

REDUCTION IN FREEWAY CONGESTION BY USAGE OF ACCIDENT INVESTIGATION SITES

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Accident investigations conducted on the freeway shoulder cause freeway congestion and delay to motorists. If the accidents are investigated off the freeway at a site concealed from motorists, congestion and delay will be reduced, and traffic flow will return to normal more rapidly. Sixteen accident investigation sites were designated along a 6-mile section of the Gulf Freeway in Houston. Eight of the sites are located on city streets adjacent to the freeway; two are located on city streets under the freeway; and the other six are on unused space within the freeway right-of-way. Houston police officers began using the sites on July 12, 1971. Data were collected for 1 year through supplementary accident report forms that each investigating officer filled out. During the first year of operation, 851 accidents were reported in the study area, and the sites were used for 339 investigations (40 percent usage). In addition, another 176 investigations were conducted at other off-freeway locations (21 percent). Benefits in terms of delay saved from usage of the investigation sites and other off-freeway locations amounted to \$203,000. Construction costs were prorated, and the annual cost and the maintenance costs were estimated at \$8,000. For the first year of operation, the benefit-cost ratio was 28:1. Analysis showed that the sites under the freeway had a higher usage rate than those located on city streets.

•**MOVEMENT OF VEHICLES** on urban freeways has become an important part of a metropolitan area. Motorists usually find uninterrupted flow and few hazards on a freeway. However, freeway incidents such as accidents or stalled vehicles cause congestion on the freeway and delay to motorists. When such an incident occurs, one or more lanes are blocked resulting in a bottleneck situation and reduction in freeway capacity. Normally, an accident causes more freeway congestion than a stall because it requires police investigation. The degree of congestion and delay caused by an accident depends on the length of time that the accident vehicles block a lane and are visible to motorists. Police usually investigate accidents on the freeway shoulder, thus extending the time period during which motorists are distracted by the accident vehicles.

POSSIBLE SOLUTION

The premise of this study is, if an accident investigation is made at a location not visible to freeway motorists, congestion and delay will be reduced and the traffic flow will return to normal more rapidly. This paper presents the more important findings of the first year of operation of a system of accident investigation sites (AIS). The sites, located on a section of the Gulf Freeway (I-45S), are concealed from freeway motorists and are used by the police to make their accident investigations.

The Texas Transportation Institute (TTI) with the cooperation and assistance of the Texas Highway Department, District 12, designed and evaluated the AIS system. The AIS study was carried out in cooperation with the Houston Police Department (HPD) and

Publication of this paper sponsored by Committee on Traffic Law Enforcement.

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the City of Houston. More complete details of this study have been published by the Texas Transportation Institute (1).

SOME PREVIOUS RESEARCH

This study is an outgrowth of earlier research of accidents in moving freeway lanes. In 1963, Wilshire and Keese (2) conducted a study on the effects of traffic accidents on freeway operation and the methods of accident investigation. In their conclusions they stressed the importance of clearing the freeway of all visible signs of the accident as quickly as possible. Lynch and Keese (3) evaluated the average time elapsed between the time of the accident and the time when the damaged vehicles were moved from the roadway. They recommended that studies be conducted to devise procedures for more rapid removal of accident vehicles. In 1969, Goolsby (4) recommended the designation and construction of accident investigation sites on the Gulf Freeway. His study showed that on the average a minor accident, occurring during peak periods, affects traffic flow for 41 min, and, of this, 24.5 min are spent in police investigation. When the accident investigation is conducted at a site off the freeway, the accident affects traffic flow for only 16.5 min. Goolsby (5) further determined that a minor accident blocking one lane of a six-lane facility reduces capacity by 50 percent even though the number of lanes is only reduced by 33 percent. Also, if the damaged vehicles are moved to the freeway shoulder, the main-lane capacity is still reduced by 33 percent because of the "gapers-block" phenomenon.

