Effects of Driver Age and Dimensions of the Stop Sign on Braking Distance Performance at Stop-Controlled Intersections
Author(s): Sunanda Dissanayake
Source: *Journal of the Transportation Research Forum*, Vol. 43, No. 2 (Fall 2004), pp. 25-36
Published by: Transportation Research Forum
Stable URL: http://www.trforum.org/journal

Effects of Driver Age and Dimensions of the Stop Sign on Braking Distance Performance at Stop-Controlled Intersections

Guidelines for the use of traffic control devices at stop-controlled intersections in the United States are provided in the Manual on Uniform Traffic Control Devices (MUTCD). Based on that, different dimensions of stop signs could be employed, even within the same jurisdiction. The study summarized in this paper investigated the effects of driver age and dimensions of stop signs on braking distance performance at stop-controlled intersections, while paying particular attention to older drivers. Data were collected at several stop-controlled intersections in non-residential areas in Hillsborough County, Florida, where three different sizes of stop signs (30", 36", and 48") were in use. Three driver age groups were also considered: older drivers, middle-age drivers, and young drivers. Statistical testing was used to find out whether the braking distances were different among driver age groups and also among different sizes of stop signs. Based on the observational data, it was found that older drivers had significantly longer braking distances for the largest size of the stop sign. Braking distances were also significantly different among the driver groups for the two larger sizes of the stop signs, but not for the smallest. In other words, older drivers see the larger sign and apply the brakes sooner resulting in longer braking distances. As such, the study recommends considering the replacement of smaller sizes of stop signs with the largest size in non-residential areas with a high older-driver population to increase safety at stop-controlled intersections.

by Sunanda Dissanayake

INTRODUCTION

The Manual on Uniform Traffic Control Devices (MUTCD) provides the necessary guidelines for the installation and operation of stop signs in the United States (FHWA, 2000). According to MUTCD, the stop sign, which is defined as a regulatory sign, shall be an octagon with white legend and border on a red background and the standard size is specified as 30 x 30 inches. The manual recommends larger sizes of the sign for places where greater emphasis or visibility is required and also allows smaller sizes for low volume local streets and secondary streets with low approach volumes. Minimum and oversized dimensions are specified in the MUTCD as 24 x 24 inches and 48 x 48 inches, respectively. Based on these guidelines, different dimensions of stop signs are utilized at different locations within the same jurisdiction.

It is well-known that the elderly population of the United States is experiencing rapid growth. A high percentage of elderly use automobiles as their preferred mode of transportation. With the identification of the presence of increasingly higher percentages of older drivers among the driver population, there have been several studies conducted on various highway safety issues of older drivers. A previous study, which dealt with the highway safety needs of special population groups, identified 'size of traffic signs and lettering' as one of the most critical highway safety concerns for older drivers (Dissanayake et.al. 1998, 1999). Another study conducted in Illinois on highway operation problems of older drivers found that for 26.79% of older drivers, reading street signs in town has become more difficult as compared to 10 years ago (Benekohal et al, 1992). Age-related deficits in attention and vision might have affected this situation and developing recommendations for stop signs would be useful towards improving the highway safety performance of older drivers.

This study investigated the effects of the dimensions of stop signs on the braking-distance performance of different driver age groups. Three sizes of stop signs were considered and braking distances for each was measured in the field by visual observation of the brake lights for three age groups: older drivers, middle-aged drivers, and young drivers. The findings are summarized in this paper.

BACKGROUND

Safe stopping distance is one of the most important measures in many applications of traffic engineering. Safe stopping distance *(d)* or the distance that a vehicle travels from the point at which the situation is first perceived to the time deceleration is complete, is equal to the sum of reaction distance (d_r) and braking distance (d_b). The reaction distance is the distance traveled during the *perception reaction time* or the time it takes to initiate the physical response. Distance traveled while continuously applying the brakes until a complete stop is reached is known as braking distance. Values of d_r and d_b in feet are estimated by:

(1) $$d_r = 1.468\, S_i t$$

and

(2) $$d_b = \frac{S_i^2}{30(f \pm g)}$$

where,

S_i = initial speed of the vehicle in mph,
t = perception reaction time in seconds,
f = coefficient of forward friction between tires and roadway,
g = grade, expressed as decimal.

