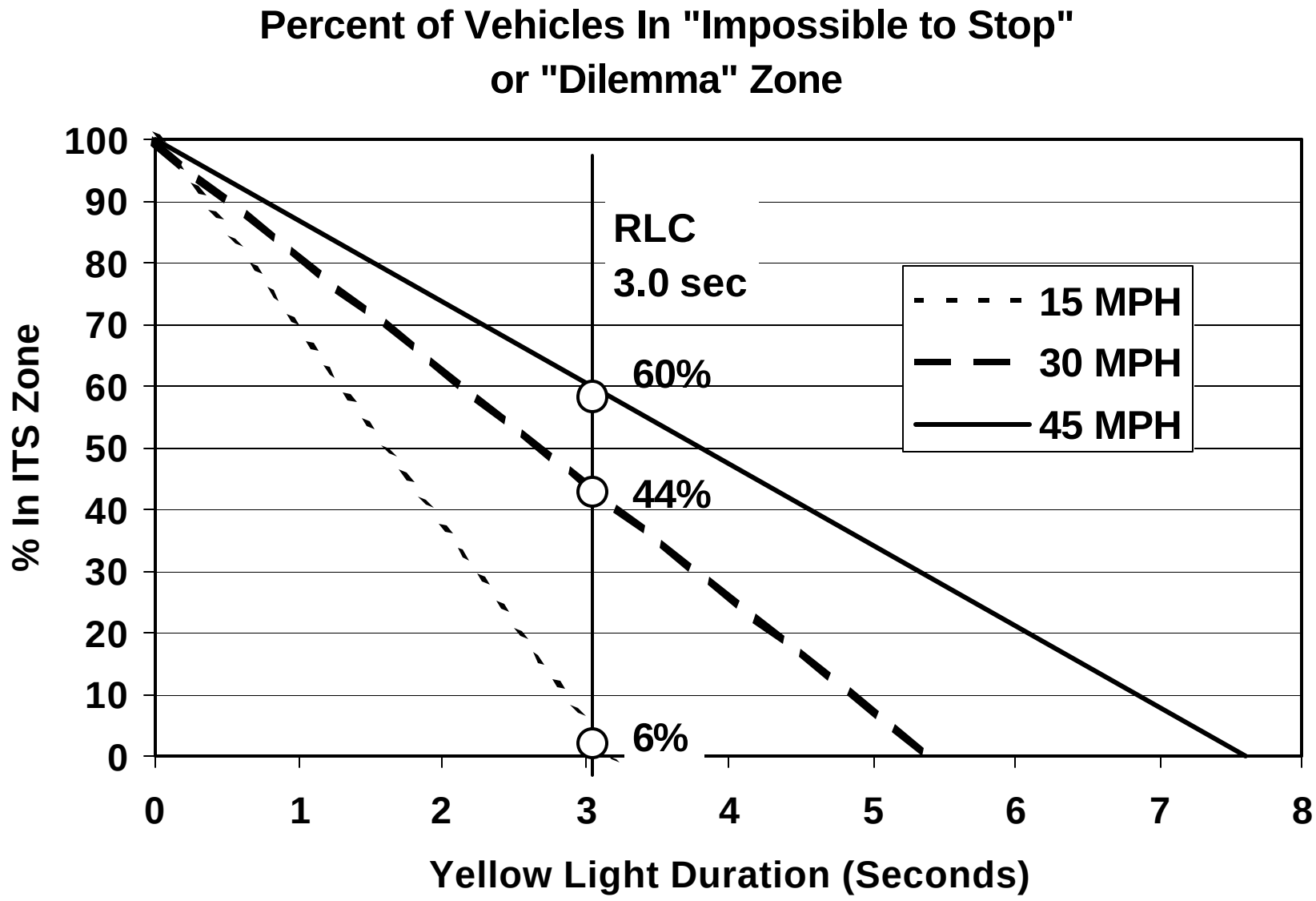
Percent of Vehicles In "Impossible to Stop"
or "Dilemma" Zone
% In ITS Zone
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
Yellow Light Duration (Seconds)
RLC
3.0 sec
60%
44%
6%
15 MPH
30 MPH
45 MPH

