problem identified. It is for this reason that full, definitive disclosure should be provided at an early stage in the design process so that solutions are incorporated architecturally in the design of the structure. We are also learning, by looking at examples of structures already built, that certain architectural configurations, like certain materials, pose greater visual hazards than others and should be avoided in environmentally sensitive areas such as along freeways.

Highly luminous light and reflected solar spot glare pollute the visual environment in much the same way that loud noises pollute the auditory environment. The solution is not reflecting it onto one's neighbors but rather trying to control it at the source or intercepting (absorbing) it before it does harm. Where neither of these solutions works, glare should at least be reflected away from those areas where it can do the greatest harm.

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Effects of Turning Off Selected Roadway Lighting as an Energy Conservation Measure

STEPHEN H. RICHARDS

In early 1973, the continuous roadway lighting on the southbound main lanes of Interstate 35 through Austin, Texas, was turned off as a power-saving measure in response to a critical area energy shortage. Analyses of accident data revealed that this cutback in roadway lighting significantly increased the frequency, rate, and severity of nighttime accidents in the affected freeway sections. The most notable increases were associated with a sharp rise in nighttime rear-end and pedestrian-related accidents. The cutback in roadway lighting saved approximately 450 000 kW·h of electrical power per year, enough to maintain 20 all-electric homes of average size for the same time period. In terms of energy cost savings to the city, this reduction amounted to $25 250/year. In addition, estimated savings of $2500/year in lamp-replacement costs were realized through the cutback. However, increases in accident costs after the lighting cutback were conservatively estimated to be slightly less than $17 000/year. Therefore, although positive energy conservation gains were made through the lighting cutback, these gains were accompanied by a measurable decrease in motorist safety.

On January 3, 1973, the Texas State Department of Highways and Public Transportation (TSDHPT) granted the city of Austin permission to turn off the continuous roadway lighting on the southbound main lanes of Interstate 35 through the city. The city requested the lighting cutback in response to a critical shortage of electrical power in the area. After the department's authorization was received, the lighting cutoff was carried out by city technicians between January 9 and 15, 1973.

The lighting reduction affected only the main lanes in three freeway sections that had a total length of 7.2 miles. Section 1 had median-mounted lighting and all lighting for the southbound lanes was turned off. Sections 2 and 3 had shoulder-mounted lighting on both northbound and southbound lanes and, again, all lighting for the southbound lanes was turned off. Ramp and frontage road lighting in the three sections was not affected by the cutback.

All three sections had four 12-ft travel lanes (two lanes per direction) with inside and outside shoulders. A 30-ft clear ditch median separated opposing traffic in section 1. A 20-ft raised median and semirigid barrier (W-beam section) separated traffic in sections 2 and 3.

Table 1 summarizes the roadway lighting characteristics of each of the three sections and also gives the average daily traffic (ADT) for each section averaged over the four-year study period. There were light to moderate increases in traffic volume on the three sections during the four-year study period, ranging from 6 percent for section 2 to 32 percent for section 1. In the computation of accident rates, 28 percent of the ADT was assumed to be nighttime traffic for all sections.

ACCIDENT STUDY

An extensive analysis of accident data gathered from all three study sections was conducted to determine the effects of the lighting cutback on motorist safety. The data, furnished by the Austin Transportation Department, consisted of computerized coded records of all accidents that occurred in the three sections during the study period. These records included information on accident location, type, and severity as well as lighting conditions during each accident. Two years of before data and two years of after data were evaluated.

The accident study revealed that 296 accidents were reported to have occurred on the main lanes of I-35 during 1971 and 1972 and 254 accidents during 1973 and 1974. It should be noted that, since entrance and exit ramp lighting was not reduced in the after period, accidents that occurred at the ramps were omitted from consideration.

Accident Frequency

Table 2 summarizes the changes in accident frequency that occurred between the before and after periods. The data in the table indicate that there was a significant decrease (-22.1 percent) in accident frequency in the after period except on the unlighted southbound side at night (1,2), where there was a significant increase in accident frequency (+47.1 percent) in the after period. The same trends were observed for all three study sections

Table 1. Lighting and traffic characteristics for three study sections.

