INFLUENCE OF LIGHTING ON ACCIDENT FREQUENCY AT HIGHWAY INTERSECTIONS

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Accident frequency for rural at-grade intersections was determined for 3-year periods immediately before and after lighting. Results from 47 intersections revealed a 49 percent overall reduction in night accidents after lighting. The average night accident rate per million entering vehicles was 1.89 before lighting and 0.91 after lighting, which is a reduction of 52 percent. This reduced night accident rate, when compared with the night accident rate before lighting and the day accident rate after lighting, is found to be statistically significant at the 99 percent level. Similar data are provided for groups of intersections for channelization, route turns, number of legs, number of lights, and average daily traffic.

•THE ENERGY crisis in November 1973 prompted a reduction in the amount of lighting at many highway intersections. Discussion of the possible effect of the reduced lighting led to development of a 2-part investigation. The first part had to do with change in accident frequency after full design lighting was installed in an area that had no lighting. The second part is an investigation of the possible change in accident frequency resulting from reducing lighting. The information in this paper concerns only the first part of the investigation.

The investigation was limited to rural intersections for which it was possible to obtain accident records for a 3-year period before operation of design lighting and for a 3-year period after operation of design lighting. It was established that no major changes in geometrics or traffic control accompanied the installation of lighting and that no such changes were made at any other time during the entire 6-year period. A total of 243 lighted road intersections in Iowa were examined for compliance with the selection criteria. From these, 47 intersections were selected for the investigation.

DATA

Because the various intersections were lighted over a period of years, the 6-year study period for each intersection did not begin on the same date. The earliest periods began in 1964, and the most recent began in 1968. A count of all vehicles entering each intersection was not available for every year of the 6-year period; however, records were complete enough to permit reasonable estimates of traffic for the 3 years before lighting and the 3 years after lighting at each of the 47 intersections. In general, traffic increased by approximately 11.6 percent from the 3-year period before lighting to the 3-year period after lighting.

Night Accidents

All accident reports for the 47 intersections during the 6-year period were reviewed, and the times at which the accidents took place were noted. Information on the time of sunrise and sunset throughout the state was used to determine those accidents that took

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place during daylight and those that took place during darkness.

Traffic Distribution

Data from 55 automatic traffic counter installations were used to estimate the proportion of total average daily traffic (ADT) assignable to hours of darkness. The data from the automatic traffic counters covered the years 1970, 1971, and 1972. It was estimated that, for the 6-year period, 27 percent of the ADT at all 47 intersections occurred during hours of darkness.

Variables

A list of variables available for consideration in a study of this type could be nearly without limit. The choice of variables used was dictated more often than not by the availability of information. For example, inclusion of level of illumination requires that an accurate record of burned out lamps, lamp replacement, and cleaning of lamps be kept. Because maintenance is often contracted to other agencies, records vary widely. The total number of variables is, of course, limited by practical consideration.

Variables that were examined for their effect in the lighting and no-lighting situations included raised channelization, a primary route turning at the intersection, and the difference between 3-leg and 4-leg intersections. It should be observed that all 47 intersections were at grade and that all intersections required traffic to stop in 1, 2, 3, or all 4 directions.

ANALYSIS

Information concerned with the entire sample of intersections is summarized in Tables 1 and 2. Breakdowns for some specific effects are given in Table 3. The first analysis, an analysis of variance, included a look at the overall situation as it pertains to the effects of lighting and time of day. Before lighting, 90 night accidents were recorded, and after lighting, 46 accidents were recorded. This represents a statistically significant 49 percent reduction in the number of accidents.

Taking into consideration traffic volumes, the average rate before and after lighting was 1.89 and 0.91 accidents/million entering vehicles (MEV) respectively. These rates were computed for each intersection and averaged over all 47 intersections. The reduction was 52 percent and more accurately reflects the improvement that took place. This reduction is statistically significant by use of a different analysis of variance. For information purposes only, it is noted that no significant reduction in the daytime accident rate was found when lighting was installed.

A further comparison of data considers the night and daytime rates. Before lighting, the night rate exceeded the daytime rate by nearly 20 percent. After lighting, the night accident rate was some 34 percent less than the daytime rate. The net effect after combining all daytime and all night data for the 6-year accident history at all intersections indicated no significant difference between daytime and night rates. There is no reason to believe that the improvement—a net long-term reduction in the night accident rate—will not continue in the future. Testing for specific effects was accomplished by using a t-test.

Channelization

The sample included 19 intersections with no channelization and 28 intersections with raised concrete curbing outlining either a grass or concrete median. Let us first consider the unchannelized intersections. Despite a seemingly large numerical difference, no statistically significant changes were indicated in the before to after night

Table 1. Individual intersection data.

