requirements. It is not, however, recommended that decreased post spacing be substituted for a structurally adequate connection because the tension capability in the guardrail is the single most important design element.

The results of this study will be used in the formulation of NDR policy on guardrail design, installation, and maintenance. The methodology and procedures developed will be included in NDR design procedures and will increase the ability of the department to evaluate new systems through the cost-effectiveness calculations based on BARRIER VII simulations.

Based on the results of this study, there has been shown to be reasonable doubt as to the cost-effectiveness of the stiff-post system under a wide range of impact conditions. A more detailed examination of the total effectiveness of the stiff-post system is needed. Further research should be conducted to compare the performance characteristics of the two systems by means of full-scale testing and computer model simulations.

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Conflicts Between Vehicle Traffic and Utility Facilities

DON H. JONES

Conflicts between vehicle traffic and utility facilities are examined in a before-and-after study of a heavily used section of a four-lane major arterial in Knoxville, Tennessee. At the beginning of the study, many utility facilities were located in the roadway and at the back of the curb in close proximity to moving traffic. Some of the underground facilities in the roadway were relocated under or to the far side of the sidewalk, and all utility poles were relocated to the far side of the sidewalk and to one side of the street. Prior to the relocation, there was a high incidence of vehicle collisions with aboveground utility facilities and considerable traffic delays caused by maintenance of underground facilities on this section of highway. In the five years since the relocation, no collisions with utility facilities have been reported. Other factors examined include accidents involving the failure of pavement cuts made when underground facilities were repaired or installed, delays resulting from utility operations, and user costs resulting from traffic delays and accidents in which utility facilities are involved. The study shows not only that serious conflicts exist in certain locations but also that considerable improvement can be achieved through cooperation in planning, design, and operations between highway agencies and utility agencies.

Utility facilities are a part of the transportation system, moving important products, such as water, gas, electricity, and communications, from sources to destinations. Problems occur when utility facilities are brought into direct contact with other transportation facilities, such as the highway and street network. When highways and utilities are merged, conflicts arise that are not easily or economically resolved.

Highways and utilities serve two totally different purposes. The highway and street system is for the purpose of moving people (as well as freight and goods) at high rates of speed and in heavy vehicles. Utility facilities move commodities--water, electricity, sewage, or communications--that are different in nature and for a different purpose.

Utilities have always shared rights-of-way with highways. This need, long recognized by law, varies only slightly from state to state with regard to occupancy and installation rights. Rights and needs to share rights-of-way are generally and mutually recognized; the difficulty occurs when service to one mode is interrupted or interfered with by the opposite mode. Furthermore, other factors, such as aesthetics and crowding, tend to aggravate the perceived adverse relation when conditions such as interrupted service develop.

This paper discusses the problems encountered in conflicts between highways and utilities and their possible solutions. The problems are presented from the following viewpoints:

1. Utilities are generally installed on existing highway rights-of-way.
2. The health, safety, and welfare of the

motoring public are of paramount concern.

3. The problems involved, whether perceived, actual, or a combination of both, are solvable.

4. Roadways and utilities are maintained by two different groups that are interested in serving their own personal interests.

The data and information presented here are based on a study begun in Knoxville, Tennessee, in 1963 (1). An extensive report dealing with the conflicts between utility facilities and highway traffic was published in 1969. A major relocation of the communication lines was begun in 1968. This consisted of relocating the overhead lines and some underground lines in the middle of the street to an area under the sidewalk. The overhead power lines were relocated in 1974. These changes brought about a substantial reduction in conflicts with vehicle traffic and an improvement in the appearance of the community. The study included a citywide sample of accidents involving utility facilities and focused on a heavily used major arterial that seemed to have an unusually high accident rate, particularly of accidents involving utility poles.

The city of Knoxville is reasonably representative and has a population of about 150 000, which is continuing to increase rapidly. The city has a good mixture of diverse occupations, including a large industrial commercial base. It is a hub city for banking and wholesale-retail businesses and is surrounded by a large agricultural base. Knoxville supports a large community of science- and research-oriented citizens and also has a university campus with an enrollment that is among the 20 largest in the country.