PILOT STUDY SYSTEM

The Gulf Freeway was selected for the study because of the research and surveillance facilities located there. The Surveillance and Control System, used by THD and TTI, consists of inbound entrance-ramp signals, two digital process control computers, and a closed-circuit television system. Designed and built in the late 1940s, the Gulf Freeway is a six-lane facility with a theoretical capacity of 6,000 vph in each direction of flow. The six main lanes are complemented by an adjacent noncontinuous frontage road, and a slip type of design is used for the ramps.

Location of Sites

Sixteen accident investigation sites were chosen along a six-mile section of the Gulf Freeway from Dowling Street to Broadway Street because of their accessibility from the freeway and concealment from freeway motorists. A site was located downstream of each exit-ramp (Fig. 1). The minimum preparation for all sites was the installation of direction signs and NO PARKING signs. Direction signs consisted of a sign(s) on the service road directing people to the site and a sign designating the site. NO PARKING signs were posted at each site to ensure available space for the investigation and accident vehicles.

The investigation sites were grouped into three types by location: on a city street, on a city street under the freeway, and on unused space within the freeway right-of-way. The first two types have the advantage of low cost, whereas the second and third types are usually more accessible. Figure 2 shows typical layouts of the investigation sites.

Because most sections of the Gulf Freeway are at-grade with the service road and city streets, many locations within the freeway right-of-way are visible to motorists. Therefore, eight sites were located on city streets adjacent to the freeway. Besides being downstream of an exit-ramp, these were on streets with light traffic flow. The only expense for preparation was \$35 per site for signs.

At one freeway overpass, the crossing city streets carry a minimum of traffic flow; therefore, two accident investigation sites were located on these streets under the freeway. Available space under the overpass could have been used; however, to reduce costs, the city streets were selected. The necessary costs were \$35 per site for installation of signs.

Design of Sites Requiring Construction

A typical accident investigation involves five vehicles: one police car, two damaged vehicles, and two wreckers. If it is assumed that each vehicle requires a 10- by 20-ft space to park, a typical site should contain at least 1,000 ft² of space. The six constructed sites have a surfaced area of approximately 30 by 85 ft, or 2,550 ft². The extra area provides a lane for driving.

One of the constructed sites is located in an open area off a city street. The ground, near a preexisting luminaire, was graded and paved. This construction amounted to \$3,200, and an additional \$35 was spent on installation of signs.

The five sites constructed under the freeway were also graded and paved, and guard-rails were placed between the pavement and the bridge supports for protection. To discourage local use of the sites, the access road between the service road and the site did not provide smooth curves for turning into the sites. All of the construction work amounted to about \$3,200 per site. In addition to direction and NO PARKING signs, it was necessary to add two clearance signs. NO THRU TRAFFIC signs were also installed to discourage motorists from using the sites for U-turns. Cost of the various signs amounted to \$115 per site. Because existing street lighting did not provide sufficient illumination, additional lighting was mounted under the overpasses. Installation of the lighting increased the construction costs at each site by about \$2,800.

Of the 16 investigation sites located on the 6-mile section of the Gulf Freeway, four sites are accessible from either the inbound or outbound direction, six sites are accessible to inbound traffic only, and six sites are accessible to outbound traffic only. Therefore, a site is located an average of every 0.6 mile for either the inbound or outbound direction. Of the six sites requiring extra construction, four sites are accessible from both directions, whereas the other two sites are accessible from one direction only.

Study Procedures

HPD officers began using the sites on July 12, 1971. Prior to this date, booklets identifying the location of the investigation sites were distributed to the police officers. At that time, they were also given supplementary freeway accident report forms to be filled out at each freeway accident. To provide a basis for the total city, officers investigating accidents on all freeways in Houston were requested to fill out the forms; therefore, freeway accidents were reported 24 hours a day, 7 days a week. These forms were revised in mid-August after representatives of TTI, THD, and HPD decided that the information provided on the original forms was confusing about location of the accident and location of the investigation. By mid-September, the revised forms were being used by a majority of the officers. Each investigating officer was requested to include the following information on the forms: date, time, location of accident, location of investigation, why investigation site not used, length of investigation, and officer's name.