Therefore,

(3) $$d = 1.468\, S_i t + \frac{S_i^2}{30(f \pm g)}$$

Drivers reaching stop-controlled intersections must be able to detect the existence of the intersection and then detect, recognize, and respond to the stop sign.

Several researchers have found evidence concerning the difficulties that older drivers experience at stop-controlled intersections. According to one study, older drivers were more than twice as involved in right angle crashes at urban stop-controlled intersections than at urban signalized intersections (Stamatiadis, 1991). Another study analyzed intersection crashes in Minnesota and Illinois and studied driver age differences in collision types, pre-accident maneuvers, and contributing factors (Council and Zegeer, 1992). The findings were that, older drivers were over represented in right-angle collisions at stop-controlled intersections and were more often cited for failure to yield, disregarding the stop sign, and driver inattention. Another research study recommended five operational improvements to address the issue of driver expectancy at stop-controlled intersections (Agent, 1988). They were, installing additional advance warning signs, modifying warning signs to provide additional notice, adding stop bars to inform motorists of the proper location to stop, installing rumple strips, transverse stripes, or post delineators on the stop approach, and installing beacons.

Florida's warm tropical climate and recreational amenities attract many special populations, including senior citizens. As such, Florida offers an excellent environment to examine the roadway safety issues associated with older drivers. As given in Table 1, 13.1% of all crashes that occurred in Florida in 1996 involved stop signs. Number of drivers involved in crashes by different age

Table 1: Crashes by Type of Traffic Control (Florida, 1996)

Traffic Control	Number of Crashes	Frequency (%)
No Control	144,157	53.1
Traffic Signal	60,434	22.3
Stop Sign	35,479	13.1
Special Speed Zone	17,983	6.6
Yield Sign	1,478	0.5
Flashing Light	1,446	0.5
School Zone	962	0.4
All Others	9,520	3.5
Total	271,459	100

Source: Obtained by analyzing the Florida Traffic Crash Database for 1996.

Table 2: Driver Crash Involvement by Age at Signalized and Stop-Controlled Intersections (Florida, 1996)

Driver Age Category	Traffic Control			
	Traffic Signal		Stop Control	
	Number	Percentage (%)	Number	Percentage (%)
Less than 25 years	25,769	21.67	15,381	23.77
25 to 35 years	29,575	24.87	15,126	23.38
35 to 45 years	25,133	21.14	12,562	19.42
45 to 55 years	16,170	13.6	8,004	12.37
55 to 65 years	9,523	8.01	5,236	8.09
More than 65 years	12,745	10.72	8,390	12.97
All drivers	118,915	100	64,699	100

Source: Obtained by analyzing the Florida Traffic Crash Database for 1996.

categories for signalized intersections and stop-controlled intersections are given in Table 2. Of crash-involved drivers at signalized intersections 10.72% were older drivers, whereas the same percentage at stop-controlled intersections was 12.97. According to these numbers, obtained by analyzing the Florida Traffic Crash Database, if all driver age categories were assumed to be equally exposed to traffic signals and stop signs, older drivers are over-involved in crashes at stop-controlled intersections. As such, finding ways of improving safety at stop-controlled intersections is important.

Accordingly, this study concentrated on the performance evaluation of stop signs of different dimensions, as indicated by braking distance, so that recommendations could be made for improved operations at the stop-controlled intersections. Particular attention was paid to older drivers to find out if decreased mental and physical capabilities could be addressed through the introduction of larger signs at stop-controlled intersections.

