DRIVER AGE DIFFERENCES IN DAY AND NIGHT GAP ACCEPTANCE CAPABILITIES

Sunanda DISSANAYAKE, Ph.D.
Research Assistant Professor
Department of Civil and Environmental Engineering
University of South Florida
Florida, USA

Jian John LU, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
University of South Florida
Florida, USA
and
Chair Professor, Transportation College
Southeast University
Nanjing, China

Ping YI, Ph.D.
Assistant Professor
Department of Civil Engineering
University of Akron
Ohio, USA

(Received November 30, 2001)

Performance of Two-way Stop-controlled (TWSC) intersections is greatly affected by the gap acceptance capabilities of drivers. However, there have been no detailed studies conducted regarding driver age differences in gap acceptance capabilities under different light conditions. Therefore, this study was conducted to fill the lack of information in that area, by considering three driver age groups (old, middle, and young), two maneuvers (left-turn, and through), and two light conditions (daytime, and nighttime). Field observations were made at several TWSC intersections and data were collected at these sites regarding available and accepted gaps on the major street and age group of minor street drivers, both during daytime and nighttime. Statistical analysis conducted in this study with a 5% level of significance revealed that there were significant differences in gap acceptance capabilities among the three driver age groups under both light conditions. Only older drivers indicated statistically different gap acceptance capabilities depending on the light condition, where they illustrated longer critical gap values during nighttime.

Key Words: Older drivers, Highway safety, Gap acceptance, Critical gap, Nighttime visibility, Driver age groups

1. INTRODUCTION

Two-way Stop-controlled (TWSC) intersections are one of the important components of the highway system where an important interaction between two traffic streams takes place. In general, TWSC intersections provide a high level of discretion to minor street drivers on how and when they should respond to the conflicting traffic streams. Accordingly, safety and operations of TWSC intersections rely heavily on driver behavior. Drivers of the vehicles arriving on the minor street approach at a TWSC intersection may either enter or cross the major street by accepting a gap in the major street traffic stream or reject it as being not sufficient and wait for a sufficiently large gap. A minor street driver can make many rejections of gaps but may make only one decision about gap acceptance. A gap is defined as the time interval between the arrivals of two successive vehicles on the major street traffic stream. Gaps are usually measured by considering either front or rear bumper of vehicles passing a certain reference line. Whenever a gap in the major flow is equal to or greater than a value that a driver on minor road believes large enough for him/her to enter or cross the major road, the driver accepts this gap. This gap is an acceptable gap for that particular driver. Otherwise, the driver rejects the gap and waits for a larger gap. It should be noted that the drivers of the vehicles on the major street always have the priority over minor street drivers and therefore not impeded by the minor street flow. The gap acceptance behavior of drivers at TWSC intersections is most commonly characterized and identified by the parameter known as the critical gap. A critical gap is defined in the Highway Capacity Manual (HCM) as the minimum time interval in the major street traffic stream that allows intersection entry to one minor road vehicle[1]. According to the manual, there exists a relationship such that the driver's largest rejected gap must be smaller than the critical gap and the driver's accepted gap must be greater than or equal to the critical gap. In a real traffic situation, this might not always be true because drivers may not always act consistently and may occasionally reject gaps that are of greater length than the accepted gap. In general traffic-engineering practice, the critical gap is defined as the median gap size that would be accepted by drivers in a given situation[2].

The elderly population in the United States is growing rapidly and most of them prefer to use the automobile as their primary mode of transportation, thereby increasing the percentage of older drivers among the overall driving population. Due to decreased mental and physical capabilities however, older drivers have been identified as having critical highway safety needs[3]. Two of the most critical highway safety issues thus identified as critically important for older drivers were gap acceptance capabilities and nighttime visibility[4]. However, there have been no detailed studies conducted regarding the nighttime gap acceptance capabilities of older drivers, or any other driver age group. This research study was therefore conducted to study the gap acceptance capabilities of different driver age groups under daytime and nighttime conditions. It was statistically tested whether the gap acceptance capabilities among the three driver age groups were different under daytime and nighttime conditions whether there were differences between left-turn and through movement gap acceptance capabilities for each driver age group, and also whether the daytime and nighttime gap acceptance capabilities were different. The study found some interesting differences in gap acceptance capabilities between driver age groups and at different light conditions.