DATA ANALYSIS

Analysis of the accident investigation sites included four major areas: usage rate, benefit-cost ratio, impact on freeway operation, and evaluation of individual sites. The usage rate was evaluated according to time of day, month, and direction of travel. Estimated delay time saved was used to determine benefits of the system. Other benefits derived from the added safety and convenience of the sites were discussed, but a monetary value was not estimated. In addition to the decrease in time during which capacity was reduced on the freeway, the impact of accident experience before and during the study was analyzed. Analysis of individual sites provided information on establishing additional criteria for an AIS system.

Use of AIS

During the first year of operation, 851 police report forms were received. In 61 percent of these, the officer indicated that he had used an AIS or some other location off the

Figure 1. Locations of investigation sites on Gulf Freeway.

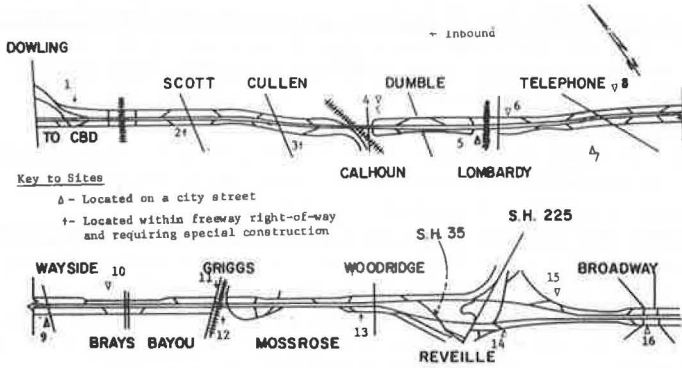


Figure 2. Typical layouts of investigation sites.

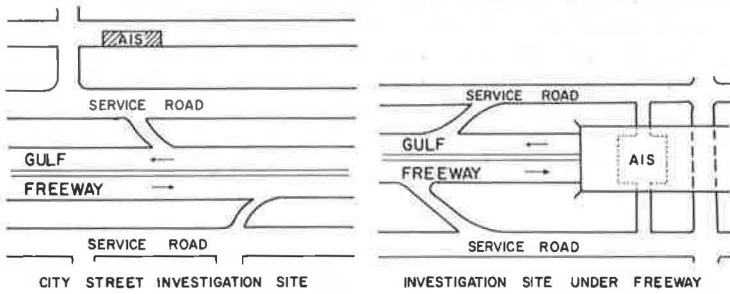


Table 1. Frequency of AIS usage.

| Information | Number | Percent |
|--------------------------------|--------|---------|
| Police report forms received | 851 | 100 |
| Use of AIS | 339 | 40 |
| Use of other off-freeway sites | 176 | 21 |
| Investigation on shoulder | 336 | 39 |

Table 2. AIS usage during peak and off-peak periods.

| Item | Peak Periods (weekday) | | Off-Peak Periods | |
|---------------------------------------------------------------|------------------------|-------------|-----------------------|------------------------|
| | 6 to 9 a.m. | 3 to 6 p.m. | Daylight ^a | Nighttime ^b |
| No. of Accidents | 152 | 186 | 321 | 192 |
| No. of investigations at AIS (percentage) | 75 (45) | 78 (42) | 132 (41) | 54 (28) |
| No. of investigations at other off-freeway sites (percentage) | 23 (15) | 39 (21) | 70 (22) | 44 (23) |
| Percentage of AIS and other off-freeway site usage | 64 | 63 | 63 | 51 |

^aFrom 9 a.m. to 3 p.m. on weekdays and from 6 a.m. to 6 p.m. on weekends.
^bFrom 6 p.m. to 6 a.m. daily.

freeway to conduct the investigation. These off-freeway locations included service roads, city streets, or parking lots. Table 1 gives the frequency of the site usage.

Data given in Table 2 compare the frequency of usage for the peak and off-peak travel periods. The morning and evening peak-period usage for the AIS was 45 percent. The usage rate for the daylight off-peak was 41 percent and for the nighttime 28 percent. One apparent reason for the lower usage rate at night is that the lighter traffic flow does not produce congestion.

