Relationship Between Lighting and Accident Experience Between Interchanges

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This paper examines the relationship between accident experience and lighting between interchanges of the Interstate Highway System in urban areas. Characteristics considered include existence of lighting, number of lanes, intensity of lighting, and average daily traffic volume. Accidents per hundred million vehicle-miles of travel are used as the primary indicator of accident experience. Results indicate that 24-hour accident rates and night (6 p.m. to 4 a.m.) accident rates are higher on lighted highways than on unlighted highways regardless of whether mainline units are classed by number of lanes or by ADT levels. Averages of various geometric, traffic, and accident characteristics for lighted and for unlighted units were compared and discrepancies noted. There is no discernible relationship between lighting intensity and accident rate on 2-lane mainline units or 3-lane mainline units.

•THE CONTRIBUTION OF LIGHTING on the Interstate Highway System between interchanges has been a subject of some recent controversy. This study was proposed to better assess the contribution of lighting in this area. The Interstate System Accident Research, Study II (ISAR-II), data base was used. This study is confined to between-interchange study units (also called mainline units) on Interstate highways in urban areas. All bridges, tunnels, and other overpasses and underpasses are excluded. All of the Interstate highways examined had from 2 to 4 traffic lanes in one direction. Lighting intensity in the data varies from 0 to 1.05 foot-candles (ft-c). The existence of lighting is studied with respect to number of lanes (2 to 4) and average daily traffic (ADT) per lane (1,000 to 10,000). The relationship between lighting intensity and accident rate is briefly examined.

FINDINGS

1. Approximately 93 percent of the lighted mainline units studied are illuminated by mercury vapor lamps.
2. The percentage of lighted mainline units increases with number of lanes; 11 percent of 2-lane units, 50 percent of 3-lane units, and 100 percent of 4-lane units are lighted.
3. During darkness (9 p.m. to 4 a.m.) when artificial lighting should be most effective, the accident rate is much higher on lighted units than on unlighted units regardless of number of lanes.
4. Comparison of lighted and unlighted units by ADT per lane, where sufficient data are available, demonstrates that lighted highways have higher accident rates.
5. There is no discernible relationship between lighting intensity and accident rate on 2-lane or 3-lane mainline units.
6. The lighted mainline units appear to be more constraining on the vehicles that move along them than unlighted units are. This is seen in the low percentage of non-collision accidents and higher percentage of rear-end collisions on lighted units. The

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obstructions along the road that cause a constraining highway are, of course, lighting poles.

7. For both lighted and unlighted units, injury rates and property damage rates are consistently and highly correlated with accident rates.

ANALYSIS

Data Characteristics

The level of lighting intensity in the ISAR-II data base is a discrete variable as follows:

Intensity Level (ft-c)	Code	Assigned Value
None	0	0
0 to 0.3	1	0.15
0.3 to 0.49	2	0.40
0.5 to 0.79	3	0.70
0.8 to 1.29	4	1.05
1.3 to 1.99	5	1.65
2.0 and over	6	2.00
Partial lighting	7	—

All partial lighting study units were discarded because partial lighting is not a definitive term and thus would be difficult to evaluate. Lighting effects were only examined on between-interchange units excluding overpasses, underpasses, or major river crossings (i.e., any bridge with a span of more than 20 ft). The between-interchange units studied varied in number of lanes in one direction from 2 to 4 lanes. In this paper, highways having 2, 3, and 4 lanes in one direction are referred to as 2-, 3-, and 4-lane mainline units.

The number of data points available are as follows:

	Urban Units		Rural Units	
No. Lanes	No.	Percent With Lighting	No.	Percent With Lighting
2	5,642	8.9	24,169	0.3
3	2,671	58.0	{765	{?
4	60	100.0		

Because 99 percent of the 2-lane rural data had no lighting, this study was confined to urban data points only. Figures 1 and 2 show the type of lighting used and the average lighting pole spacing in the mainline units studied.

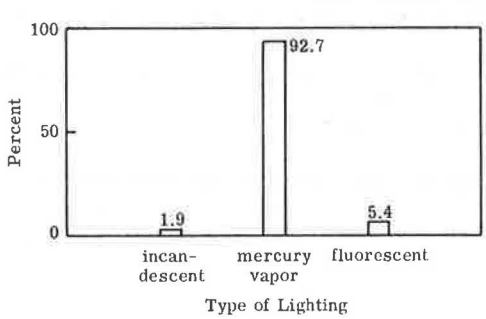

Figure 1. Type of lighting.