UTILITY LOCATION POLICY

The general policy for sharing rights-of-way has been for utilities to locate as near the roadway as possible. In urban areas, underground facilities are usually located under the pavement and overhead lines are at the back of the curb or very near the edge of the pavement. Since highways and streets are usually designed and built to serve only vehicle traffic, the utility is viewed as a trespasser, and any installation or maintenance has the potential for disrupting traffic. Utilities usually view their work as being necessary and of short duration and see the problem as being one of lack of patience on the part of highway users. Although there has been a marked improvement in recent years in cooperation between highway users and utility groups, historically there has been a lack of understanding by both groups of each other's needs and problems. Relations are strained by such things as vehicles knocking down utility poles and fire hydrants and utility companies blocking traffic for maintenance and installation purposes. The utility group views as too harsh the requirements and regulations governing backfill procedures, signing, and flagging, and the highway-street group views the utilities as trying to short-circuit the standard operating procedures and sound engineering practices normally used in highway operations.

Group meetings to discuss the reasons for certain specifications or mutual concerns are not the standard mode of operation. Although meetings do occur occasionally and some are productive, most are scheduled as a result of a prospective change in the utility's plant or in the roadway, and the meeting usually takes place only between the utility representative and the highway utility officer. Many cities lack a formal and separate street organization. Many diverse engineering operations are placed under a public works administrator who is responsible for several areas, including streets and sanitation and storm sewers. Other utilities, such as gas, electricity, and sometimes water, are separate entities in the management scheme. As a result, there is little, if any, coordination of street and utility operations.

NATURE OF THE CONFLICTS

The fact that any conflict occurs between highway vehicles and utility facilities is sufficient to warrant an examination of the causes, kinds, and extent of the conflicts and policies on utility installation and maintenance. Before this study began, however, there was an unproved theory that a large number of accidents involved utility facilities. As a result of that theory, an effort was begun by highway department representatives in that region of Tennessee where the study was conducted to have all relocated utility facilities placed at the back of the sidewalk or along the right-of-way lines as far away from the traveled lanes as possible. Unusually strong resistance was encountered--partly because of typical resistance to change, partly because of economic reasons, and partly because of utility company concern that they would eventually be forced from highway rights-of-way. This resistance might not have been so great had documentation of accidents and their causes been a part of the evaluation and planning process. From these rather difficult beginnings, the study discussed here was begun.

An examination of vehicle accident records for the specified study section for a number of years revealed many accidents involving utility facilities (1). The following table gives the number of accidents for each type of utility facility over a six-year period:

Type of Facility Involved	Number of Accidents
Utility poles	103
Fire plugs	8
Bus benches	1
Mailboxes	7
Signs	6
Guy wires	2
Telephone booths	2

Table 1 gives data on utility-facility accidents for four locations over a six-month period. The data indicate that a disproportionately high number of these conflicts involved utility poles and that a disproportionately high number of personal injuries and fatalities occurred in collisions with utility poles (see Figure 1). A survey of newspaper articles also revealed that the conflicts were not just related to recent times and/or high-volume highways and streets (2, p. 1). One should also note that the selected study site had at least a 30-year history of vehicle accidents involving utility facilities, especially poles.

Observations during the long study period also substantiated suspected conflicts of a different nature, particularly those involving pavement cuts (see Figure 2). Pavement cuts in urban areas are rather common. During the study period, numerous failures of the restored cuts were noted. A search of accident records did not indicate a high incidence of accidents involving the failure of repaired pavement cuts. However, through a careful search of newspaper articles and interviews with police traffic officers, the reason for the lack of data was determined: Very few accidents of this type were formally reported.

Accidents involving burst tires, wheels knocked

Table 1. Comparison of accidents involving utility facilities for six-month period at four Knoxville locations.