The monthly usage rates of the AIS showed a general increasing trend. Except for the first 2 weeks, the usage rate increased from 27 percent to about 50 percent. A 48 percent usage rate during the first 2 weeks was probably due to the initial efforts of starting the study. The combined usage rates of the AIS and other off-freeway sites varied between 53 and 74 percent, with no increasing trends observed.

The frequency of AIS usage related to direction of travel was similar. The investigation sites on the inbound side of the freeway were used 44 percent of the time, and on the outbound side they were used 43 percent. Such usage was expected because 10 sites were accessible to inbound traffic and 10 sites to outbound traffic.

A total of 115 officers reported accidents in the study area during the first year of operation. The usage rate for a police accident investigator was obtained by dividing the number of times investigation sites were used by the number of accidents investigated. Twenty-eight officers investigated only one accident, and their usage rate (18 percent) was much lower than that of other accident investigators (40 percent).

Comments From Officers

To obtain first-hand opinions on the value of the AIS system, 18 Houston police officers were interviewed in June. Each officer had investigated more than 10 accidents in the study area during the previous year, and their usage rates varied from 14 to 68 percent. Most of the officers agreed that the AIS system improved traffic operations during an accident investigation. When queried on the conditions under which they would not move the accident vehicle off the freeway, they cited the following situations: when a fatality or possible fatality has occurred, when a crime has been committed, or when photographs or measurements are needed at the scene. Several of the officers said that they hesitate to move the vehicles when too many cars are involved and when an accident site is some distance away. Because the AIS system is a new concept, one officer stated that sometimes he forgot the investigation sites were available.

One of the problems encountered by the officers was that they had to explain to the motorists how to get to a site. Also, motorists were not aware that they could move their vehicles off the freeway before the police arrived. During the last quarter of the study year, wrecker drivers were instructed by the police department to move noninjury accident vehicles to a site as soon as possible. Several officers pointed out that this procedure caused problems if the wrecker driver failed to report where he had relocated the vehicles.

The officers agreed that using a site made their jobs easier because of the more relaxed atmosphere there. The sites provided a place concealed from freeway motorists and with reduced noise levels. Under-freeway sites provided an added convenience of sheltering police and motorists from inclement weather. In general, the theme that the officers related in the interviews was to inform the motorists of the locations and purpose of the sites. Most officers preferred using the under-freeway sites because they are more accessible. Placing some type of communication system at the sites was suggested by a majority of the officers.

Benefit Analysis

The anticipated benefits of the AIS system were improvement in safety and convenience, reduction in delay time, and reduction of secondary accidents. Benefits derived from the safety and convenience that the investigation sites provide were difficult to evaluate quantitatively. Eliminating the 25 min for the actual investigation on the freeway results in only 16 min during which traffic flow would be affected. Thus freeway operation is restored to normal more rapidly, making it possible for emergency

and other vehicles to reach their destination more quickly.

Use of the accident investigation sites also decreases delay to freeway motorists inasmuch as "gapers-block" or "rubbernecking" is eliminated after the vehicles are removed from the freeway. Usage of the sites also reduces the hazards to persons involved in an accident investigation.

Reduction in Delay—Use of the AIS system and other off-freeway locations reduced the number of vehicle-hours of delay significantly. Time-delay graphs were developed to estimate the total hours of delay saved during the first year. Initially, time-flow graphs were used to develop the time-delay relationships.

To provide a conservative estimate, we made the following assumptions: all accidents blocked only one lane, accident vehicles were moved from the freeway in 15 min, and no injuries were incurred by occupants of the accident vehicles. The time-flow graph shown in Figure 3 illustrates the effects of such an accident occurring at 7:00 a.m. on the inbound Gulf Freeway at Telephone Road. The demand curve was based on normal operational data, and the reduced volume curves (5) were plotted by using the following three-lane flow rates: accident vehicles on freeway, 2,750 vph; accident vehicles on freeway shoulder, 4,030 vph; and service volume during normal peak, 5,560 vph. The area between the demand and service volume curve is the delay in vehicle-hours that motorists will experience. The 15 min of freeway blockage produced a fixed delay of 690 vehicle-hours. Additional delay is a function of the investigation procedure, of which three cases are presented.