Response Variable

A rate based on vehicle-miles was used to avoid bias caused by ADT or unit length. Accident rate is the number of accidents per hundred million vehicle-miles. Although accident rate served as the response variable, injury, fatality, and property damage rates were also computed. Property damage rates and injury rates simulated accident rates consistently and accurately (Fig. 4).

Accident Rate by Lighting Intensity on 2- and 3-Lane Mainline Units

Figure 3 shows accident rate by lighting intensity on mainline units of 2 and 3 lanes. Three-lane mainline units have high accident

rates in each of the lighting intensity categories relative to those 3-lane units without lighting. For 2-lane mainline units, the 2 lighting intensity categories, 0.01 to 0.29 and 0.30 to 0.49, should be ignored because few data points were available. Otherwise, the 2 highest lighting categories have accident rates slightly lower than those 2-lane mainline units without lighting. From these data, no relationship can be discerned between accident rate and lighting intensity. That is, accident rate did not increase or decrease consistently with increasing lighting intensity.

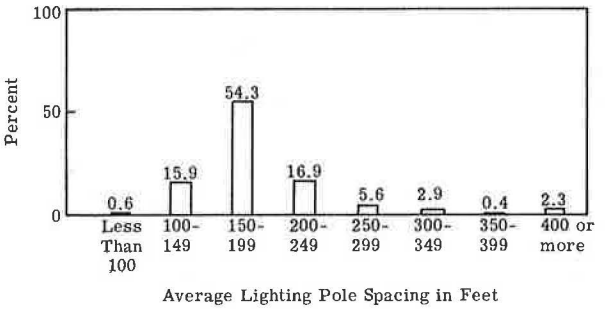

Figure 2. Average spacing of lighting poles.

Accident Rate by Existence of Lighting and Number of Lanes

All data were divided into 3 groups (2-lane, 3-lane, and 4-lane mainline units) to enable comparisons to be made. In each group, those units with lighting were separated from those without lighting, and accident rates were computed. As shown in Figure 4, only on 2-lane mainline units was the accident rate higher on unlighted units than on lighted units. Because the accident rates shown in Figure 4 were calculated for the entire 24-hour day, perhaps a closer examination of periods of the day could show other results. The periods of the day for which accident rates were computed are as follows:

Day	9 a.m. to 4 p.m.
Rush	7 to 9 a.m. and 4 to 6 p.m.
Dawn	4 to 7 a.m.
Dusk	6 to 9 p.m.
Night	9 p.m. to 4 a.m.

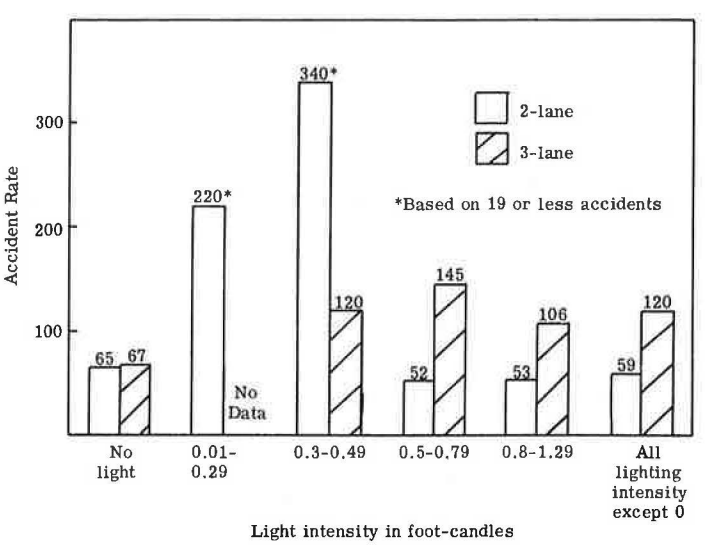

Figure 3. Accident rate by light intensity on 2- and 3-lane mainline units.

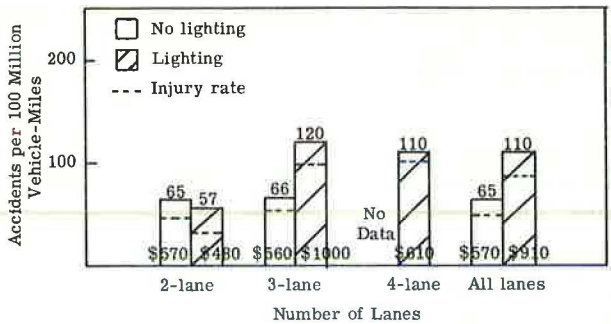

Figure 4. Accident rate by number of lanes.