2. LITERATURE REVIEW

While there have been a considerable number of studies conducted in relation to driver gap acceptance performances with some studies related to driver age differences, almost all of those studies are confined to daytime conditions. One previous research study conducted to evaluate driver age differences in left-turn gap judgements demonstrated reliable age differences in both target recognition distance and judged minimum safe gap distance as well as age-speed interaction for gap judgement[5]. This study tested a total of 79 young (mean age, 33.3 years), young-old (mean age, 65.1 years), and old-old (mean age, 79.4 years) subjects in a controlled field study and in laboratory studies by using varying simulation techniques. However, the drivers of this study were not necessarily required to come to a complete stop before making the left turn like in the case of TWSC intersections. As such, these findings do not directly correspond to the study described in this paper. Another study examined the definition of the critical gap to better reflect the actual driver behavior and estimate the capacity of TWSC intersections, and concluded that the distribution of major street traffic could have a substantial effect on the capacity of the minor street left-turn movement[6]. The study mainly focused on investigating the delay effects on driver gap acceptance characteristics at TWSC intersections. On the basis of a limited amount of field data, the critical gap was found to be significantly affected by the amount of front-of-queue delay incurred by individual drivers. However, this study did not differentiate between different driver age groups. Yi studied elderly driver gap acceptance on rural highways, where comparisons were made between elderly and other drivers[7]. Data were collected at four TWSC intersections with a single lane at each approach. In this study, results from statistical testing indicated that the critical gap, average rate of usable gaps rejected, and the impeded speed on the main road were all significantly different at the 90% level of confidence for the two driver age groups. Lu and Dai analyzed the gap acceptance capabilities at a stop sign controlled intersection for three different driver age groups and found significant differences among the groups at the 95% level for both through and left-turn movements[8]. Capacity reductions have also been observed at stop-controlled intersections due to the presence of older drivers[9]. Many other researchers have also studied the general characteristics of the performance of TWSC intersections as well. One such study examined the relative impacts of various gap acceptance attributes on the capacity of unsignalized intersection approaches using a traffic simulation model[10]. Capacity and delay characteristics at TWSC intersections were also investigated using traffic flow, delay, and geometric data collected at 9 sites[11]. The size of the accepted gap was found to be affected by the length of the time that a vehicle has been delayed, the flow on the conflicting approaches, and the directional movement of the subject vehicle. All of the studies in this section considered daytime conditions only whereas very few studies have focused on differences in gap acceptance based on driver age.

Although various characteristics and performances of different driver age groups, at TWSC intersections have been studied, there was no comprehensive effort to investigate whether there are differences in gap acceptance capabilities during different light conditions. However, there is evidence that older drivers are more likely to be involved in crashes both under poor light conditions and also at stop-controlled intersections[12-14]. This study therefore attempted to further investigate this problem by studying gap acceptance capabilities of different driver age groups under daytime and nighttime conditions. However, a lack of detailed studies in the areas considered in this study makes it difficult to make a comparative analysis with previous studies.

3. METHODOLOGY

In light of the criticisms that the HCM has received regarding its TWSC intersection analysis procedure and associated definitions, this study utilized a more meaningful and better definition for critical gap as suggested and used by many other researchers[6-9]. Thus, the critical gap used in this study is a gap value that 50% of drivers would accept. In other words, probability of gap acceptance for the critical gap would be 0.5. The logit model was used to fit the distributions of gap acceptance, which is defined by the following equation:

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

where, p = probability of accepting a gap smaller than t,
t = time length of a gap in seconds, and
$f(t)$ = linear function related to gap t.

The linear function has the form:

$$f(t) = a\,(t - b) \quad (2)$$

Where, a and b are constants to be estimated. By combining equations (1) and (2), the format of the equation is:

$$Ln\left(\frac{p}{1-p}\right) = a\,(t - b) \quad (3)$$

After a and b are estimated by linear regression analysis based on data collected in the field, the probability of accepting a gap can be fitted by using the logit model. The gap acceptance curves can then be plotted based on the accepted gaps and corresponding probabilities. According to the critical gap definition used in this study, the probability p would be 0.5 when t is equal to the critical gap. By substituting $p = 0.5$ into equation (3), it can be inferred that $t = b$. This result indicates that the value of b is the critical gap.

4. FIELD DATA COLLECTION

To study the differences in gap acceptance capabilities of different driver age groups under daytime and nighttime conditions, it was necessary to obtain field data on gap acceptance together with driver age estimation. The expected outcomes from the field data collection in daytime vs. nighttime were as follows:

1. The number of available gaps on the major road,
2. The percentage of drivers in different age groups accepting a certain gap, and
3. The percentage of drivers in different age groups rejecting a certain gap.