DATA COLLECTION

Study Sites

Stop-controlled intersections where three different sizes of stop signs were employed within Hillsborough County, Florida, were selected for the field data collection of this study. The sizes were 48 x 48 in., 36 x 36 in., and 30 x 30 in., and an effort was made to utilize locations of similar characteristics except the dimensions of the stop sign. Among the available sites, selection of sites for field data collection was done based on land use type, geometry, and visibility requirements. To avoid the drivers' complete familiarity with the intersections under investigation, stop-controlled intersections in residential areas were avoided and all the sites were either in business or rural areas. As for geometry, intersections with one lane in each direction were selected without any exclusive left-turning or right-turning lanes. For each size of the stop sign, at least three sites were selected for field data collection with proper visibility and sight distance requirements and similar retro-reflectivity of signs. Retro-reflectivity is the capability to return the light to its source.

Field Data Collection Method

Two basic parameters were collected for each vehicle approaching the stop-controlled intersection: braking distance, and age group of the driver. Markings were put on the edge of the road indicating the total distance from the stop line. One observer at a distance from the stop line recorded the distance (from the stop line) at which the driver started applying the brake through the visual observation of the brake lights. The same observer also recorded the color and type (ie. black car, red van) of the vehicle using a coding system, and the queue position of the vehicle when it reached the stop sign, if there was a queue. A specifically designed data collection sheet was used for this purpose. Another observer who synchronized with the first observer recorded the age group of the driver through visual observation. Although this method is somewhat subjective and depends on the observer's opinion (after vigorous training), it is capable of collecting a large amount of data within a short period of time. An alternative approach that could have been used is using a controlled sample of drivers whose ages were known. But in general, such studies yield very small sample sizes because of the high cost associated with conducting fully controlled experiments, and hence they have different types of errors.

To be compatible with many other research studies, older drivers were considered as those who are older than 65, young drivers are those aged less than 25, and the rest are middle age drivers. However, because the age group judgment was based on visual observation, if the drivers clearly appeared to be old, they were considered as older drivers and if they clearly looked young, they were considered as young drivers, to be conservative. The second observer stayed at the stop sign so that the drivers could be clearly seen when the vehicle stopped at the stop line. This observer while synchronizing with the first observer recorded the age group of the driver. The same observer also recorded the color and type of the vehicle so that the data parameters from two observers could be matched and verified with each other. Every effort was made to position the observers strategically so that their existence would not affect the behavior of drivers. All the data were collected during weekdays under daylight and clear weather conditions. Site characteristics and number of observations made for each category are given in Table 3.

Data Analysis

Data collected at the sites were later processed in the lab. For each vehicle, distance from the stop line at which the brakes are applied (referred as braking distance here), age group of the driver, and queue position were recorded together with the two basic (static) characteristics at the approach, speed limit and the size of the stop sign. It should be noted that the performance evaluation of the size of the sign in this study was based only on braking distance (not the stopping distance), since the distance traveled after the brakes were engaged was measured in the field. As given in Equation 2, the braking distance of a vehicle is a direct function of the initial speed

Table 3: Sample Characteristics

(a) Site Characteristics

Site / Intersection	Approach	Speed Limit	Size of the Stop Sign
Williams at Harney	Harney	40 mph	36″
	Williams	40 mph	36″
County Road 579 at Skewlee	CR 579	50 mph	48″
	Skewlee	40 mph	36″
Robertson at Moon	Robertson	30 mph	48″
	Moon	25 mph	48″
Williams at US 301	Williams	30 mph	30″
Livingston at Vandervort	Vandervort	40 mph	30″
Fowler at 58th Street	58th	35 mph	30″
Skipper at 42nd Street	42nd	30 mph	36″
	Skipper	25 mph	36″
Japtucker at Trapnell	Japtucker	45 mph	48″

(b) Number of Valid Observations by Category*

Size of the Stop Sign	Driver Age Group			
	Older Drivers	Middle Age Drivers	Young Drivers	Total
48″	879	2,066	1,112	4,057
36″	520	1,487	472	2,479
30″	380	1,655	570	2,605

*First vehicles at the stop line only.