Location	Total Number of Accidents	Accidents Involving Utility Facilities: Number	Personal Injury	Fatal	Number of Drunk Drivers Involved
Kingston Pike	66	17	8	2	1
Broadway	325	9[a]	5	0	0
Chapman Highway	236	7[b]	5	0	1
Clinton Highway	122	4[c]	2	0	1

[a] Involved utility facilities located at the back of the curb.
[b] Involved utility poles located at the back of the curb.
[c] All vehicles struck utility poles in the median area.

Figure 1. Low-speed head-on collision with a utility pole that resulted in personal injuries.

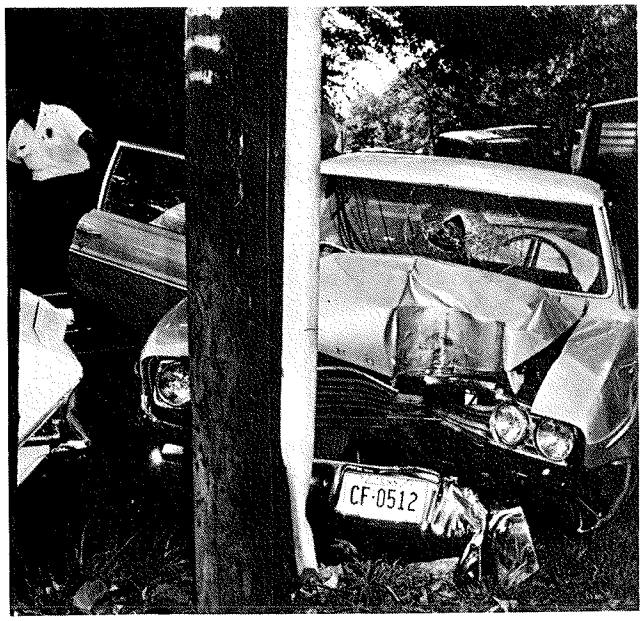


Figure 2. Failure of pavement over new installation of a sanitary sewer line that resulted in several accidents involving property damage and minor personal injury.

Figure 3. Traffic queue caused by maintenance of a utility facility.

out of alignment, or ruined shocks were rarely reported. These types of accidents usually did not involve personal injury. Most were reported by telephone. The caller would give the location of the pavement failure and indicate only that there was a hole in the pavement. A call to the utility company involved would usually result in the quick dispatch of a truck and crew to place a saw horse with a flashing lantern as a warning to motorists. Repairs were begun as soon as possible.

Such problems do not occur often at a given location and, after one or two return trips for repairs, the serious, hazardous failures no longer seem to occur. Yet, as Figure 2 indicates, poorly repaired pavement cuts sometimes create a serious problem that can result in serious accidents involving personal injury (3, p. B-1). It may be better in the long run to install all underground facilities in locations other than directly under the traffic lanes. On the other hand, proper methods of backfilling and pavement patching would eliminate this type of problem.

Probably the most visible encounter between utilities and the traveling public involves delays resulting from the maintenance of utility facilities (see Figure 3). Accidents that occur in this situation are usually slow-moving, rear-end collisions or occasionally sideswipe or lane-change collisions. Accident reports rarely note a utility maintenance operation as a contributing factor (4, p. 10). The most obvious result of these delays is economic, because of lost time and higher operating cost.

The nature of the conflict between vehicles and utility facilities, as noted in the University of Tennessee study (1), generally consists of collisions with such objects as poles, fire hydrants, and phone booths; vehicles running into depressions caused by collapsing patches of pavement; and delays caused by utility maintenance, repair, and installation. A literature search provided little information to support the study findings, since few research projects in this area had been conducted at that time. However, a few research studies that support the findings have been conducted since 1970, most relating to utility poles (5-7). Some of the reports cited quote statistics that indicate that a serious problem does indeed exist.