In order to achieve the above outcomes, several pieces of information were collected in the field using a computer program, which was particularly developed for that purpose. This data collection software was developed using Microsoft Access 97 and is capable of collecting the required data related to the gap acceptance behavior. The main functions of the software were to record the available gaps on the major road and the accepting/rejecting the response of the minor road drivers to those available gaps for left-turn or through movements. Right turning was observed to have different characteristics than the other two types of movement. A stable gap selection pattern cannot be established for right turning vehicles. Thus, right turning was not considered in this study. The age of minor-street drivers were recorded based on three groups, older drivers, young drivers, and middle age drivers, which was based on visual observation and personal judgement of the observer. For the purpose of this study, older drivers were considered as those who are older than 65 years and, young drivers as younger than 25 years. The remainder were middle age drivers. Although it is possible to conduct a fully controlled experiment with subjects of known age, the experiment is expensive, and the results from the study may be biased if the drivers realize they are being observed, or simply know that they are part of a driving study. As an alternative, a simple verification process, which has been used by other researchers as well, was conducted[15]. The observers recorded the age group of a random sample of twenty drivers based on their perception, and each driver's actual age was subsequently verified. The only discrepancy was in the case of a young driver who was misinterpreted as a middle age driver. Based on these findings and also by considering the possible shortcomings of conducting a fully controlled experiment with subjects of known age, it was assumed that the accuracy of age group assignment is sufficiently acceptable for the purpose of this study.

When the vehicles arrived from the minor street, the age group of the driver was recorded using a laptop computer. When the drivers arrived at the STOP sign, if the driver belonged to the older driver group '1' was pressed. Similarly, '2' or '3' were pressed for middle age or young driver groups, respectively. For nighttime observations, a special night vision device (Night Owl Cyclops Compact Monocular – NOCC3) was used to see the drivers in order to decide the age group of the driver. Upon arrival of the minor street vehicle at the STOP sign, the observer pressed "P" for each major street vehicle that crossed the reference line on the major street. Location of the selected reference line with respect to other features is indicated in Figure 1. Each time "P" is pressed, the computer recorded the clock time that was used to obtain the available gaps. When the minor road vehicle waiting at the stop sign finally accepted a gap, the observer waited until the next following vehicle in the major stream passed the reference line, and pressed "L" if the minor street vehicle turned left or "T" if it made a through movement. Pressing either "L" or "T" also recorded the time using the system clock available in the computer. The time difference between the last "P" and either "L" or "T" gave the gap that had been accepted by that particular minor street driver. The time difference between two consequent "P"s gave an available gap, which had been rejected by that particular minor street driver.

The field data collection for gap acceptance at TWSC intersections was a time consuming task mainly due to the fact that data were required by different age groups and also during nighttime. In particular, obtaining nighttime data for older drivers was extremely time consuming. Even though the data were collected in Florida with high percentages of older drivers among the driving population, the number was low compared to the other two age groups. In addition, older drivers tend to reduce the amount of driving done during nighttime, making it extremely difficult to get a large sample size within a reasonable period of field data collection.

5. SITE SELECTION

Various factors were considered in the site selection process for field data collection. First, the selected TWSC intersection should have a relatively large non-platoon type of volume on the major road, so as to provide various sizes of gaps. Second, the volume on the minor road should not be too small in order to be able to record as many observations as possible during a certain period of time. Of particular concern was the number of older drivers present in the traffic stream on the minor street during nighttime. By taking all these factors into account, three TWSC intersections were selected for field data collection, where each major road had one lane in each direction with no median. A typical intersection indicating different conflicting maneuvers from the minor street approach and the reference line is given in Figure 1. As there was no median or storage length available, the minor street vehicles were required to make the left-turn or through maneuver in one step. Each minor street approach also had one lane in each direction with no exclusive left turning or right turning lanes. Daytime data were collected during various time periods during the day, and nighttime data were collected from around 7 PM to 10 PM, where the starting time depended on the fall of darkness. The intersections that yielded comparatively higher percentage of older drivers while satisfying other requirements were, US 301 and 9th Avenue in Zephyrhills, Himes Avenue and Idlewild Avenue in Tampa, and Lois Avenue and Watrous Avenue in Tampa. These intersections are located in the Hillsborough County in Florida. All the three sites had very similar characteristics in terms of geometry, roadside environment, traffic volume, vehicle arrival distribution, and speed. Due to those similarities, the differences in gap acceptance capabilities among these sites were not studied in this study.