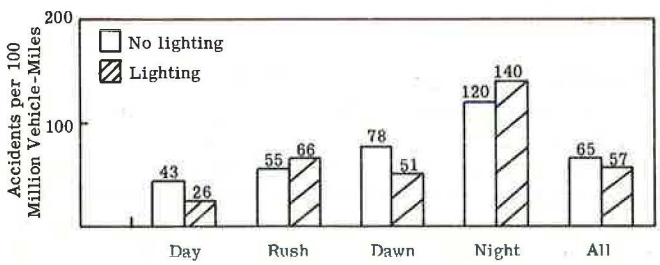

Figure 5. Accident rate by period of day on 2-lane mainline units.

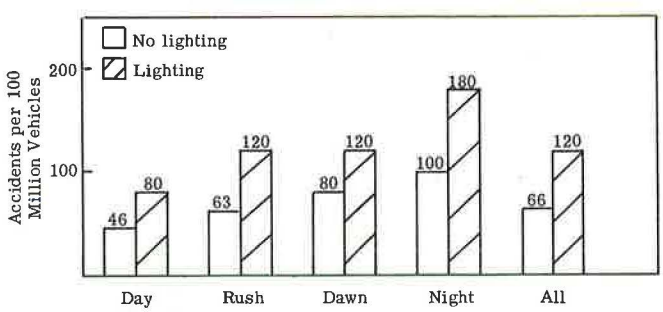

Figure 6. Accident rate by period of day on 3-lane mainline units.

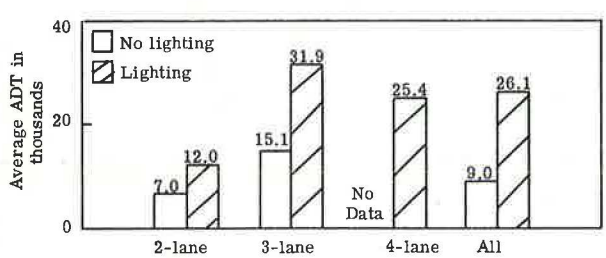

Figure 7. ADT by number of lanes.

These particular groupings were chosen because the data base had traffic volume and number of accidents separately for each of them and, therefore, accident rates could be developed. This breakdown by periods of the day was not done for 4-lane mainline units because of limited data. Figures 5 and 6 show the accident rates by time periods for 2- and 3-lane mainline units respectively. Of the 4 time periods, only day and night indicate the light conditions; day is always light and night is always dark. One would expect to find the greatest effect of lighting during the night (i.e., in darkness from 9 p.m. to 4 a.m.). In both 2-lane and 3-lane mainline units, however, the accident rate is higher on the lighted units during the night period. Of all the time periods, only day, dusk, and dawn on 2-lane units had a higher accident rate on unlighted units than on lighted units. On 3-lane mainline units, the accident rate on lighted units is nearly double the accident rate on unlighted units for each time period.

Figure 7 shows that the lighted units have a much higher ADT than unlighted units regardless of the number of lanes. This was expected because of the results of an informal survey of the lighting policies used by 5 states that contributed heavily to the ISAR-II data. Four of the 5 states have policies that require urban highways to have lights when the ADT levels warrant. In most cases, state planning manuals or AASHO (1) was cited as providing standards for lighting policies. Other reasons given for lighting an urban highway were (a) substantial commercial or industrial building development and (b) 3 or more successive interchanges with an average spacing of $1\frac{1}{2}$ miles or less. None of the 5 states claimed to use accident rate as an indicator in lighting urban highways, though by using ADT they indirectly used accident rate because the ADT level is the most important predictor of accident rate (2).

Accident Rate by Existence of Lighting and ADT Levels per Lane

A comparison was made of mainline units with and without lighting by ADT levels per lane. For each mainline unit, the ADT per lane is computed and then placed in one of the following 10 categories:

0 to 1,000
1,001 to 2,000
2,001 to 3,000
3,001 to 4,000
4,001 to 5,000
5,001 to 6,000
6,001 to 7,000
7,001 to 8,000
8,001 to 9,000
9,001 and over