EVALUATION OF CONFLICTS

The original study cited here examined a 3.25-km (2-mile) section of a major arterial that was

Figure 4. Typical collision diagram for a location that has a high incidence of conflicts between utility poles and vehicles.

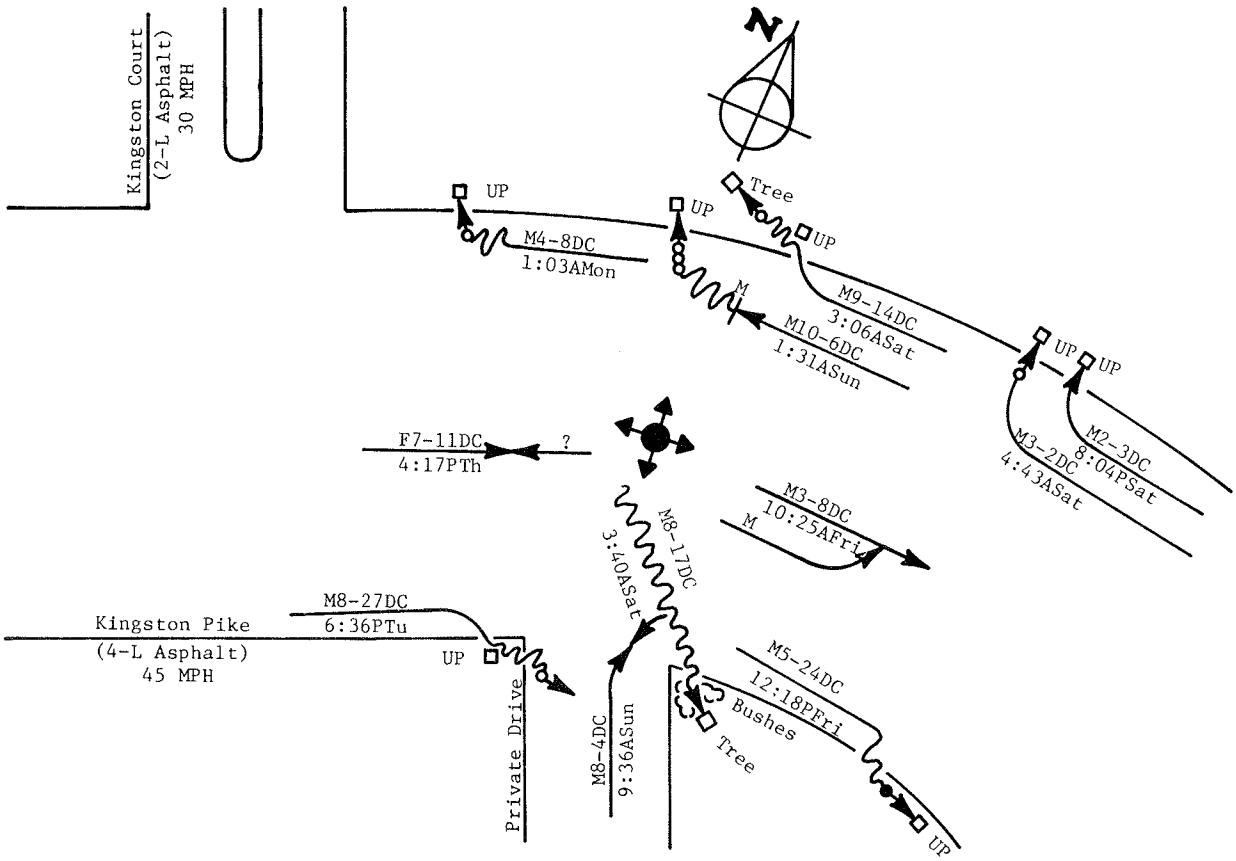
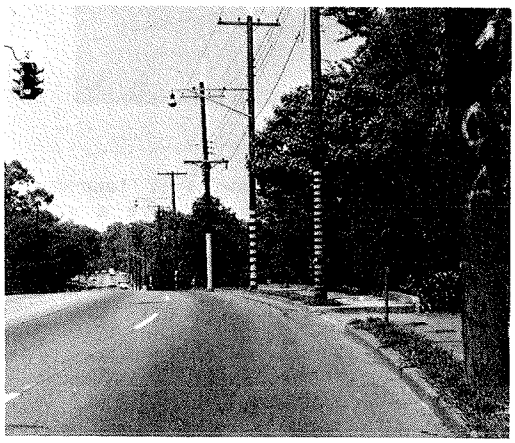