Intersection	Before Lighting ADT	Before Lighting Accidents Day	Before Lighting Accidents Night	Before Lighting N/D[a]	After Lighting ADT	After Lighting Accidents Day	After Lighting Accidents Night	After Lighting N/D[a]
1	4,431	9	2	0.60	4,533	2	0	0
2	5,647	3	1	0.90	6,835	7	0	0
3	3,475	5	0	0	3,578	4	1	0.68
4	1,275	3	3	2.70	1,793	3	0	0
5	4,376	3	1	0.90	5,567	6	0	0
6	2,722	4	3	2.03	2,914	3	0	0
7	2,797	5	3	1.62	3,160	6	0	0
8	2,744	2	2	2.70	3,294	1	1	2.70
9	6,346	5	0	0	5,778	4	0	0
10	3,857	8	1	0.34	4,960	11	1	0.25
11	2,369	2	2	2.70	2,336	6	1	0.45
12	5,444	5	4	2.16	7,661	5	0	0
13	4,428	7	3	1.16	5,779	3	1	0.90
14	2,862	5	1	0.54	3,279	4	1	0.68
15	5,711	6	2	0.90	6,272	4	0	0
16	1,942	1	2	5.41	2,289	2	0	0
17	2,481	3	3	2.70	2,659	3	1	0.90
18	4,316	8	4	1.35	4,532	15	0	0
19	2,540	1	0	—	3,050	0	2	—
20	6,599	15	0	0	7,263	8	1	0.34
21	3,363	3	2	1.80	3,176	12	3	0.68
22	2,569	5	2	1.08	2,784	3	2	1.80
23	3,582	1	1	2.70	3,704	1	0	0
24	1,657	5	0	0	1,827	2	1	1.35
25	2,096	4	1	0.68	2,692	4	0	0
26	2,654	2	0	0	2,546	2	2	2.70
27	3,096	11	3	0.74	3,454	9	1	0.33
28	5,140	3	2	1.80	5,478	3	1	0.90
29	4,357	1	0	0	4,393	0	0	0
30	2,566	2	2	2.70	2,580	2	3	4.06
31	1,919	1	0	0	2,671	1	1	2.70
32	3,004	5	0	0	3,098	5	2	1.08
33	1,941	2	3	4.06	2,115	3	0	0
34	3,275	4	0	0	4,141	1	0	0
35	3,713	6	3	1.35	3,665	1	1	2.70
36	4,673	6	4	1.80	3,881	6	1	0.45
37	4,043	6	6	2.70	5,085	6	2	0.90
38	5,505	9	7	2.10	6,556	4	5	3.38
39	3,389	3	1	0.90	2,781	5	2	1.08
40	3,242	1	0	0	3,533	1	2	5.41
41	5,010	3	3	2.70	4,748	2	1	1.35
42	3,243	5	2	1.08	4,161	4	1	0.68
43	5,759	5	2	1.08	5,804	4	1	0.68
44	3,839	3	1	0.90	4,958	6	0	0
45	6,437	9	4	1.20	7,815	7	1	0.39
46	8,104	17	2	0.32	9,853	11	2	0.49
47	3,346	3	2	1.80	3,547	5	1	0.54

[a]Night-to-day ratio adjusted for traffic.

Table 2. Data totals.

Item	Before Lighting	After Lighting
Traffic		
Night (ADT × 0.27)	48,028	53,616
Day (ADT × 0.73)	129,856	144,962
Total ADT	177,884	198,578
Accidents		
Night	90	46
Day	225	207
Total	315	253
Accident rate/MEV[a]		
Night	1.89	0.91
Day	1.58	1.38
Overall	1.73	1.15

[a]Average of 47 accident rates per million entering vehicles.

Table 3. Effect of channelization, route turn, number of legs, and intersections by number of lights on accident rate per million entering vehicles.

Intersection	Number in Test	Day Before Lighting	Day After Lighting	Night Before Lighting	Night After Lighting
Channelized	28	1.53	1.27[a]	2.01	0.88[b]
Nonchannelized	19	1.64	1.55[a]	1.72	0.97[a]
With route turn	21	1.60	1.42[a]	2.45	1.13[b]
Without route turn	26	1.56	1.35[a]	1.44	0.74[a]
3 legs	15	1.54	1.26[a]	1.76	1.28[a]
4 legs	32	1.59	1.44[a]	1.96	0.74[b]
3 to 5 lights	19	1.47	1.11[a]	1.38	0.93[a]
6 to 9 lights	21	1.67	1.32[a]	2.12	0.96[b]
10 to 15 lights	7	1.59	2.30[a]	2.56	0.74[b]

[a]Not significant before to after.
[b]Significant at 99 percent level before to after.

rates and the day and night rates after lighting (Table 3). The variances within this sample were such that the apparently large numerical differences might have occurred by chance more than 10 percent of the time.