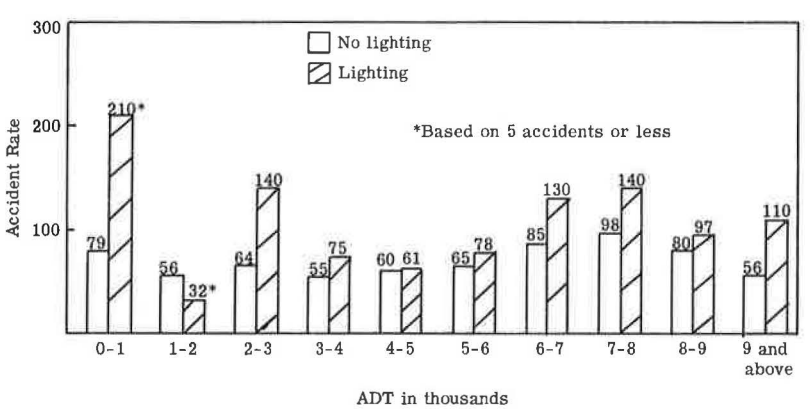

Figure 8. Accident rate by ADT per lane.

In each group, distinction is made between a lighted unit and an unlighted unit. Figure 8 shows the comparisons of accident rates on lighted and unlighted units by ADT per lane. As ADT per lane increases, accident rates for lighted mainline units and for unlighted mainline units are lowest in the 3,000 to 5,000 vehicle-per-lane (VPL) category and peak in the 7,000 to 8,000 VPL category. That is, accident rate on lighted mainline units and accident rate on unlighted mainline units increase with increasing ADT per lane only in the 4,000 to 8,000 VPL categories.

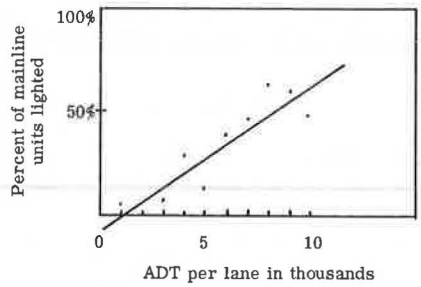

Figure 9. Mainline units lighted and ADT per lane.

The data shown in Figure 9 support the results of the informal survey mentioned earlier that urban mainline highways are lighted principally by ADT level. The percentage of mainline units lighted increases with ADT. The line shown was fit by simple linear regression. The correlation coefficient between percentage of mainline units lighted and ADT per lane is 0.91, which implies that they are highly correlated.

Two of the accident rates are higher on lighted units than on unlighted units for all ADT levels per lane except the first 2 levels. Each of these ADT levels per lane was

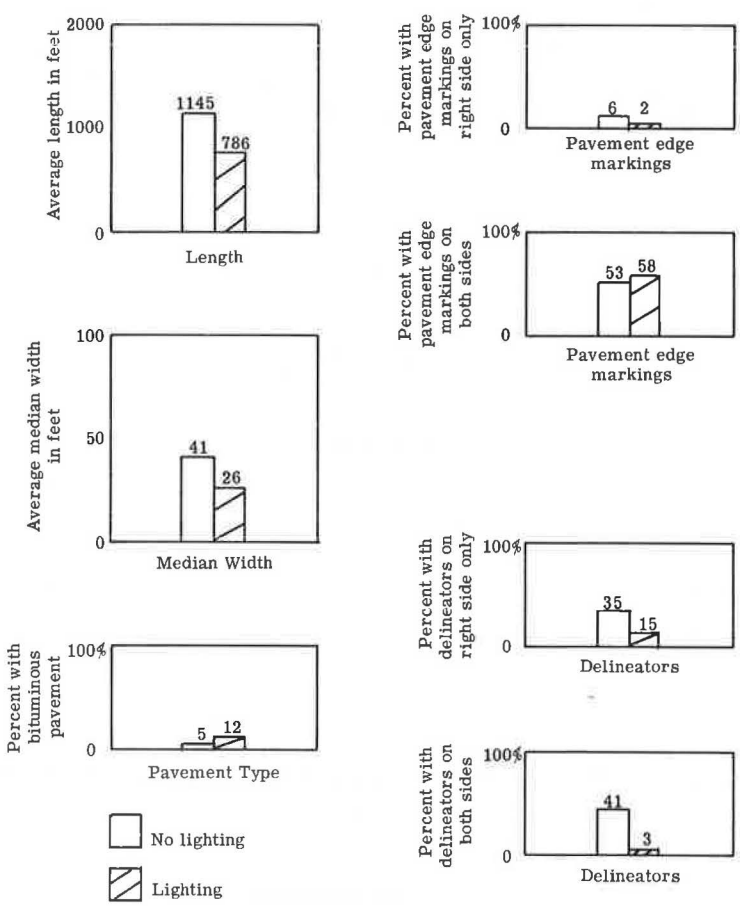

Figure 10. Geometric variables.