Section	ADT (no. of vehicles)	Lighting		
		Location	Mounting Height (ft)	Spacing (ft)
1	22 300	Median	50	300
2	52 580	Shoulder[a]	30	175
3	42 050	Shoulder[b]	30	175

[a]Opposite. [b]Staggered.

Table 2. Statistical analysis of changes in accident frequency observed in after period.

Accident Group	No. of Accidents in Before Period	Change in After Period (%)	Confidence Level at Which Change Is Significant (%)	
			Chi-Square Test	Poisson Test
Lighted side				
Day	140	-24.2	95	99
Night	35	-25.7	85	95
Unlighted side				
Day	87	-17.2	85	95
Night	34	+47.1	95	99
All except unlighted night accidents	262	-22.1	95	99

individually. The overall trend toward decreasing accident frequency is attributed, at least in part, to adoption of the 55-mile/h speed limit in 1974. The significant increase in the frequency of nighttime accidents on the unlighted side in the after period is attributed to the cutback in roadway lighting.

Accident Rates

The same trends observed in accident frequencies were also noted in accident rates despite moderate to light increases in traffic volume in the after period. For example, the accident rate on the unlighted southbound side at night increased from 1.51 accidents/million vehicle miles in the before period to 1.91 in the after period, a 27 percent increase. However, accident rates for all other accident groups (northbound day, northbound night, and southbound day) decreased significantly in the after period. As noted earlier, in the computation of accident rates, 28 percent of the ADT was assumed to be nighttime traffic.

Accident Severity

The severity of accidents also increased on the southbound side in the nighttime after period. Although the frequency of fatal accidents remained stable in the before and after periods, the frequency and rate of injury accidents rose sharply in the after period, the frequency by 129 percent and the rate by 96 percent. In comparison, the number and rate of injury accidents in all other accident groups declined in the after period.

Accident Type

All types of accidents on the unlighted southbound side increased in the nighttime after period. There were 30.0 and 18.2 percent increases in sideswipe and one-car accidents, respectively. The most significant increases, however, were recorded for rear-end and pedestrian-related accidents. Nighttime rear-end collisions increased by 125 percent on the southbound side in the after period; the number of pedestrian-related accidents rose from zero to six. In comparison, nighttime rear-end and pedestrian-related accidents decreased in the after period on the northbound (lighted) side.

Accident Costs

From an economic standpoint, the cost of nighttime accidents on the unlighted side increased by $33 880 in the two-year after period. This amounts to an increase in accident costs of approximately $17 000/year. The cost of accidents in the other accident groups, however, decreased by $71 640 in the two-year after period. These accident cost figures were computed by using average accident costs for 1972 published by the National Safety Council (3).

ENERGY SAVINGS

An evaluation of the energy savings resulting from the lighting cutback was also made. The number of mercury vapor lamps, by wattage, that were cut off is given below:

Type of Lamp (W)	Number Cut Off	Power Reduction (W)
250	8	2 000
400	100	40 000
700	1	700
1000	69	69 000
Total	178	111 700

These data indicate that 178 lamps were turned off and that this resulted in a reduction of 111 700 W of power demand. Assuming 11 h of on time per day, this reduction yielded a savings in power consumption of 448 475 kW·h/year (the assumption of 11 h of on time is based on an average day length for central Texas of 13 h).

Based on the cost of electrical power in the area at the time of the lighting cutback (fuel cost of $0.029/kW·h and fuel adjustment charge of $0.025/kW·h), the reduced power consumption resulted in a savings of $24 200/year to the city. If one relates these savings in electrical power to other uses, the power saved in one year by the lighting cutback could have been used to maintain 20 all-electric homes of approximately 1500 ft² for the same time period. This approximation is based on an average rate of electrical power use of 1958 kW·h/month for all-electric homes in the central Texas area.