In case 1, it was assumed that the accident vehicles were moved to an AIS or other off-freeway site. Thus, no additional delay occurred, and freeway operation was normal by 8:15. For case 2, the investigation was conducted on the freeway shoulder and required 20 min. This procedure caused a total delay of 1,470 vehicle-hours. A 40-min investigation on the shoulder (case 3) produced 2,170 vehicle-hours of delay. Similar graphs were drawn for hypothetical accidents occurring at various times during the day at three additional locations. Because of the light flow rates, delay times between 7:00 p.m. and 6:00 a.m. were nearly zero.

Time-delay graphs consisting of three curves of delay versus the time of day were plotted for accidents occurring near the four locations. Only the 13-hour period from 6:00 a.m. to 7:00 p.m. was summarized on each graph. Figure 4 shows the time-delay graph for accidents occurring at the Telephone Road overpass. For example, if an accident occurred on the inbound freeway over Telephone Road at 7:30 a.m., the amount of delay to freeway motorists is 460 vehicle-hours if the investigation is conducted off the freeway. If the investigation is conducted on the freeway shoulder and takes 20 min, the amount of delay is 1,000 vehicle-hours. Therefore, 540 vehicle-hours of delay are saved by moving the vehicles off the freeway. Similarly, a 40-min investigation on the freeway causes 1,480 vehicle-hours of delay. The delay saved in this instance would be 1,020 vehicle-hours if the investigation is conducted at an off-freeway site.

There was no significant difference in delay for the three cases during the daylight off-peak periods (9 a.m. to 3 p.m.) because traffic demand usually did not exceed the reduced capacity caused by an accident investigation on the shoulder. Thus, for this study, delay time saved was computed for accidents occurring during the peak periods only. From September 13, 1971, to July 9, 1972, the estimated delay time saved by the 93 uses of the investigation sites was 29,250 vehicle-hours. An additional 8,100 vehicle-hours were saved by investigations conducted at other off-freeway locations. Data prior to mid-September were not included in the analysis because the information on the original forms was insufficient for this analysis.

In 1969, researchers (6) determined that one vehicle-hour of travel on the Gulf Freeway was worth \$2.92. If we assume a compounded increase of 5 percent per year and increased occupancy from 1.0 to 1.2 persons per passenger vehicle, the value of one vehicle-hour in 1972 would be \$4.50. By using this updated value, the monetary savings can be calculated. The total delay saved for the 43-week period was 37,350 vehicle-hours, which represents an annual savings of \$203,000.

Reduction in Accidents—Restoring freeway operations more rapidly also aids in the reduction of secondary accidents that occur as a result of shock waves. Data for the analysis of secondary accidents were obtained from records in the surveillance office

television room during peak periods. During the year prior to the AIS system 15 of 212 accidents were classified as secondary, whereas with the use of the AIS the secondary accidents decreased to 8 of 179 accidents. Thus, the total number of peak-period accidents decreased by 33, and the number of secondary accidents decreased by 7. Secondary accidents, therefore, represented 21 percent of the reduction in peak-period accidents.

Data obtained from the City of Houston showed that, on a 24-hour basis, 1,046 accidents occurred in the study area during the year prior to the study. Since the AIS system was installed, there were 851 accidents, a reduction of 195 accidents. If it is assumed that the probability of occurrence of a secondary accident is the same for peak periods and off-peak periods, then about 41 secondary accidents were prevented (that is, 21 percent of 195 accidents).

Burke (7) in 1970 determined the costs for various types of accidents. By assuming a 5 percent per year compounded increase, the cost involved for a property damage accident in 1972 would be \$307 per vehicle. It was further assumed that all secondary accidents involved only two cars; therefore, the annual savings due to a reduction of 41 secondary accidents was approximately \$25,000.