Figure 5. Utility poles located too close to the roadway on a superelevated curve and painted in an attempt to reduce accidents.



purported to have a high incidence of accidents involving utility facilities. The collision diagrams prepared from police accident reports for that highway section bore out the suspicions (1). Figure 4 and the following table illustrate the accident data for the period from January 18 to October 14, 1968:

Category	Day	Night	Total
Total accidents	5	6	11
Fatalities	1	0	1
Injuries	1	6	7
Property damage only	3	2	5
Utilities involved	2	5	7

An analysis of the accident data consistently pointed to one thing--that utility facilities were located too close to moving traffic. Utility poles, guy wires, and fire hydrants were usually placed at the back of curbs and occasionally in the street. They were often placed only 15 cm (6 in) from the pavement edge on the outside of nonsuperelevated curves (see Figure 5). Of course, those utility facilities located under the pavement not only disrupted the flow of traffic when they were repaired but also presented a traffic hazard when improperly compacted backfill failed under pavement patches.

The utility companies were somewhat aware of the conflicts between vehicles and their facilities. In some cases, where particular poles were often struck, extra precautions had been taken to protect the facilities with heavy concrete barriers (see Figure 6), steel posts concreted in the ground, or other devices. Many of these barriers were placed along routes where posted speeds were 45 miles/h or higher. A utility pole is a fixed object that will break when struck with enough momentum, although usually not before destroying the striking vehicle and its contents. A concrete barrier is a fixed object that is almost indestructible (Figure 6).

In analyzing the accident data, it was difficult to determine whether the struck utility facility was a primary or secondary accident factor. Herein lies the basis for the argument that the accidents were the fault of the drivers and not the utility facility. In accidents that involve pavement failures over underground utility facilites, there is little doubt as to who is at fault (although responsibility, liability, and negligence may be factors to be decided through legal proceedings). But collisions that involve roadside objects such as

Figure 6. Protection of utility poles with heavy concrete encasements that created a much worse hazard for vehicles.

poles and fire hydrants are another matter. It can be claimed that the poles blocked the view or interfered with sight distance.

The evidence seems to indicate that struck poles are secondary factors in many vehicle accidents. Some typical examples are a pole being struck after control of the vehicle is lost on wet pavement or a pole being hit by a vehicle that is forced off the road or out of a lane by another vehicle that is attempting a lane change. The utility pole is considered a primary factor when, for example, the operator of a vehicle that pulled out from a driveway or a side street into the path of an oncoming vehicle reports that the view was blocked by utility poles at the edge of the pavement or the running lane. In one incident, a pole was knocked down by one vehicle and immediately struck by another (1).

A great deal of disagreement may arise over the causes of accidents occurring in a queue that is the result of a utility operation such as that shown in Figure 3. Direct collisions with utility barricades, with utility vehicles parked at the scene, or with parts of the facility--e.g., manhole covers--may constitute primary or secondary involvement of the utility facility. These types of collisions are also well documented in the University of Tennessee study (1).

Accidents that occur well back in a queue are not so easily reconciled. Would they have occurred if the queue were not present or if the utility operation were not present? However, the only concern here is that the accident occurred in a queue that resulted from a utility operation and interfered with or disrupted the movement of traffic.

The argument over who creates the problem seems endless. The utility company can often and justly argue that utility facilities, such as poles, are frequently destroyed by vehicles, so that large areas are left without vital power and communications. The counter argument may be that the highway has paramount rights and utilities should be placed somewhere else. And so the costly problem goes on.