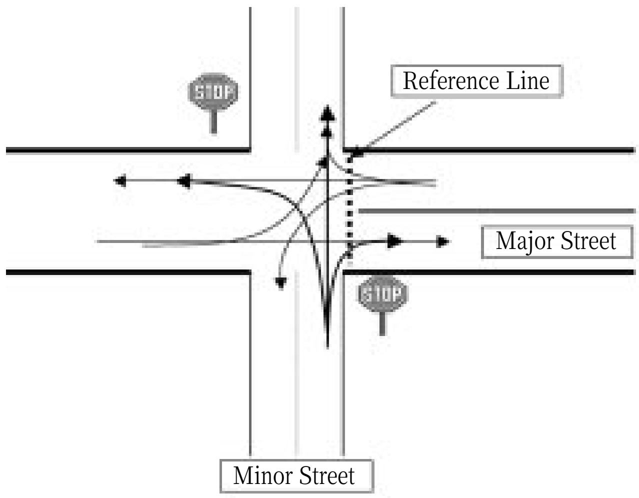

Fig. 1 A typical intersection indicating different conflicting maneuvers from the minor street

6. RESEARCH FINDINGS

6.1 General

Data collected under different conditions were then analyzed using the logit model as explained in the methodology section and the results are presented here. The statistics about the total number of daytime and nighttime accepted gaps for which observations were made are given in Table 1.

Table 1 Summary of the number of observations

Driver Age Group	Movement	Number of Observations	
		Daytime	Nighttime
Older	Left-Turn	154	68
	Through	188	85
	Sub-Total	342	153
Middle	Left-Turn	206	219
	Through	212	189
	Sub-Total	418	408
Young	Left-Turn	90	89
	Through	118	94
	Sub-Total	208	183
Total Number of Observed Accepted Gaps		968	744

6.2 Gap distribution

The availability of gaps on the major road affects the gap acceptance behavior of drivers on the minor road. The available gaps represent the volume characteristics of the major road. If the traffic volume on a major road is light, most of the gaps will be relatively large and it will be easy for the minor street drivers to get an acceptable gap. On the other hand, if the volume on the major street is heavy, it will be difficult for the minor street drivers to sufficiently find enough gaps to accept. Therefore, when evaluating the gap acceptance behavior of drivers, availability of different sizes of gaps or random arrival of vehicles would be the best. Based on raw field data, the distributions of available and accepted gaps were plotted in Figure 2 for daytime and nighttime conditions.

6.3 Critical gap values

Critical gap is the gap at which the cumulative probability of accepting (or rejecting) the gap is 50%, which is the key characteristic of gap acceptance behavior of

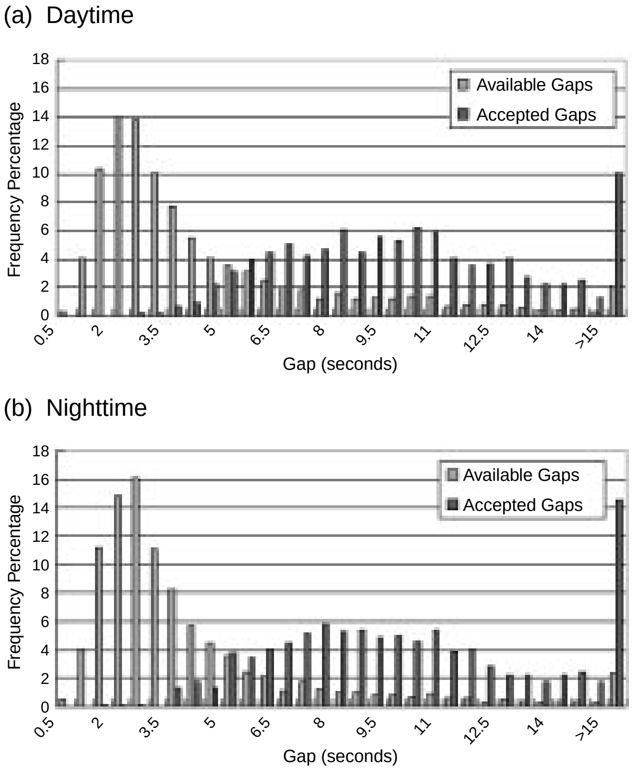

Fig. 2 Distribution of available and accepted gaps (raw data)

