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Effects of Traffic Signal Locations on Stop Line Compliance of Vehicle Drivers in Korea

Jin-Tae KIM

Graduate School of Transportation, Korea National University of Transportation, Uiwang, 437-763, Republic of Korea; Email: jtkim@ut.ac.kr

Abstract: It was learned that the drivers' stop line compliance rate in Korea had been high only during the safety campaign period imposing traffic fine intensively; laying out a long-term scheme to preserve a high stop line compliance rate is necessary. This paper presents a probe study testing if the changes of traffic signal locations could primarily improve the stop line compliance rate. It was found that the stop line compliance rate increased when traffic signals were placed at the nearside (10-20 *m*) of an intersection. It satisfies the minimum distance regulation and no effect on dilemma zone when a pedestrian crossing area is placed. It suggested with promising discussion on placing the traffic signals at the nearside of an intersection when a pedestrian crossing is placed.

Keywords: Traffic Signal, Stop Line, Compliance Rate, Safety, Pedestrian Crossing

1. INTRODUCTION

A stop line indicates where a vehicle should stop when a traffic signal light is red at signalized intersections. Drivers' stop line compliance is one of potential factors that affect pedestrian safety. A vehicle stopping beyond the stop line may threaten and endanger pedestrians and disturb the flow of cross-traffic. For example, when both vehicles and pedestrians are mixed in a crossing area during a pedestrian green signal, the required crossing time of some people, such as the children, the disabled, and the elderly, may increase. This can prevent pedestrians from fully crossing the street before a signal change and expose them to vehicular flow. It is essential in practice to ensure that most drivers are reconciling themselves to their obligation in regulated traffic environment. The optimistic assumption that drivers obey stop line regulations in most situations has been commonly considered in traffic engineering and transportation policy deployment.

It was recognized that drivers do not observe stop lines significantly in Korea. The Korean National Police Agency (KNPA) has toughened enforcement of stop line laws and conducted a national campaign to increase the stop line compliance rate. The Korean Non-life Insurance Association (KNIA) reported, based on the data collected from 23 cities, that the percentage of drivers obeying stop lines changed before and after the campaign. Compliance increased to 86.3% during the campaign but reverted to 78.4% after the campaign. The percentage decreased even to 63.6% in Seoul after the campaign (KNIA, 2005). Figure 1 shows pictures taken in Seoul before and after the campaign.

(a) During the campaign

(b) After the campaign

Figure 1. Driver's stop line compliance during and after the campaign in Seoul, Korea

It was learned that a national campaign toughening traffic fines would not be a long-term solution. It has been ineffective especially in a metropolitan urban area where driving patterns are relatively aggressive. Recursive congestion and frequent incidents in urban highway networks limit the number of police officers issuing fines to the violators. In addition, a safety campaign cannot be maintained as long as desired.

In order to achieve long-term safety enhancement, a drivers' stop line compliance rate needs to be increased and remained high. Fundamental changes directly affecting driving behavior in traffic environment are necessary. Such alterations may include reconfiguration of intersection layouts and relocation of control devices.

One possible change is to limit the visibility of control devices when drivers violate stop line compliance. Traffic signal lights would be the one considered. It is fundamental that traffic signal heads should be placed clearly for optimal visibility and that drivers should keep them in sight to determine right-of-way status at signalized intersections. Drivers would want them in sight so that they can avoid their inconvenience they experience otherwise.

Traffic signals are consistently located at the far sides of intersections in Korea; traffic signals are clearly visible even to stop line violators. In this study, it was hypothesized that better traffic signal light locations may affect drivers' stop line compliance and hence pedestrian safety.

This paper presents a study investigating the relationship between traffic signal locations (in particular, the horizontal distances from stop lines to signals) and drivers' stop line compliance. The study was based on the assumption that stop line compliance should correlate positively with pedestrian safety in pedestrian crossing areas, by limiting the cases to the mast arm-mounted traffic signals.

2. TRAFFIC SIGNAL LOCATION REVIEW

There are few previous studies that measured the relationship between stop line compliance and horizontal distance from a stop line to traffic signal. Most are related to driving behavior, and some are associated with automated road-side enforcement at unsignalized intersections (Lum and Wong, 2003; Goh, 2005; Yang, 2004; NHTSA, 2002; Johnson, 2005).