Comparison of Benefits and Costs

The construction cost for the AIS system was determined as follows: 10 sites at \$35 each, one site at \$3,235, and five sites at \$6,115 per site. Total construction costs for all sites amounted to approximately \$34,200. Maintenance for the AIS system was minor for the first year. No cost figures were available, so a very conservative estimate of \$200 per month was made. An estimate of maintenance costs for the first year was, therefore, \$2,400.

To determine the annual cost of the AIS system, we multiplied the initial construction costs by a uniform series capital-recovery factor and added the sum to the annual maintenance costs. The capital-recovery factor was based on a conservative interest rate of 10 percent for only 10 years. The annual cost was about \$8,000, whereas the benefits of the system due to delay saved and reduction in secondary accidents totaled \$228,000. Thus,

$$\text{Benefit/cost} = \frac{\$228,000}{8,000} = 28.5$$

Evaluation of Individual Sites

An analysis of the usage rate for each site was made. This usage rate was obtained by dividing the number of times a site was used, obtained from the supplementary police forms, by the number of accidents that occurred near it, determined by subjective analysis. No accident was considered for more than one site, and, when there was a question of which was the nearest site, the accident was omitted from analysis.

The sites located under the freeway, including the two on city streets, had a combined usage rate of 53 percent, whereas the usage rate for the sites located on city streets was 35 percent. The rates at individual sites varied from 12 to 64 percent. Of the seven sites that had usage rates greater than 50 percent, only two are on city streets. These two are the only city-street sites immediately downstream of an exit ramp. To reach the other city-street sites, motorists must drive farther. Thus, there is a definite trend to use sites that are located under the freeway or directly adjacent to it.

An analysis of the nighttime usage of the accident investigation sites was made to determine whether the sites were being used at night and whether the additional cost for lighting was justified at the five sites. Unfortunately, the number of accidents near each site was too small in most cases to provide a valid analysis. Most sites had a decrease in the usage rate at night. The nighttime usage rate for sites under freeway overpasses, where lighting was installed, was 41 percent as compared to 52 percent for 24 hours. For the other sites, the usage rate decreased from 39 percent to 22 percent.

Figure 3. Time-flow relationship for a one-lane blocked, noninjury accident over Telephone Road inbound.

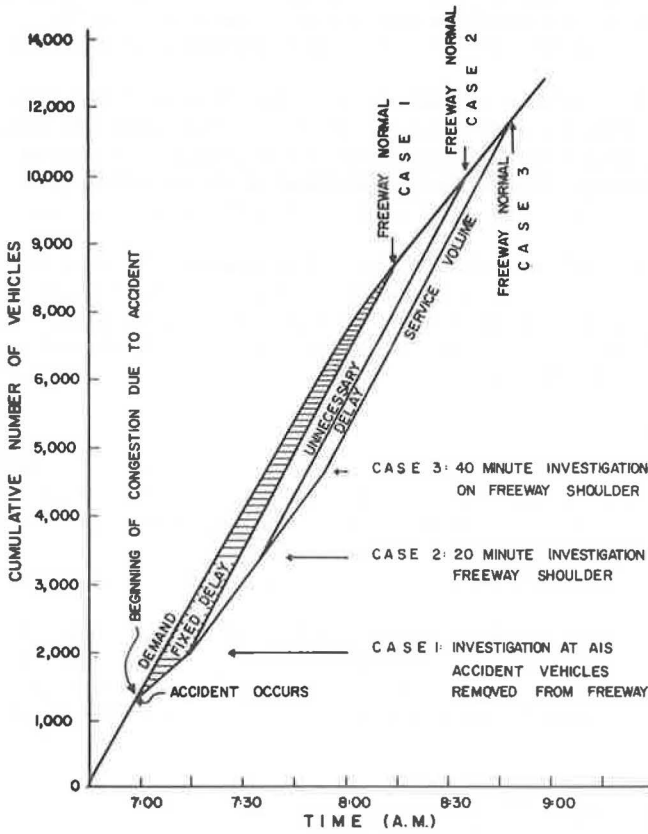


Figure 4. Time-delay relationship for a one-lane blocked, noninjury accident over Telephone Road inbound.