drivers at stop-controlled intersections. The critical gap value for each driver group for each type of maneuver was estimated by using a curve fitting analysis for gap acceptance. Accepted gaps that are too large were not considered in the analysis as all the drivers are expected to accept such large gaps. The upper limit for the accepted gaps was chosen as 10 seconds in the case of this study. The logit model, explained earlier was used in the curve fitting. This was done by calculating the probability of accepting a gap (p) using the observed data and then estimating parameters a and b by carrying out linear regression using equation (3). The critical gaps obtained from daytime data are given in Table 2, where p is the probability of accepting a gap smaller than t seconds. The R^2 statistic that gives an indication on how well the model

Table 2 Results of using the logit model for fitting daytime gap acceptance capabilities of driver age groups

Driver Group	Maneuver	The Model	R^2 for the Model	Critical Gap (sec.)
Older	Left-Turn	Ln (p/1-p) = −8.908 +1.243 t	0.91	7.164
	Through	Ln (p/1-p) = −9.007 +1.271 t	0.88	7.084
Middle	Left-Turn	Ln (p/1-p) = −8.560 +1.263 t	0.91	6.775
	Through	Ln (p/1-p) = −7.705 +1.169 t	0.88	6.585
Young	Left-Turn	Ln (p/1-p) = −10.335 +1.715 t	0.85	6.024
	Through	Ln (p/1-p) = −9.706 +1.622 t	0.75	5.985

fits the available data, varies from 0.75 to 0.91. An R^2 value closer to 1.0 indicates a better explanatory power of the model. Thus, it can be seen that all of the daytime models fit reasonably well with the observed data. The estimated intercept and coefficient in each model can be used to estimate the critical gap value under each condition. For example, the model for older driver's left-turn has an intercept of magnitude 9.16 and coefficient of 1.254. The ratio between these two values, 7.3 seconds, is equal to the critical gap value. The results of similar calculations indicated that the critical gap value decreases as age becomes younger. The older driver group gave the longest critical gap value for both left-turn and through maneuvers. It can also be observed that for each age group, critical gap value varies depending on the maneuver under consideration, where left turns always require longer critical gap values than that for through movements. This finding is reasonable as left turns in general are more difficult to make than through movements.

The models developed by using nighttime data are given in Table 3, where the R^2 statistic varies from 0.79 to 0.92, indicating a good fit with the observed data collected in the field. Using the estimated intercept and the coefficient value for the gap yielded a critical gap value of 7.58 seconds for older driver's left-turn movement. Similar calculations using the nighttime data indicated that the nighttime critical gap value also decreases when age gets smaller. The older driver group had the longest critical gap value for both left-turn and through maneuvers, and the left-turn maneuver always resulted in longer critical gap values than that for the through movement. These findings illustrated a similar trend to that of daytime observations.

6.4 Gap acceptance curves

Based on the logit models developed, daytime gap acceptance curves shown in Figures 3(a) and 3(b) were obtained for left-turn and through movements, respectively. The curves clearly illustrate the differences in gap acceptance behavior between different age groups. It can be further noticed that for left-turn movements, the difference between age groups is slightly more than that for through movements. However, this observation is not as obvious in nighttime gap acceptance curves shown in Figures 4(a) and 4(b).

Table 3 Results of using the logit model for fitting nighttime gap acceptance capabilities of driver age groups

Driver Group	Maneuver	The Model	R^2 for the Model	Critical Gap (sec.)
Older	Left-Turn	Ln (p/1-p) = −10.52 +1.387 t	0.79	7.585
	Through	Ln (p/1-p) = −8.852 +1.202 t	0.79	7.361
Middle	Left-Turn	Ln (p/1-p) = −8.73 +1.231 t	0.92	7.088
	Through	Ln (p/1-p) = −8.724 +1.27 t	0.92	6.871
Young	Left-Turn	Ln (p/1-p) = −9.15 +1.437 t	0.87	6.367
	Through	Ln (p/1-p) = −9.115 +1.506 t	0.86	6.054