The Korean Manual on Uniform Traffic Control Devices (KMUTCD) indicates that the horizontal distance from a s top line to traffic signals shall be 10~40 *m* (KNPA, 2011). The vertical clearance of traffic signal heads is likewise set to be 4.5~5.0 *m*. It reveals that current maximum vertical angle between the ground and a driver's line of sight to a traffic signal is about 30°, as shown in Figure 2.

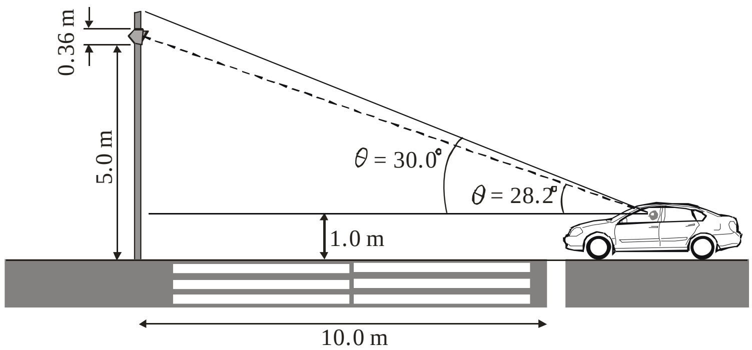


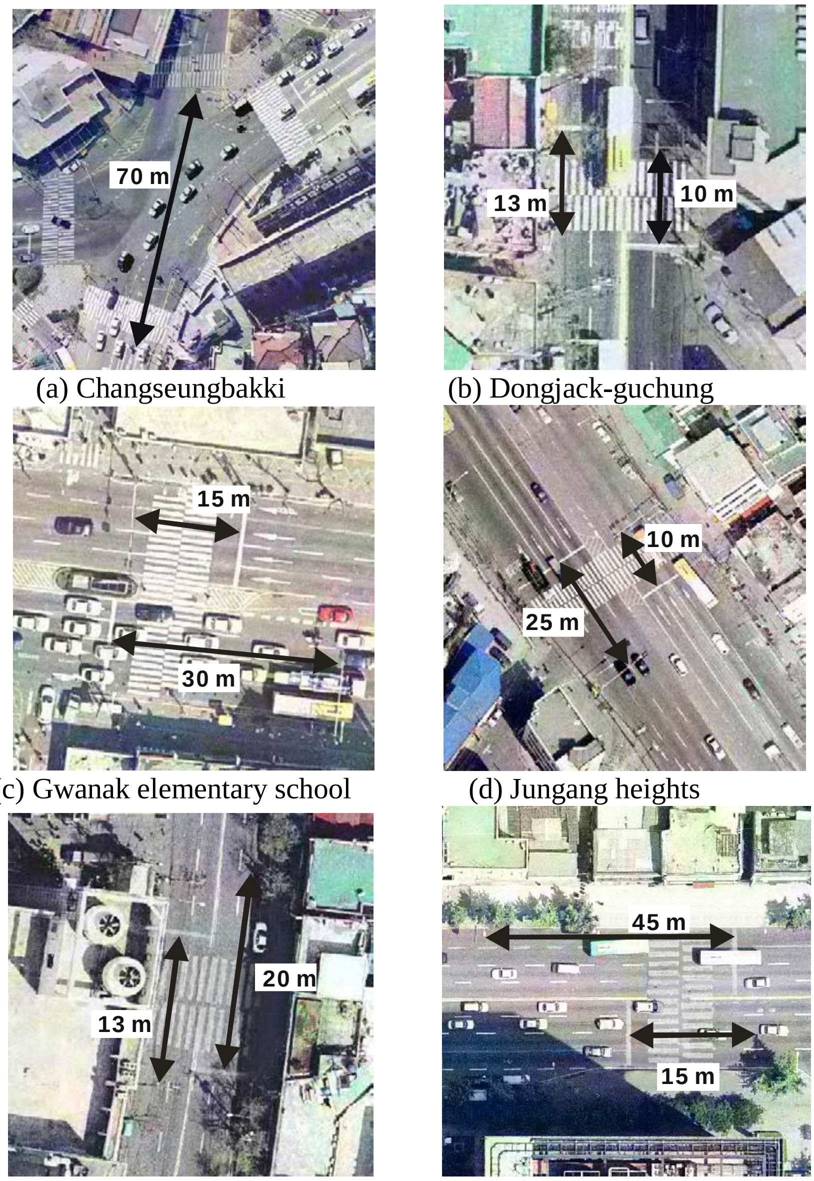
Figure 2. Vertical clearance of traffic signals