The analysis for the channelized intersections, however, showed a highly significant (99 percent level) overall reduction in the accident rate when lighting was installed. Most of this improvement lies in the lowered night rate because the daytime rate reduction is of no consequence. After lighting was installed, no significant difference was noted between channelized and nonchannelized intersections. This does not minimize the improvement made when channelized intersections are lighted. Before lighting, the channelized intersections performed in a less satisfactory manner than the nonchannelized intersections. After lighting, although the difference in accident rates was not significant, the numerical balance favored the channelized intersections. This is particularly worth mentioning when one notes that lighting also improved nonchannelized intersection performance.

Route Turns

Twenty-one intersections were recorded as having had 1 or more routes entering in one direction but departing in another direction. The night accident rate before lighting for this group, 2.45/MEV (Table 3), is the highest of any subsample examined. The rate is, in fact, significantly higher than the night rate of 1.44 for the 26 intersections having no turning route. This rate of 2.45 was also significantly higher than the daytime accident rate for intersections with a turning route.

Accident history for the intersection after lighting indicated that intersections with and without turns showed numerical improvement (a reduced accident rate) in day and night categories. Those intersections with no turning route did not indicate a significant change until the 90 percent level was reached, but, nonetheless, a reasonable ensurance of improvement was provided. The route-turning intersection group showed a significant reduction in the night accident rate at the 99 percent level. The result is that no real difference in night accident rates after lighting is installed exists between intersections with and without turning routes. Apparently the challenge of a turning route to the night driver is negated with the addition of lighting.

Number of Legs

Fifteen intersections of the original sample were either T-intersections or Y-intersections. Again, a numerical reduction in accident rates was noted (Table 3) when lighting was installed, but no change of any significance could be determined. It should be pointed out that the daytime and night accident rates before lighting were slightly less (although not significantly less) than those found for 4-leg intersections. This is probably accounted for by the presence of fewer conflicts.

The accident rates for 32 intersections having 4 approaches also showed a numerical reduction when changed from not being lighted to being lighted. A reduction in the night rate from 1.96 accidents/MEV to 0.74/MEV is significant at a 99 percent level. This reduction was accomplished to such an extent that under lighted conditions the accident rate at 4-leg intersections was less than at 3-leg intersections at a 90 percent level of significance. However, this does not imply that lighted 4-leg intersections at night are the safest. Other factors undoubtedly are influential. At this time we consider the results interesting based on this particular sample of 47 intersections.

Number of Lights

No basis existed for subdividing the number of lights in any particular manner. Generally not more than 5 lights were found at intersections containing either no channelization or channelization used simply to direct turning movements. Intersections con-

taining 10 lights generally included some type of channelization extending beyond the turning areas to separate opposing traffic flow. Following these guidelines, 3 groups were defined that included intersections with 3 to 5 lights, 6 to 9 lights, and 10 to 15 lights. Table 3 gives accident rates as calculated for each group.

One may state generally that as the level of lighting increases the complexity of the intersection also increases. In the before lighting situation, this was paralleled also by an increase in the night accident rate. After lighting, all categories showed night improvement; the 6-to-9 and 10-to-15 levels are significant at 99 percent. The end result shows little numerical difference and no significant differences in night accident rates between light levels. We suggest that lighting has made the night driving situation less difficult in the more complex intersections.

Average Daily Traffic and Lighting

To identify ADT levels that might respond most favorably to lighting, we ran an analysis of variance by using the number of night accidents as the dependent variable. Two levels of lighting—lights and no lights—were used. Six ADT levels were selected in such a way that each group contained approximately the same number of observations. These ADT levels are as follows:

1. Lower than 2,500,
2. 2,500 to 2,999,
3. 3,000 to 3,499,
4. 3,500 to 4,399,
5. 4,400 to 5,699, and
6. 5,700 and higher.

Until traffic volumes reached 3,500 vehicles/day, little effect was noted. At levels 4 and 5, however, the installation of lighting produced a significant reduction in the number of night accidents. This does not mean that intersections at ADT levels 4 and 5 are safer than other levels after lighting; it merely means that these were the levels of greatest improvement. Level 5 did exhibit a significantly higher accident rate than all other levels before lighting. No difference was apparent between ADT levels after lighting, which indicates that no level of ADT resulted in a disproportionate share of accidents.

These statements may or may not apply to ADT level 6. The traffic volumes in this group are in a wide range. Refinement of what is occurring at these higher traffic volumes requires more data than are now available and any conclusions at this point would be speculative.

CONCLUSIONS

Based on the 47 intersections included in this study, installation of lighting with no regard for other effects results in a significant reduction in the average night accident rate. In this investigation, the rate was reduced from 1.89 to 0.91 accidents/MEV. These figures amount to a 52 percent reduction and a statistically significant change at the 99 percent level.

With the addition of lighting, specific situations showing significant improvement included intersections with channelization, a primary route changing direction, and 4 legs. In general, lighting significantly reduced the number of night accidents at ADT levels above 3,500. Note that these situations require more of the night driver than would be necessary if the situation were less complex. The study indicates, then, through accident experience, that lighting allows the driver to meet certain additional demands with no loss in safety.

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