COST STUDIES

Deriving the cost involved in conflicts between highways and utilities is not easy. The Texas Department of Highways and others (8) have developed procedures for inventorying roadside hazards and for developing safety improvement alternatives. Wright and Robertson (6) developed procedures for determining probable sites with high rates of accidents that involve roadside hazards and for setting priorities for modifications. Jones (1) developed some procedures for costing out accidents and delays resulting from vehicle-utility conflicts. The procedures are cumbersome and fragmented and often require on-site studies. On-site analysis can feasibly be conducted by the utility agency involved, but utilities seem reluctant to conduct such studies. Yet good bases are available for developing excellent cost estimates.

For delays caused by queuing around utility operations, one must begin with traffic-volume studies. If these are not already available, they must be conducted to derive average daily traffic, peak-hour volume, weekday volume, etc. Cooperating utility companies can provide dates, the nature of the operations, and the costs for crews, equipment, and materials.

In studies of the cost of delays, some typical data must be gathered--e.g., the average number of stops per vehicle while the vehicle is in the queue and before it passes the point of interference. The total effect on all directions of traffic movement must be determined. Some idea of the average number of collisions between vehicles and utility-related equipment must also be developed. If on-site analyses are made, all of the factors are included as data collected at the site; however, the dependability of the data must be considered and appropriate factors included, if necessary.

Again, most utility companies can provide actual cost data for each operation, including fringe benefits and overhead cost. For accidents involving property damage, personal injury, and fatalities, cost data are published intermittently by the National Safety Council, the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (9), and others. These data can be used in costing accidents. Otherwise, insurance claims, court awards, and out-of-court settlements would have to be evaluated, which is not an easy task.

The cost of accidents involving utility facilities was determined for a nine-month period in 1968 over the 3.25-km (2-mile) study section by using cost data and appropriate interest rates. This cost amounted to about $136 000. Today, the cost of the same accidents would probably approach $500 000. Two incidents that involved substantial delays were costed out at an average of $1655/incident in highway user costs (1). These were substantial costs for 1968. In developing such cost analyses, attention must be given to the category in which the costs are placed. Rarely are benefits or utility enhancements involved, except for the possible extension of service life for the one pole, hydrant, or other unit involved. The questions of when to apply interest rates and what rates to apply also require attention, especially today.

Figure 7. Study area after major relocation of utility poles.

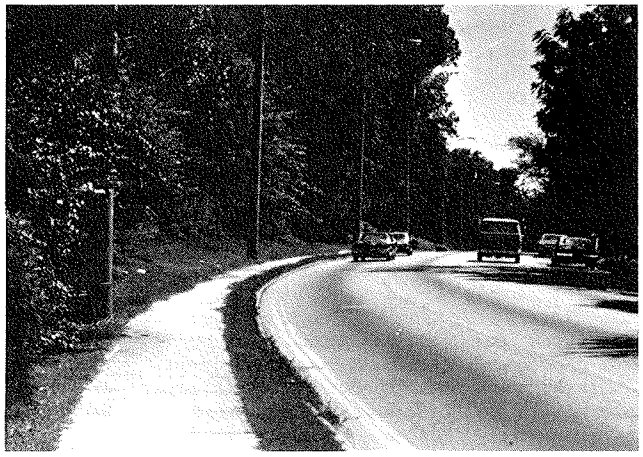


Table 2. Comparison of personal injuries and fatalities before and after completion of major 1974 relocation of utility poles.

Year	Average Daily Traffic	Personal Injuries	Fatalities
1963	27 470	8	0
1964	24 940	8	1
1965	20 900	3	1
1966	20 860	18	0
1967	19 550	11	0
1968	22 143	16	2
1974	25 230		
Before		4	1
After		0	0
1975	28 190	0	0
1976	28 650	0	0
1977	25 570	0	0
1978	26 600	0	0
1979[a]	32 090	0	0

[a]Through August.