Figure 4

Comparison of Yellow Light Times

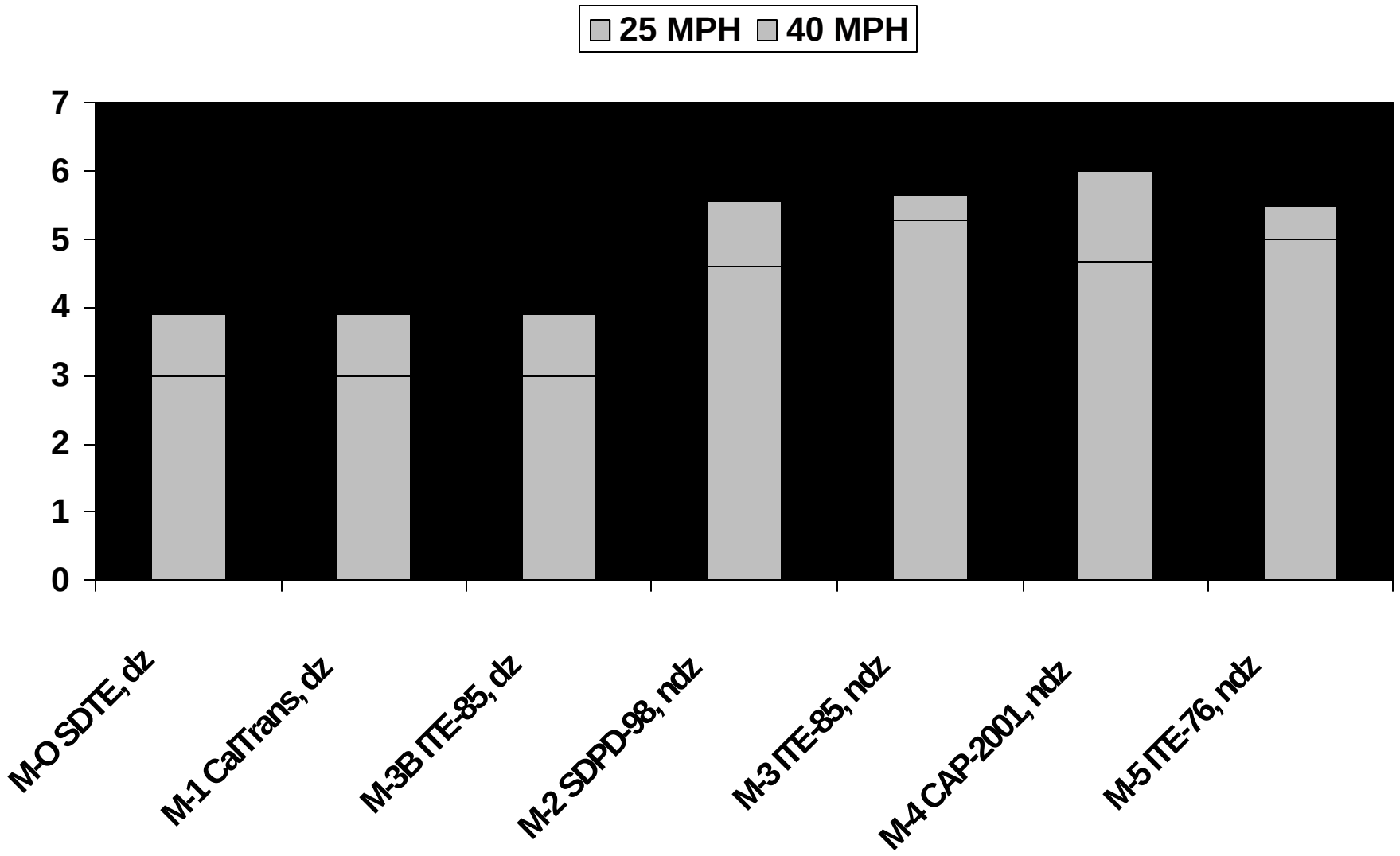

Figure 8