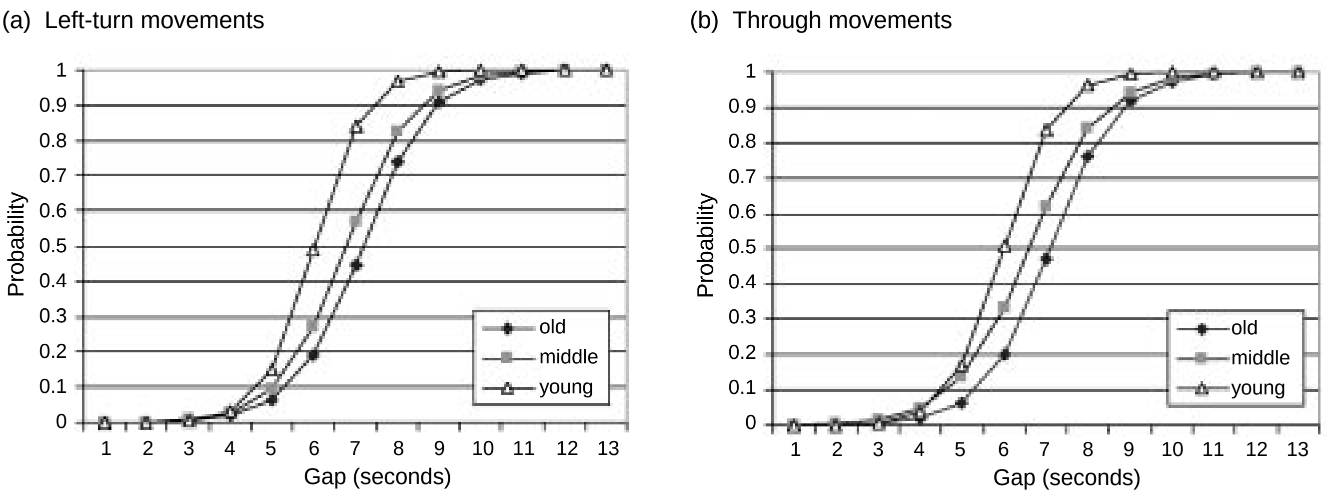

Fig. 3 Gap acceptance curves for daytime

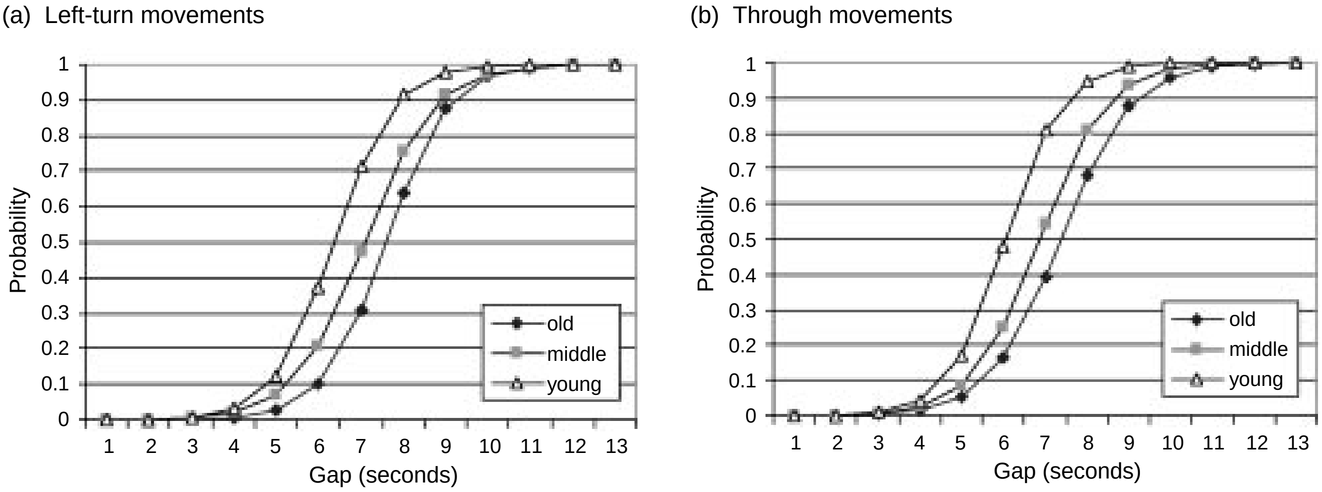

Fig. 4 Gap acceptance curves for nighttime

6.5 Statistical significance

Even though the critical gap values appear to be different among the driver age groups for each type of maneuver, it is important to statistically test whether such differences are significant. Therefore, one-way ANOVA tests were performed to see if the differences in gap acceptance capabilities were statistically significant. Underlying normality assumption for using the ANOVA test was examined by using the Chi-square Goodness-of-Fit test. Distribution of accepted gaps during daytime was in good fit with the Normal Distribution with 95% level of confidence. However, nighttime accepted gaps fitted the Normal Distribution only at the 88% level, even though that was considered acceptable for the purpose of ANOVA tests.