(S_i). Initial vehicle speed in this study was assumed to be equal to the posted speed limit of the road because of the difficulties in measuring individual speeds of vehicles in the field.[1] If the posted speed limit was higher, the braking distance would be longer irrespective of the size of the stop sign. To evaluate the real effect of the size of the sign, it was necessary to compare the braking distances under uniform posted speed limit situations. However, it was not possible to find all the field data collection sites with the same posted speed because of the other site selection considerations mentioned earlier. Thus, the braking distances under all the other speed limits were adjusted to be equivalent to the braking distance under the speed limit of 40 mph, which was the most common posted speed limit among all the sites. This was done by applying an adjustment factor to the braking distances under speed limits other than 40 mph, which was developed as shown in Table 4, by taking the minimum required braking distances into account. This adjustment factor was applied for each braking distance and equivalent braking distances under the base speed limit were used in conducting statistical tests. As an example, minimum braking distances for 25 mph and 40 mph speed limits estimated using Equation 2 are 55 feet and 167 feet respectively. The difference between these two values, 112 feet,

Table 4: Adjustment Factors for Braking Distances Based on Speed Limit

Speed Limit	Coefficient of Friction* *(f)*	Required Minimum Braking Distance	Adjustment Factor for the Deceleration Distance
25 mph (40 km/h)	0.38	55 feet	+112 feet
30 mph (48 km/h)	0.36	83 feet	+84 feet
35 mph (56 km/h)	0.34	120 feet	+ 47 feet
40 mph (64 km/h)	0.32	167 feet	0 (base)
45 mph (72 km/h)	0.31	218 feet	- 51 feet
50 mph (80 km/h)	0.30	278 feet	- 111 feet

*Based on *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials, 1994.

was added to all the braking distances for the 25 mph speed limit. In other words, the adjustment factor for braking distances measured under the 25 mph speed limit was +112 feet. This procedure was repeated for other speed limits and adjustment factors were estimated.

Because individual drivers of vehicles should have complete random behavior without the influence of the vehicles in front of them, only the vehicles that became the first vehicle at the stop line were considered in the analysis. Vehicles that had queue position other than first were discarded from the analysis. Data in Table 3 (b) refer to valid observations, meaning that they all were first vehicles at the stop line. Additionally, as the size of the vehicle may have an impact on the deceleration distance, heavy vehicles such as buses and large trucks were also not considered in the analysis process. Accordingly, only passenger cars, minivans, sports utility vehicles, and small pick-up trucks were considered in the analysis.

RESEARCH FINDINGS

Mean and 85th Percentile Braking Distances

The logit analysis, which models the cumulative probability distributions, was used to fit the distributions of braking distances for each case. The functional form of the logit model is defined by the following equation:

$$p=\frac{e^{f(x)}}{1+e^{f(x)}} \quad (4)$$

where,

p = cumulative probability of having a braking distance smaller than a certain value,

x = braking distance, and

$f(x)$ = linear function of x.

The linear function has the following form:

$$f(x)=a(x-b) \quad (5)$$

where, a and b are the parameters to be estimated.

By combining Equations 4 and 5,

$$\ln(p/1-p)=a(x-b) \quad (6)$$

Using this model format, linear regression was estimated using the observed data and the parameters a and b were estimated for each category of driver group and size of the stop sign. The value of parameter b in this case was the average braking distance obtained through the curve fitting. Since the 85th percentile value is often of interest in many traffic engineering applications, 85th percentile braking distance was estimated by sub-stituting p = 0.85 in Equation 6 with a and b values that were estimated using actual data. The summary of the average and 85th percentile braking distances is given in Table 5.