REMEDIAL MEASURES

The study completed in 1968 pointed out that, in the first nine months of that year, 16 persons were injured and 2 were killed when vehicles struck utility poles over the 3.25-km highway section studied. The study also noted that this section of highway had probably the highest rate of accidents involving utility facilities in the city of Knoxville. The study also pointed out that there were other sections of highways within the urban area where the rates of such accidents approached this one and that special attention should be given to particular locations. The study received widespread publicity in the local news media. City officials, including the city traffic engineer, and officials of the utility agencies conducted a number of discussions and planning sessions. Estimates for some recommended adjustments to the utility facilities, such as the cost of placing overhead lines underground, were developed. Many other alternatives were also examined in the study, such as locating utility facilities in alleys and putting utility vaults under sidewalks and special utility strips.

In the period from 1968 to the present, action was taken in the four areas described below.

Relocation of Overhead Lines

The owners of overhead communication lines assigned first priority to the highway section under study and, slipping some other proposed improvements back in their program, began immediately to relocate overhead lines underground and to remove some troublesome facilities from underground locations in the middle of the street to an area under the sidewalk or to the far side of the sidewalk. This work was begun in 1968 and completed in about 1970. It resulted in a substantial improvement in the costly disruptions of traffic that had been caused by frequent maintenance of such communication facilities. It did not, however, result in the removal of a single utility pole, the only utility elements involved in vehicle collisions in which personal injuries and fatalities were reported.

Adjustments to Utility Facilities

Some welcome financial relief came in the form of the Traffic Operations to Increase Capacity and Safety (TOPICS) program. No TOPICS money was used in the 3.25-km study area; however, in other locations chosen for redesign under the TOPICS program, utility facilities were a major consideration and were relocated if they were considered to present a hazard. But many problems emerged in the TOPICS projects where substantial adjustments to utility facilities were considered necessary. The utility agencies were not compensated for adjustments to their facilities if they were on public rights-of-way. The utility agencies felt, in some ways, that they had been "had" again. But more effort was made under this program to point out and explain the necessity of relocating poles from corners, from just behind the curb, and from the middle of the highway. Another problem that arose under the TOPICS program was the virtual impossibility of attributing specific portions of improvements in traffic flow and accident rates to the utility adjustments because so many other elements at the selected sites were changed. However, improvements in traffic flow and accident rates at each site where utility facilities were adjusted were so great that it was felt that some contributions had been made by these adjustments.

Relocation of All Utility Poles

Relocation of all utility poles on the 3.25-km study section did not occur for some time. By 1971, the recommended relocation of utility poles appeared to be a dead issue. But a new city mayor was elected that year, and he immediately resurrected the study and mandated the relocation of all utility poles in the 3.25-km highway section as part of a beautification and safety program. The final approved plan included the relocation of all poles to one side of the street, to an area behind the sidewalk, about 1.83 m (6 ft) from the permanent edge. Large steel poles were used. Considerable thought was given to blending the poles and the overhead lines into the surrounding environment of well-landscaped estates, shrubs, and walls. The spacing of the new poles was to be increased as much as possible over the maximum spacing of 45.7 m (150 ft) for the existing poles. Special attention was to be given to sites that were considered to be especially hazardous.

The city agreed to bear most of the cost of the relocation, which was completed in 1974 (see Figure 7). Ironically, before the relocation was completed and the old wooden poles were removed, four personal injuries and one fatality occurred. The good news, however, is that the total accident rate dropped substantially after the relocation was completed. No more utility poles have been struck to date, even

though average daily traffic has almost doubled. Table 2 gives a comparison of accidents involving utility facilities and resulting in personal injuries and fatalities for the years 1963-1968 and 1974 through August 1979. The data are taken from 1963-1968 traffic records of the Knoxville Police Department and from 1974-1979 accident records in the Tennessee Department of Transportation (DOT) computer bank.