Differences among age groups for each maneuver

Results of the one-way ANOVA tests are given in Table 4. It can be seen that the accepted gap values are significantly different among age groups for each type of maneuver in different light conditions. The null and alternative hypotheses for this case were:

H_0: The accepted gap values for the three driver age groups are equal.

H_a: The null hypothesis is not true.

The one-way ANOVA tests were performed at a confidence level of 95% (α = 0.05). The results were interpreted using F and $F_{critical}$ values. For cases where the estimated F statistic is greater than the critical F statistic the null hypothesis cannot be accepted. Such a situation implies that the accepted gaps could be expected to be significantly different.

Differences between maneuvers for each driver group

Results of the one-way ANOVA tests to show the difference between the two types of maneuvers for each driver group are given in Table 5. The null and alternative hypotheses for this case were:

H_0: The accepted gap values for the two maneuvers are equal.

H_a: The null hypothesis is not true.

The results of the ANOVA tests between left-turn and through maneuvers indicated that there was no statistical difference for any of the three driver groups either during daytime or at nighttime. Therefore, gap acceptance capabilities for the two maneuvers can be considered as similar for all age groups. However, for the older driver group, the differences between left-turn and through maneuvers were significant at the 10% level at nighttime.

Table 4 ANOVA test results for differences in gap acceptance capabilities among driver age groups

Light Condition	Maneuver	F Statistic	$F_{critical}$ (α = 0.05)	**p** value	Differences Significant
Daytime	Left-Turn	5.20	3.01	0.005	Yes
	Through	3.09	3.01	0.046	Yes
Nighttime	Left-Turn	3.37	3.01	0.035	Yes
	Through	3.29	3.01	0.038	Yes

Table 5 ANOVA test results for differences in gap acceptance capabilities between left-turn and through maneuvers

Light Condition	Driver Group	F Statistic	$F_{critical}$ (α = 0.05)	p value	Differences Significant
Daytime	Older	0.33	3.9	0.56	No
	Middle	0.18	3.9	0.66	No
	Young	0.76	3.9	0.38	No
Nighttime	Older	2.93	3.9	0.08	No
	Middle	1.52	3.9	0.21	No
	Young	0.64	3.9	0.42	No

Comparison of daytime and nighttime gap acceptance capabilities

Summary of the critical gap values for each driver group for each maneuver type under daytime and nighttime conditions are given in Table 6. The null and alternative hypotheses for this situation were:

H_0: The accepted gap values during daytime and nighttime are equal.

H_a: The null hypothesis is not true.

The results of the ANOVA test are given in Table 7. According to the findings, significant differences in gap acceptance capabilities at 95% level can only be observed for older drivers. Thus, older drivers need significantly larger gaps during nighttime when making either a left-turn or through movement at stop-controlled intersections. Out of the two types of maneuvers that were taken into consideration in this study left-turn movements required longer available gap value than through movements for older drivers. Young drivers did not illustrate differences in gap acceptance capabilities in different light conditions at 5% level of significance, regardless of the type of maneuver. However, at the 10% level of significance, middle age driver gap acceptance capabilities were statistically different between daytime and nighttime for the left-turn movement.

Table 6 Summary of the critical gap values obtained through the logit model

Driver Group	Movement	Critical Gap (seconds)	
		Daytime	Nighttime
Older	Left-Turn	7.164	7.585
	Through	7.084	7.361
Middle	Left-Turn	6.775	7.088
	Through	6.585	6.871
Young	Left-Turn	6.024	6.367
	Through	5.985	6.054

7. CONCLUSIONS

This study represents the first detailed attempt to study the gap acceptance capabilities while considering such factors as driver age, vehicle maneuver, and the light/visibility condition. While the computer program developed for collecting the field data related to available and accepted gaps was capable of gathering accurate data, determination of the driver age group was somewhat subjective in this study. However, results from a training sample had shown that the field observers could make reasonably accurate age group judgments of the drivers. There are statistically significant differences in gap acceptance capabilities among the three considered driver age groups, under both light conditions. When tested for the differences between left-turn and through maneuvers, however, the gap acceptance behavior was not statistically different at the 95% level for any of the