Chi-square goodness-of-fit test was performed in each case to find out whether

Table 5: Average and 85th Percentile Braking Distances Obtained Through Logit Model

Category	Braking Distance (feet)	
	Average*	85th Percentile
Older Drivers / 48″ stop sign	292.9	352.6
Middle-Age Drivers / 48″ stop sign	266.0	343.4
Young Drivers / 48″stop sign	255.5	313.6
Older Drivers / 36″ stop sign	283.4	338.8
Middle-Age Drivers / 36″stop sign	265.0	336.2
Young Drivers / 36″ stop sign	256.5	305.4
Older Drivers / 30″stop sign	274.5	331.9
Middle-Age Drivers / 30″stop sign	270.3	326.0
Young Drivers / 30″stop sign	254.2	303.1

*Equal to b in equation 5.

Table 6: Chi-Square Goodness-of-Fit Test Results to Determine if the Braking Distances are Normally Distributed

Size Of the Stop Sign	Driver Age Group	Chi-Square Statistic	Data Normally Distributed (Yes/No)	
			α *= 0.05 (Critical Chi-Square =7.81)	α *= 0.01 (Critical Chi-Square = 11.34)
48″	Old	10.60	No	Yes
	Middle	11.35	No	Yes
	Young	12.17	No	No
36″	Old	9.16	No	Yes
	Middle	11.33	No	Yes
	Young	9.77	No	Yes
30″	Old	7.74	Yes	Yes
	Middle	11.4	No	Yes
	Young	9.75	No	Yes

*Level of Significance

the observed braking distance was normally distributed. It was found that the assumed normal distribution and the data were not statistically different in most of the cases under 0.01 level of significance. A summary of the goodness-of-fit test results is given in Table 6. Because the individual vehicles that became the first vehicle at the stop line were considered in the analysis, they were treated as completely random virtually homogeneous experimental units. As such, the analysis was considered to be a completely randomized design, and one-way analysis of variance (ANOVA) technique was used to test the null hypothesis that the braking distances were different among the three driver groups for each size of the stop sign. The null hypothesis H_0: $(d_b)_{OD} = (d_b)_{MD} = (d_b)_{YD}$, was tested against the alternative hypothesis H_a that they are not equal, where $(d_b)_{OD}$, $(d_b)_{MD}$, and $(d_b)_{YD}$ are the braking distances for the older, middle-age, and young driver groups respectively. The results of the ANOVA tests for the three different sizes of stop signs for 0.05 level of significance are given in Table 7 and the findings are discussed.

Differences Among Driver Groups for 48 in. Size Stop Signs

The estimated F statistic was 46.04, which is much larger than the critical F value at 5% significance level ($F_{critical}$=3.00). So the null hypothesis of equal braking distances for all driver groups was rejected for 48 in. stop signs. Also the p-value was very small indicating that the differences between braking distances of the three driver groups were highly significant for the largest size of the stop sign.

Differences Among Driver Groups for 36 in. Size Stop Signs

The estimated F statistic was 13.24, which is larger than the critical F value ($F_{critical}$=3.00). The null hypothesis of equal braking distances for the three driver age groups was therefore rejected for 36 in. stop signs. The p-value was also very small but the differences among braking distances for different driver age groups were not as significant as in the case of the 48 in. stop sign.

Table 7: ANOVA Test Results for Different Sizes of Stop Signs

ANOVA Results for 48" Size Stop Sign						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	27154.70	2	13577.35	46.04	0.00	3.00
Within Groups	1195665.97	4054	294.93			
Total	1222820.68	4056				
ANOVA Results for 36" Size Stop Sign						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	10485.07	2	5242.54	13.24	0.00	3.00
Within Groups	980157.52	2476	395.86			
Total	990642.60	2478				
ANOVA Results for 30" Size Stop Sign						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	1624.52	2	812.26	2.53	0.08	3.00
Within Groups	836827.22	2602	321.61			
Total	838451.74	2604				

SS = Sum of squares, *df* = Degrees of Freedom, *MS* = Mean sum of squares

Differences Among Driver Groups for 30 in. Size Stop Signs

The estimated F statistic was 2.53, which is smaller than the critical F value ($F_{critical}$=3.00). Thus, the differences between braking distances for the three driver groups were not significant at the 5% level. The p-value for the ANOVA test was 0.08, indicating that the differences were however significant at the 8% level.