Other Programs

Other programs that have helped are the program of high-accident-site studies and the Governor's Highway Safety Program. Generally, no funds have been available to assist utility agencies in relocating or adjusting facilities that were located on public property. But these programs have created an awareness of hazardous conditions and have pinpointed locations where accidents or serious injuries and fatalities consistently occur.

Most utility agencies respond favorably to good documentation and supporting evidence, since they share the concerns of the highway agencies for highway and community safety. FHWA has considered the possibility of reimbursing utility agencies for the adjustments and relocations required to improve conditions at sites where accident rates are high. Under current law, however, FHWA can only participate in such activities to the extent to which the states participate. As a result, in many states reimbursement is approved only if the utility facilities are located on private property, in which case 100 percent of the cost involved is reimbursed to the utility. In many states, and especially in Tennessee, if the facilities are located on public property, the utility agency must bear the total cost except on Interstate highway projects (10).

CONCLUSIONS

During the past 15 years, there has been considerable evidence that conflicts do occur between vehicle traffic and utility facilities when the two are in very close proximity. However, utility agencies and highway groups (traffic engineers, utility relocation personnel, and safety program administrators) still seem reluctant to discuss openly and candidly such issues as legal requirements, financial constraints, hazardous or potentially hazardous conditions, and cooperation through joint planning.

Many roadway sites are made extremely hazardous by the location of utility facilities. Minor adjustments or relocations can often solve the problem; in some situations, however, such as that presented in this paper, a costly and extensive relocation may be the only practicable solution. Through cooperative effort and financial participation, adequate solutions can be found.

Today, a great deal of emphasis is placed on the cost-effectiveness of almost any activity. Although procedures are available for determining the cost-effectiveness of utility adjustments or relocations to alleviate vehicle-utility conflicts, this should not always be the sole criterion. When the potential for personal injuries and fatalities exists, corrective action must be taken. Customer service is not going to be improved by a utility agency adjusting its facilities to alleviate a traffic problem, and benefits to the highway user are not going to accrue to the utility. But it is necessary and beneficial to the community for the utility to pursue every avenue of potential financial assistance.

There is a need for closer interaction between agencies, beginning at the local planning and development stage and continuing through regular group meetings, so that a feeling of mutual cooperation can be developed. Both utility agencies and highway agencies have the potential to help each other, but this potential is not always fully realized.

There seems to be more awareness today of potential conflicts between vehicles and utility facilities and operations. There also seems to be more cooperation between agencies to improve potentially hazardous conditions. This is probably the result of continuing research efforts, publications, both favorable and unfavorable publicity through the news media, numerous safety programs, and more and more lawsuits challenging both utility agencies and highway agencies. No matter what the reasons, the increased cooperation is welcome.

It is strongly recommended that highway-utility liaison groups be established to develop better communications. Perhaps representatives of the utilities could be appointed to the highway safety committees that are active in many states in the review of hazardous locations. Utility companies could be provided copies of accident reports for cases in which utility facilities are involved. Such programs could result in greater cooperation and assist in locating funding for some of the changes considered necessary for safe highways and unhampered operation of utilities.

ACKNOWLEDGMENT

The research for the original study discussed in this paper was funded in part by the Tennessee DOT and the University of Tennessee. I performed all of the work, from 1963 to the present, as an employee of these two agencies. In essence, therefore, all support, financing, and encouragement have come from these two agencies. The Knoxville Police Department provided space and access to traffic records over a period of months and cooperated in a number of interviews. The Knoxville News-Sentinel was probably the greatest supporter of the project. Former Knoxville mayor Kyle Testerman was the individual most responsible for accomplishing the relocation of utility facilities that resulted in a substantial reduction in traffic accidents, apparently eliminated the conflict between utility poles and vehicles, and greatly enhanced the aesthetic environment of the area. I am most grateful to all these agencies and to some very close friends within them.

The views and opinions expressed here are solely my own, and I am responsible for the content and the accuracy of the data presented.

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