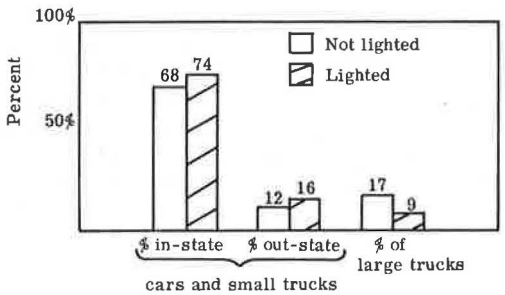

Figure 11. Traffic variables.

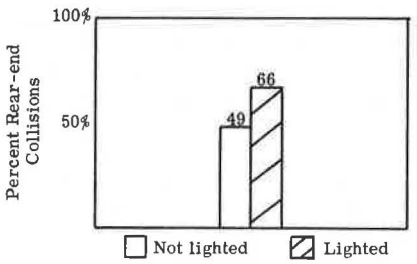

Figure 12. Rear-end collisions.

examined by period of the day. Again, during the night period, accident rates were much higher on lighted units than on unlighted units.

Differences Between Lighted and Unlighted Mainline Units

The lighted mainline units studied have accident rates higher than those on the unlighted mainline units in all but one ADT category. An attempt was made to explain this situation by averaging separately available geometric, traffic, and accident variables for lighted and unlighted units.

The geometric variables examined are median width, length of section, pavement type, pavement edge markings, and delineators. Figure 10 shows each geometric variable by lighted and unlighted units. The average unlighted mainline unit has a 56 percent wider median and is 47 percent longer than the average lighted unit. A greater percentage of unlighted units have delineators on the right side and delineators on both sides than do lighted units. Pavement type and pavement edge markings vary little between lighted and unlighted units.

The traffic variables examined are percentage of in-state cars and small trucks, percentage of out-of-state cars and small trucks, and percentage of large trucks (Fig. 11). Unlighted units have a much larger percentage of trucks (and smaller percentage of in-state and out-of-state cars and small trucks) than lighted units. The traffic variable ADT was examined earlier. In units with comparable number of lanes, the lighted units had much greater ADT than unlighted units, especially in 3- and 4-lane units.

The accident variable examined was manner of collision. Lighted units had a greater percentage of rear-end collisions (Fig. 12) than unlighted units and a smaller percentage (31 percent) of accidents in which the vehicle left the road, with or without striking an object, than unlighted units (44 percent). Thirty-four percent of the vehicles that left the unlighted roads did not strike an object, and only 9 percent of vehicles that left the lighted roads did not strike an object.

These data indicate that geometric conditions such as curbs and guardrails on lighted highways prevent a greater percentage of vehicles from leaving the roadway than geometric conditions on unlighted highways. In addition, if a vehicle does leave the lighted roadway, 90 percent of the time it strikes an object (e.g., lighting pole). These figures are presented only to illustrate differences in various variables between lighted and unlighted mainline units, and are only tentatively offered to explain accident rate differences between units.

CONCLUSIONS

In this study, only urban mainline units of the Interstate Highway System have been examined. Comparison of 24-hour accident rates and night (6 p.m. to 4 a.m.) accident rates between lighted (all lighting intensities) and unlighted mainline units by number of lanes and by ADT-per-lane groupings demonstrated that the lighted units have higher accident rates. This is understandable in the number-of-lanes analysis because the ADT was much higher on the lighted units than on the unlighted areas. But, in the ADT-

per-lane analysis, even in the same ADT-per-lane grouping, the lighted units had a higher accident rate. This statement should not be interpreted to mean that the lighting of a mainline unit causes a higher accident rate because many variables were not considered. Therefore, various geometric, traffic, and accident characteristics of lighted and unlighted units were contrasted. In general, these variables indicated some marked discrepancies between lighted and unlighted highway. These discrepancies, however, are not offered as the reasons for the difference in accident rates between lighted and unlighted units because only averages of the variables were considered (i.e., standard deviations and exposures were not calculated thus preventing statistical significance tests to be made).

Although the lighting policies used by the 5 states surveyed indicated that accident rate was not a criterion for lighting, it may be that the high-accident mainline units were lighted first.

No relationship was found between lighting intensity and accident experience, but the data were very limited.

ACKNOWLEDGMENTS

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2. Cirillo, J. A., Dietz, S. K., and Beatty, R. L. Analysis and Modeling of Relationships Between Accidents and the Geometric and Traffic Characteristics of the Interstate System. U.S. Govt. Print. Office, Washington, D.C., 1969, p. 14.