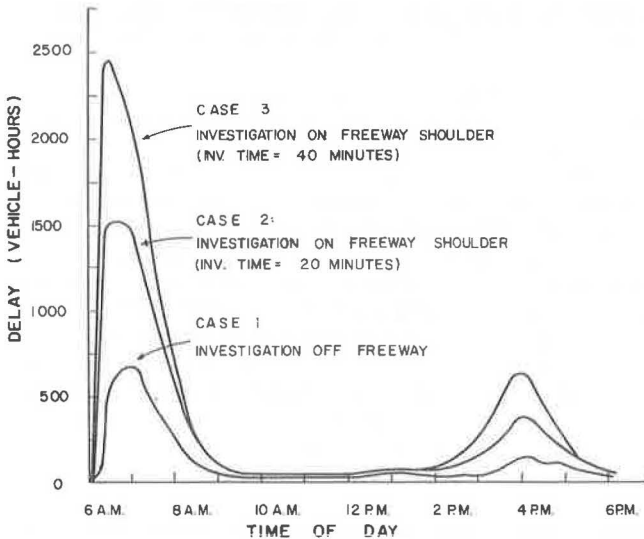
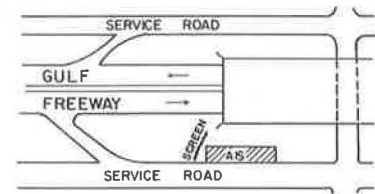


Figure 5. Modification of accident investigation site.



Discussion of Analyses

After a year of experience, the AIS system on the Gulf Freeway has proved satisfactory, based on design and location of sites. The basic design of the sites on unused freeway rights-of-way was sufficient; however, the use of the site as a U-turn roadway continued to be a minor problem. A low curb at the entrance to the site could be used to discourage improper use. Location of the entrance and exit of the site directly opposite a driveway or street is undesirable. The sites located on city streets should be at least 30 ft wide to allow traffic to pass the site in both directions during an investigation. A street narrower than 30 ft should have NO PARKING signs on both sides of the street.

The installation of lights at a site may not be justified based on the added cost. The purpose of the lighting is to illuminate the area and not to provide light for completing the investigation forms (officers use flashlights). Therefore, additional lighting should be limited to sites that have a high usage rate and no city lights.

The most used sites were those under the freeway overpasses. Several sites were located at places with low accident rates and may be unnecessary. However, the cost of installation was low, and other sites were difficult to reach. In general, a site should be located so that it is accessible from the freeway and easy to find. Locating the site so that it is out of view of freeway motorists should take secondary consideration inasmuch as screens (metal or foliage) could be installed. Where possible, sites should be constructed adjacent to the service road as shown in Figure 5.

SUMMARY

The usage rate for the accident investigation sites on the Gulf Freeway was 40 percent during the first year of operation. Although this was lower than was anticipated, it is felt that the program has been a success. The AIS system is a new concept for handling accidents, and, therefore, it should be expected that, through an educational and managerial process, the usage rate will increase. That is to say, as policemen and motorists become more familiar with the purposes and benefits of the AIS, the usage rate will increase. Expansion of the AIS system to all freeways in Houston is being proposed.

In addition to the use of the AIS, another 21 percent of the accident vehicles on the Gulf Freeway were moved to locations off the freeway. Analysis showed that normal delay, encountered by freeway motorists driving past an accident investigation on the shoulder, was eliminated when the accident investigation was conducted at the investigation sites or other off-freeway sites. The benefits derived from usage of the investigation sites or other off-freeway sites were valued at \$228,000, whereas the cost of installation and maintenance of the AIS was less than \$8,000. Therefore, the benefits of accident removal exceeded installation costs by a ratio of 28:1.

The initial design of sites proved to be satisfactory. The following criteria have been established for an acceptable accident investigation site: easily accessible, well-marked, concealed from freeway motorists, located near high-accident areas, low construction costs, at least 1,000 ft² of space, and sufficient lighting. These criteria should be considered in establishing an AIS system on other freeways.

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