The Connecticut Department of Transportation (2001) preferred far side signal faces and addressed that placement of signal heads "should not cause motorists to look up rather than in front and to the side." In the Unites States, the Manual on Uniform Traffic Control Devices (MUTCD) regulates the horizontal distances from the stop line to traffic signals (FHWA, 2009), and prescribes a distance of 12 ~ 55 *m*. The traffic signal head is to be within 20° of the center of approach. The maximum permitted distance from the stop line varies depending on the size of the signal face and whether there is a nearer (supplemental) signal face; for 200 *mm* (8 *in*) signal faces, a supplemental near-side signal head should be placed when the horizontal distance from the stop line is longer than 35 *m*.

Most European countries locate traffic signals much closer to the stop line than the ones in the others. For example, in Germany, traffic signal lights should be placed no further than 6 *m* from a stop line (RTRA, 2003) on a road side at driver's eye height. National guidelines for installation location evidently vary widely.

3. DATA COLLECTION

Field data were collected at eleven stop-line points where traffic signals were installed at varying distances (see Figure 3). Those data collection points were selected by ensuring the low or moderate levels of pedestrian crossing demand to exclude the effect of the number of pedestrians on the test results. Those eleven sample points were from six sites: one was from a crosswalk at an intersection and the others were from isolated crossing areas in midblock. Figure 3 gives images of those.

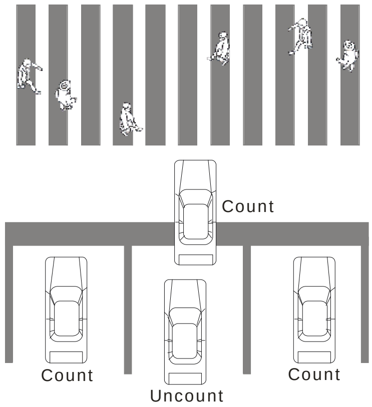


(a) Changseungbakki (b) Dongjack-guchung
(c) Gwanak elementary school (d) Jungang heights
(e) Iris (f) Saemoonan church

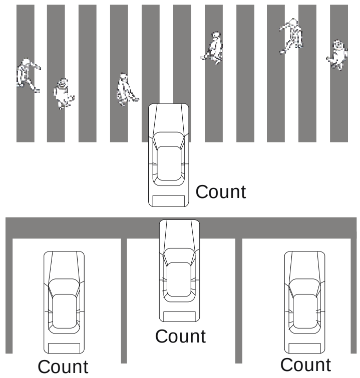
Figure 3. Data collection sites

Figure 3(a) shows an intersection whose traffic signal is located 70 *m* from the stop line. Figures 3(b), 3(c), 3(d), 3(e), and 3(f) show isolated pedestrian crossings where traffic signals are installed 10, 13, 15, 20, 25, 30, and 45 *m* from stop lines, respectively, as illustrated in the figures. Video streaming data was collected for 6 hours (9:00 a.m. ~ 12:00 p.m. and 13:00 p.m. ~ 4:00 p.m.) on a weekday at each location.

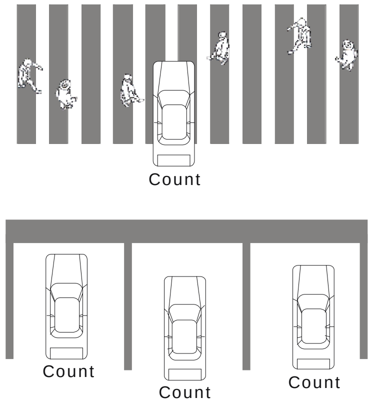
The data was reduced in the laboratory according to the rules developed in this study. This study dealt with a small number of vehicles selectively counted. Figure 4 gives the rules preset by the authors for determining the numbers of vehicles violating and observing the stop line. The counted data includes (1) the front most vehicles (those nearest the stop line) when the traffic signal changes to red and (2) the following vehicles whose decision was unaffected by their front vehicles.



(a) A stop line violation eliminating the possibility that the following vehicle makes a violation.