In general, as the size of the stop sign gets larger the differences between the observed braking distances for the different driver groups become more significant. The second part of the analysis used the ANOVA technique to test whether the braking distances of the three sizes of stop signs were different for each driver group. Null hypothesis, H_0: $(d_b)_{48} = (d_b)_{36} = (d_b)_{30}$ was tested against the alternative hypothesis that they were not equal, where $(d_b)_{48}$, $(d_b)_{36,}$ and $(d_b)_{30}$ were the braking distances for each size of the stop sign for a particular driver group. The results of the ANOVA tests for the three driver groups are given in Table 8 and the findings are discussed.

Differences Among Three Stop Sign Sizes for Older Drivers

The F statistic, 7.08 was larger than the critical value of 3.00 ($F_{critical}$= 3.00) and also the p-value was almost zero. Thus the null hypothesis of equal braking distances for three sizes of stop signs was rejected, indicating that the differences between braking distances for the three sizes of stop signs were significant at the 5% level of significance for the older driver group.

Differences Among Three Stop Sign Sizes for Middle-Age Drivers

As for middle-age drivers, the F statistic (1.16) was smaller than the $F_{critical}$ value at the 5% level of significance. Therefore, the differences between braking distances for different sizes of stop signs were not significant for the middle-age driver group. The p-value for this test was only 0.31.

Table 8: ANOVA Test Results for Different Driver Groups

ANOVA Results for Older Drivers						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	5004.09	2	2502.04	7.08	0.00	3.00
Within Groups	627866.31	1777	353.33			
Total	632870.39	1779				
ANOVA Results for Middle-Age Drivers						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	743.10	2	371.55	1.16	0.31	3.00
Within Groups	1663739.73	5205	319.64			
Total	1664482.84	5207				
ANOVA Results for Young Drivers						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between Groups	64.31	2	32.16	0.10	0.91	3.00
Within Groups	721044.67	2150	335.37			
Total	721108.99	2152				

SS = Sum of squares, *df* = Degrees of Freedom, *MS* = Mean sum of squares

Differences Among Three Stop Sign Sizes for Young Drivers

The F statistic for the ANOVA test for young drivers is only 0.01, which is much smaller than the critical value at the 5% significance level ($F_{critical}$=3.0). The p-value was 0.91. So the differences between braking distances for the different sizes of stop signs were highly insignificant for the young driver group.

Discussion of Results

This study indicated that as the size of the stop sign increased, the differences between field-observed braking distances for the driver groups become more significant. For the largest size of the stop sign, older drivers had the longest braking distances and the differences between the driver groups were highly significant. However, the size of the sign had very little or no effect on the driving performance of young drivers and middle-age drivers, perhaps because they were able to see the sign irrespective of the dimensions. A summary of the ANOVA test results is given in Table 9. These findings have certain implications for the highway safety of the driver groups and also on the performance evaluation of the stop signs. Due to the difficulties in designing a proper field experiment, perception reaction times of the drivers were not taken into consideration in this research. However, a study by Lerner et al. through an on-road experiment concluded that older driver perception reaction was not longer than young drivers' (Lerner et al, 1995). Some other researchers have found that the perception reaction time of older drivers to be significantly longer than that of the younger drivers (Naylor and Graham, 1996, Fambro et al, 1998). If older drivers have longer perception reaction times, such a situation may make the safe stopping distance to be even more significantly different than the braking distance for the three sizes of stop signs and also for the three driver age groups. Thus, the implications of the findings would still be valid.