LAMP-REPLACEMENT COSTS

Although not extensively analyzed, the savings in lamp-replacement costs resulting from the lighting cutback were also considered. The costs of mercury vapor lamps used in computing these savings are given below:

Type of Lamp (W)	Cost ($)
250	15.5
400	18.0
700	23.0
1000	28.0

A liberal replacement rate of 33 percent/year was assumed. The costs for labor and installation equipment were assumed to be equal to the lamp costs; therefore, the total yearly cost savings for lamp replacement were roughly estimated to be two times the cost of the lamps that would have needed replacement each year. By using these assumptions,

combining the data from the two tables above yields an estimated savings in lamp-replacement costs of $2500/year. Although this figure is only approximate, it indicates that lamp-replacement cost savings are a relatively minor consideration. In fact, the savings represent only 10 percent of the savings realized from reduced power consumption.

PUBLIC ATTITUDE

At the time the city made its request for reduced roadway lighting, the Austin area was experiencing a severe energy shortage. The shortage was brought about by the failure of the city's contracted natural-gas supplier to furnish sufficient quantities of natural gas to meet all of the area's electrical power needs. It appeared that the shortage would be long term and that there would be critical peaks dependent on environmental conditions. In response to the energy shortage, the city launched an extensive campaign for energy conservation. The lighting cutback on I-35 was a sincere attempt by the city to make apparent its willingness to contribute to this conservation program.

A critical concern, then, is the effect that the reduction in roadway lighting had on public attitude toward energy conservation. Unfortunately, very few conclusive data were available on public reaction to the lighting cutback. Personnel of the Austin Transportation Department and TSDHPT who were interviewed in conjunction with this study indicated that they received only a minimal amount of reaction from the public in the form of complaints or praise.

CONCLUSIONS

Based on the findings of the research reported in this paper, a substantial cutback in roadway lighting on urban and suburban freeways may not be a satisfactory energy conservation measure. The savings in electrical power consumption associated with such a cutback are offset to a large extent by significant increases in accident frequency and severity resulting from the added hazard of nighttime driving on an unlighted or partly lighted roadway. In addition, the savings in lamp-replacement costs and gains made toward increasing public awareness of the energy problem appear to play only a minor role in determining the effectiveness of a lighting cutback to conserve energy.

It should be noted that this study only addressed one strategy for conserving energy consumed by roadway lighting installations--i.e., turning off the lighting. There are other conservation techniques--e.g., conversion to high-pressure sodium lamps and staggered lighting cutbacks--that may result in substantial energy savings without adversely affecting traffic safety. In addition, no attempt was made to measure or calculate lighting levels in the affected sections.

In 1975, the findings of the study were forwarded to the Austin Transportation Department. Since then, the roadway lighting on I-35 through Austin has been returned to its full level of operation.

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Abridgment

Operational Field Study of Urban Freeway Guide Signing in Dallas

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A traffic operational field study conducted on an urban freeway in Dallas, Texas, is described. Major signing modifications were made to the freeway guide signing by state forces exogenous to the research effort. Before and after study data on lane volumes, lane changes, and erratic maneuvers were collected and evaluated. Some specifics and a few general conclusions and recommendations are offered. The operational field study was conducted along westbound I-30 near downtown Dallas. The before study was conducted during 1977 and the after study in 1979. During this period, the freeway guide-signing system was updated to 1970 Manual on Uniform Traffic Control Devices standards. Operational studies of volumes, lane changing, and erratic maneuvers were made to determine what effects might be attributed to the signing and what changes, if any, occurred as a result of these changes. Some positive operational changes were noted, but the causal relations were clouded by the fact that the Dallas-Fort Worth Turnpike was made into a toll-free road (I-30) between the before and after studies.

Traffic operational field studies were conducted along Interstate 30 in Dallas to determine what changes, if any, occurred in the traffic flow due to changes made in freeway guide signing. Operational performance measures used to determine operational changes included lane volumes, lane changes, and erratic maneuvers.

LOCATION OF STUDY SITE

The study site was located along westbound I-30 near