(b) A stop line violation followed by another violation



(c) A stop line violation followed by a vehicle properly stopped

Figure 4. Various cases of vehicle stops considered in the test

Figure 4(a) shows a case in which the leading vehicle violates a stop line in the middle lane and the following vehicle does not have the option to pass over the stop line. In this case, only the leading vehicle was counted in the data collection. The following vehicle was dropped from sampling. Figures 4(b) and 4(c) illustrate cases in which a following vehicle may have the option to violate the stop line. In those cases, both the leading and following vehicles were counted as samples. Statistical tests were applied to the data to quantify the relationship between the subject variables: the horizontal distances from stop lines to traffic signals and driver's stop line compliance.

4. ANALYSIS AND RESSULTS

A total of 36 hours video of streaming data (6 locations × 6 hours/location) were recorded at the field sites. Table 1 summarizes basic statistics of the data. A total of 2,891 vehicles were counted according to the data reduction procedure and extracted from 1,070 green-to-red traffic signal changing situations.

Table 1. Data summary

Distance from a stop line (m)	Number of Cycles observed	The number of vehicles			Compliance Rate		
		Private(auto)	Commercial	Total	Private(auto)	Commercial	Total
10 m	229	170	304	474	76.5	63.5	68.1
13 m	185	61	173	234	80.3	55.5	62.0
15 m	150	273	308	581	69.6	51.9	60.2
20 m	119	71	172	243	73.2	72.7	72.8
25 m	58	128	107	235	64.1	38.3	52.3
30 m	53	110	79	189	63.6	44.3	55.6
45 m	124	232	260	492	53.0	29.2	40.4
70 m	152	168	275	443	56.6	43.3	48.3
Total	1,070	1,213	1,678	2,891	67.1	49.8	57.5

Commercial vehicles include buses, taxis, and trucks.

Buses, taxis and trucks were categorized into the "commercial group." The data show that stop line compliance of commercial vehicles was lower than that of private auto vehicles: The compliance rate of commercial vehicles was 49.8%, and that of private auto was 67.1%. Commercial vehicle drivers are routinely experienced with the traffic, the geometric, and the control conditions at the selected points in this study; their driving patterns have been trained by their work-oriented experiences.

The average compliance rate in the eleven pedestrian crossing areas was 57.5% (stop line compliance of all types of vehicles were considered). Figure 5 plots the relationship between those average rates and the locations of traffic signals.

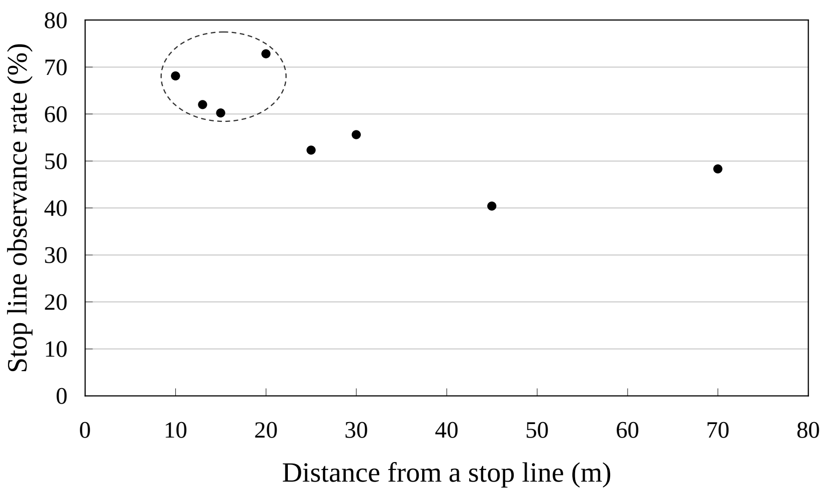


Figure 5. Plot of traffic signal locations and stop line compliance

Figure 5 shows the inverse relationship between the variables. The compliance rates decrease with increasing distance to traffic signals. The compliance rates are higher than 60% where traffic signals are within 20 *m* of the stop lines and below 60% when signals are more than 20 *m* from the stop line. Pedestrians count may affect stop line compliance, but it may stray out of a conservative condition.

4.1 Relationship between Stop Line Compliance and Traffic Signal Locations

The inverse trend between the variables was statistically quantified using Pearson's correlation coefficient analysis. The numbers of samples of the variables were large enough to consider them as following a normal distribution. The Pearson's correlation coefficient was found to be -0.725, and the P value was 0.021. The analysis thus suggested that driver's stop line compliance be inversely correlated with the horizontal distance from the stop line to the traffic light. However, the results do not prescribe an ideal location for traffic signals.