Table 9: Summary of the ANOVA Test Results for Braking Distances

Scenario	Differences Significant (Yes/No)	
	α *= 0.05	α *= 0.1
For 48″ differences between driver groups	Yes	Yes
For 36″ differences between driver groups	Yes	Yes
For 30″ differences between driver groups	No	Yes
For older drivers differences between sizes	Yes	Yes
For middle-age drivers differences between sizes	No	No
For young drivers differences between sizes	No	No

* Level of Significance

CONCLUSIONS

This research investigated the effects of driver age and dimensions of stop signs on braking distance at stop-controlled intersections. From the three driver age groups treated in this study, older drivers showed increasingly longer braking distances as the dimensions of the stop sign increased. The differences were significant at the 5% level of significance. Longer braking distance (distance from the stop line at which brakes were applied) could lead to higher safety performance at stop-controlled intersections. Also for the largest size of the stop sign, the braking distances were significantly different among the driver groups. These findings may have certain implications for improving highway safety at stop-controlled intersections. This could be particularly important at locations where a high concentration of older drivers is evident. As such, the study recommends considering the replacement of smaller stop signs with the largest size in non-residential areas with high older driver population. This can be expected to increase safety at stop-controlled intersections, through the increase of driver expectation. Particularly, older drivers will see the larger sign in advance and be able to apply the brakes sooner, resulting in longer braking distances.

References

Agent, K. R. "Traffic Control Accidents at Rural High-Speed Intersections." *Transportation Research Record.* No. 1160. Transportation Research Board, National Research Council, Washington D. C., 1988.

American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* 1994.

Benekohal, R. F., P. Resende, E. Shim, R. M. Michaels, and B. Weeks. *Highway Operations Problems of Elderly Drivers in Illinois.* Final Report, Illinois Universities Transportation Research Consortium, Chicago, Illinois, December 1992.

Council, F. M. and C. V. Zegeer. *Accident Analysis of Older Drivers and Pedestrians at Intersections-Task B Working Paper.* Publication No. DTFH61-91-C-00033, Federal Highway Administration, U. S. Department of Transportation, Washington D. C., 1992.

Dissanayake, S., J. J. Lu, H. Tan, X. Chu, and P. Turner. *Evaluation of Highway Safety Needs of Special Population Groups – Phase I.* Final Report, Department of Civil and Environmental Engineering and Center for Urban Transportation Research, University of South Florida, Tampa, Florida, October 1998.

Dissanayake, S., J. J. Lu, X. Chu, and P. Turner. *Use of Multi-Criteria Decision Making to Identify the Critical Highway Safety Needs of Special Population Groups.* TRB Preprint No.99-0864 (CD-ROM), 78th Annual Meeting of TRB, January 1999.

Fambro, D. B., R. J. Koppa, D. L. Pitcha, and K. Fitzpatrick. *Driver Perception-Brake Response in Stopping Sight Distance Situations.* TRB Preprint No.98-1410 (CD-ROM), 77th Annual Meeting of TRB, January 1998.

Federal Highway Administration, United States Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways,* 2000.

Lerner, N. D., R. W. Huey, H. W. McGee, and A. Sullivan. *Older Driver Perception Reaction Time for Intersection Sight Distance and Object Detection. Volume I.* Final Report. No. FHWA-RD-93-168, Federal Highway Administration, United States Department of Transportation, Washington D. C., 1995.

Naylor, D. W. and J. R. Graham. *Intersection Design Decision/Reaction Time for Older Drivers*. TRB Preprint No.97-0181, 75th Annual Meeting of TRB, January 1996.

Stamatiadis, N., W. C. Taylor, and F. X. McKelvey. "Elderly Drivers and Intersection Accidents." *Transportation Quarterly* 45(3), (1991): 377-391.

Sunanda Dissanayake *is an Assistant Professor attached to the Department of Civil Engineering at the Kansas State University. She received her Ph.D. from the University of South Florida and worked there as a Research Assistant Professor before joining K-State in Fall 2002. Her research interests include various aspects of traffic engineering, highway safety, and access management.*