Table 7 ANOVA test results to see the differences between daytime and nighttime gap acceptance capabilities

Driver Group	Movement	F Statistic	$F_{critical}$ (α = 0.05)	p value	Differences Significant
Older	Left-Turn	6.07	3.9	0.014	Yes
	Through	4.06	3.9	0.045	Yes
Middle	Left-Turn	3.13	3.9	0.077	No
	Through	1.53	3.9	0.217	No
Young	Left-Turn	0.01	3.9	0.937	No
	Through	0.18	3.9	0.674	No

driver age groups and any light condition. For older drivers, gap acceptance capabilities during daytime and nighttime were significantly different at the 95% level. Thus, older drivers required significantly longer gaps during nighttime. These findings are useful for the transportation engineering community to understand the driving behavior of different age groups, and adjust the existing practices of traffic control and roadway design to accommodate the needs of commuters at selected places. The findings of this study may have an influence on the capacity of TWSC intersections, which is required to be further investigated through research.

REFERENCES

1. ***Special Report 209: Highway Capacity Manual***. Transportation Research Board, National Research Council, Washington D.C. (1994).
2. McShane, W. R., and Roess, R. P. ***Traffic Engineering***. Prentice Hall, Englewood Cliffs, N.J. (1991).
3. Dissanayake, S., Lu, J. J., Chu, X., and Turner, P. "Use of Multi-Criteria Decision Making to Identify the Critical Highway Safety Needs of Special Population Groups." ***Transportation Research Record*** No. 1693. Transportation Research Board, National Research Council, Washington D. C., 13-17. (1999).
4. Dissanayake, S., Lu, J. J., Tan, H., Chu, X., and Turner, P. ***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. (1998).
5. Staplin, L. "Simulator and Field Measures of Driver Age Differences in Left-Turn Gap Judgements." ***Transportation Research Record***. No. 1485. Transportation Research Board, National Research Council, Washington D. C., 49-55. (1995).
6. Kittelson, W. K., and Vandehey, M. A. "Delay Effects on Driver Gap Acceptance Characteristics at Two-Way Stop-Controlled Intersections." ***Transportation Research Record***. No. 1320. Transportation Research Board, National Research Council, Washington D. C., 154-159. (1991).
7. Yi, P. "Gap Acceptance for Elderly Drivers on Rural Highways." ***ITE Compendium of Technical Papers***. 66th Annual Meeting, Institute of Transportation Engineers, 299-303. (1996).
8. Lu, J. J., and Dai, J. X. ***The Impact of Driving Behavior of Older Drivers on Intersection Capacity***. Final Report. Department of Civil and Environmental Engineering, University of South Florida, Tampa, Florida. (1997).
9. Sridevi M., and. Lu, J. J. ***Capacity Reductions due to Older Drivers at Stop-Controlled Intersections***. Final Report. Department of Civil and Environmental Engineering, University of South Florida, Tampa, Florida. (1998).
10. Valen S. M., and Aerde, M. V. "Gap Acceptance and Approach Capacity at Unsignalized Intersections." ***ITE Journal***, Volume 66, No. 3, 40-45. (1996).
11. Kyte, M., Clemow, C., Mahfood, N., Lall, B. K., and Khisty, C. J. "Capacity and Delay Characteristics of Two-Way Stop-Controlled Intersections." ***Transportation Research Record***. No. 1320. Transportation Research Board, National Research Council, Washington D. C., 160-167. (1991).
12. Stamatiadis, N., Taylor, W. C., and McKelvey, F. X. "Elderly Drivers and Intersection Accidents." ***Transportation Quarterly***, Volume 45, No. 3. (1991).
13. Council, F. M., and Zegeer, C.V. ***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).
14. Dissanayake, S., and Lu, J.J. "Effect of Lighting Condition on the Highway Crash Involvement of Older Drivers." Pre-Print CD-ROM, 79th Annual Meeting of Transportation Research Board, National Research Council, Washington D. C. (2000).
15. Knoblauch, R. L., Pietrucha, M. T., Nitzburg, M. "Field Studies of Pedestrian Walking Speed and Start-Up Time." ***Transportation Research Record*** No. 1538. Transportation Research Board, National Research Council, Washington D. C., 27-38. (1996).