4.2 Determination of Traffic Signal Locations Promoting Stop Line Compliance

A non-parametric statistical test, Duncan's test, was conducted at a 95% significance level in order to capture differences among the samples. Depending on the distance to traffic signals, field data from the eleven pedestrian crossing areas were categorized into eight groups. Table 2 summarizes the test results. The results statistically suggested that the data in those groups be sampled from six different population sets overlapping each other.

Table 2. Duncan's multiple test design

Distance from a stop line (m)	The number of vehicles	α =0.05					
		1	2	3	4	5	6
45	492	0.4045					
70	443		0.4831				
25	235		0.5234	0.5234			
30	189		0.5556	0.5556	0.5556		
15	581			0.6024	0.6024	0.6024	
13	234				0.6197	0.6197	
10	474					0.6814	0.6814
20	243						0.7284

Table 2 shows the distribution of field data among the population sets. The data from the site where traffic signals were located at 45 *m* downstream from the stop line were statistically from Population 1. Those from the sites where traffic signals were at 70 *m*, 25 *m* and 30 *m* were from Population 2. The test results show that the samples from Populations 1-2 and Population 5-6 did not overlap and are thus statistically different. The results show that the stop line compliance rate is significantly greater where the traffic signal head is located within 20 *m* from a stop line.

5. AVAILABILITY OF IMPLEMENTATION

Drivers need traffic signal lights to be visible so that they can determine right-of-way status at signalized intersections. The study showed that driver's stop line compliance increases when the traffic signal head is located near the stop line, within a range suggested by KMUTCD. The study suggested that the ideal horizontal distance from a stop line to traffic signals be less than or equal to 20 *m*. The result satisfies the minimum permitted distance (10 *m*), official requirement of Korea.

The locations of traffic signals are in practice determined on a case by case and, in Korea, are usually at the far sides of intersections. When traffic signals are mounted on the sides of mast arm poles at the isolated pedestrian crossings, the proposed locations of traffic signals could be easily applied. At signalized intersections, however, the proposed locations may in practice be unavailable because of geometric limitations, such as the cross street width and the existence of a pedestrian crossing.

The study suggests that traffic signals on mast arm poles should be located at the near sides of intersections. When a pedestrian crossing is provided on an approach, the proposed distance from a stop line to traffic signals would be assured with the width of the pedestrian crossing and the distance to it from a stop line. In Korea, the width of the pedestrian crossing is 8 *m*, and the distance from a stop line to it is 2 to 5 *m*. Therefore, a total of 10 to 13 *m* of distance from a stop line to the traffic signal head can initially be secured. In addition, there is additional room beyond the pedestrian crossing. The corner radius of a signalized intersection begins at the downstream side of the pedestrian crossing and is regulated to be between 6 and 12 *m*. Since a traffic signal pole is placed in the corner area beyond the pedestrian crossing, the proposed distance (10 to 20 *m*) can be generally secured at signalized intersections if the pedestrian crossing is provided. Different discussions may apply in nations with different design standards.

5. CONCLUDING REMARK

The relationship between traffic signal locations and stop line compliance was analyzed through statistical tests of field data. The study showed that traffic signal locations and drivers' stop line compliance were statistically correlated at the 95% significance level. It was found that a shorter distance from a stop line to a traffic signal tends to yield greater compliance. It was found from the additional statistical test that traffic signals placed equal to or less than 20 *m* from a stop line were the most effective in promoting stop line compliance.

The minimum permitted horizontal distance from stop lines to traffic signals varies among different countries. It is 10 *m* in Korea. It is 12 *m* in the United States. It is 6 *m* in Germany. The minimum distance from the stop line to the traffic signal also depends on the use of supplemental traffic signals installed in the median at the height of drivers' eyes. For the countries and provinces where traffic signals are mostly on mast arm poles, the proposed range of locations for a traffic signal would promote stop line compliance as long as the local guidelines are satisfied. This proposed range would reduce strop line violations and enhance pedestrian safety. For further studies, a field test is recommended to compare actual before-and-after stop line compliance by relocating traffic signals at a small set of intersections and pedestrian crossings in field.

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