Methodology for Evaluating the Feasibility of Grade-Separated Pedestrian Crossings

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ABSTRACT

Construction of a grade-separated pedestrian crossing, an overpass, or an underpass is often considered as a potential solution to midblock pedestrian safety problems. Often, however, the option of constructing a grade-separated pedestrian crossing is rejected early in the decision-making process because of the relatively high cost of constructing such a facility. Clearly, however, there are instances in which construction of such a facility could be justified if user (both pedestrian and vehicle operator) costs were considered along with construction and maintenance costs in the economic analysis and if qualitative as well as quantitative analysis techniques were used in the evaluation. A procedure developed to evaluate the feasibility of a potential pedestrian bridge improvement in Fairfax County, Virginia, is described. The procedure included a determination of the attitudes and concerns of area residents, merchants, and pedestrians through in-person and mail-back surveys; an economic analysis based on both user and capital costs; and a summary of various intangible benefits and liabilities. Individually, these evaluation techniques are not new; however, their combined use in a single evaluation procedure is rare. Application of the evaluation procedure resulted in the proposed pedestrian bridge being the most favorable of the four improvement alternatives considered. The evaluation procedure described is straightforward and repeatable by traffic engineers and planners who need to make feasibility decisions for similar facilities.

The Seven Corners area is located in one of the most densely developed parts of Fairfax County, Virginia. It is located at the crossroads of several major highway facilities, which has led to dense commercial as well as residential development. One of the major traffic facilities through the Seven Corners area is US-50, which is one of the most heavily traveled highway arterials in the Washington, D.C., metropolitan area.

The largest development in the Seven Corners area is the Seven Corners Shopping Center, a major regional shopping facility. The shopping center and the businesses in the area surrounding it attract thousands of shoppers a day. Opposite the Seven Corners Shopping Center, across US-50, are a large number of apartments and condominiums along with additional shopping facilities. The relative location of the residential and commercial land uses in this area creates a great deal of pedestrian traffic across US-50.

There are currently no protected pedestrian crossing points across US-50 at the Seven Corners Shopping Center. The closest protected pedestrian crossing points are located more than 1,000 ft away and are not heavily used. Most pedestrians currently choose to cross US-50 at midblock locations near the shopping center, where they must cross not only four to six high-speed lanes but also the service roads adjacent to US-50, which carry significant volumes of traffic. This mix of large numbers of pedestrians and high-speed vehicles is a dangerous combination that has led to many pedestrian accidents in the last several years.

As a result of continuing concern about pedestrian safety in the Seven Corners area, the Fairfax County Department of Public Works commissioned the Seven Corners Pedestrian Bridge Feasibility Study to investigate the possibility of providing a pedestrian bridge or constructing other facilities that would improve pedestrian safety in the area. A methodology for performing the alternative analysis portion of this feasibility study, which included interviews and surveys to measure pedestrian, resident, and merchant attitudes and concerns; a comprehensive economic analysis; and an analysis of intangible benefits and liabilities, was developed and is described in this paper.

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STUDY METHODOLOGY

The overall methodology used for the Seven Corners Pedestrian Bridge Feasibility Study (hereinafter referred to as the Seven Corners study) closely followed the normal evaluation process used for most transportation studies. The first phase of the study focused on the collection and analysis of data such as the physical characteristics of the study area, pedestrian and vehicle volumes, pedestrian delay data, and accident data. The second phase was to develop improvement alternatives to address the pedestrian safety problems in the study area. The final phase of the study evaluated and compared the improvement alternatives that had been developed. It was for this final phase that several traditional evaluation methods were combined in a comprehensive evaluation procedure that proved to be successful and well received and should be repeatable for other studies of this type.

The evaluation procedure developed for the Seven Corners study contained three major components:

- Merchant and pedestrian interviews and a mail-back survey of local residents;

• Economic analysis, including consideration of both facility and user costs; and
• Assessment of various intangible benefits and liabilities.

The purpose of the merchant interviews was to determine the merchants' perception of the importance of pedestrian traffic to their businesses and to obtain their opinions on the proposed improvement alternatives. Approximately 20 percent of the merchants in the study area were interviewed.

The purpose of both the pedestrian interviews and the mail-back surveys was to evaluate pedestrian trip patterns and to determine pedestrian concerns and attitudes toward existing conditions and proposed improvement alternatives in the study area. Mail-back surveys was distributed to approximately 60 percent of area residents with a return rate of 30 percent. A total of 50 pedestrian interviews were conducted in the study area.

The economic analysis method used was the annual cost method. In this method all costs and benefits of a particular alternative are converted to annual costs and benefits and are summed. The alternative with the lowest total annual cost (or largest total annual benefit) is the preferred alternative from an economic standpoint. The costs and benefits considered in the economic analysis are

1. Facility costs
   • Construction costs
   • Maintenance costs
2. User benefits and costs
   • Accident benefits and costs
   • Vehicle delay benefits and costs
   • Pedestrian delay benefits and costs

The types of costs and benefits listed were chosen with the Seven Corner study area in mind, but they should also be the main areas of cost consideration for other studies of this type.

Facility costs were determined using traditional cost estimation techniques. Accident costs were calculated using data from a recent study in Texas (1), which represents the most recent and comprehensive data on accident costs. Expected increases and reductions in various types of accidents for different types of improvements were obtained from a synthesis of safety research prepared for the FHWA (2). The costs of vehicle operation and time delay for motorists and pedestrians were calculated using the 1977 AASHTO red book (3) and adjusting for inflation to May 1985 using the Consumer Price Index.

When the magnitudes of the various costs and benefits had been calculated, they were converted to annual costs using an annual interest rate of 12 percent. Useful lives for the various alternatives were estimated using the FHWA publication, "Identification, Analysis, and Correction of High Accident Locations" (4).

The intangible benefits and liabilities considered for the Seven Corners study are

• Number of vehicle trips,
• Commercial patronage,
• Land values,
• Air pollution,
• Noise, and
• Aesthetics.

These items were chosen specifically for the Seven Corners study. A much narrower or broader list of intangible considerations is possible depending on prevailing local conditions. A good source of candidate intangible factors is Table 21-5 in the FHWA publication, "Design of Urban Streets" (5).

After analysis of the survey and interview data and economic considerations and intangible factors, the rank of each alternative within these three components of the analysis was determined. Each rank was weighted and an overall ranking was determined. For the Seven Corners study, an equal weight for each of the analysis components was used. However, this weighting will vary from study to study, depending on local conditions and jurisdictional desires. For instance, it may be desirable to place less emphasis on the intangible factors and more on the economic analysis.

The remainder of this paper will be devoted to a discussion of how the evaluation procedure was applied to the Seven Corners study area to demonstrate its applicability and usefulness. This discussion will provide additional detail on how the various components of the evaluation procedure should be applied and will serve as a detailed case study of the procedure as a whole.

SITE DATA

Physical Site Conditions

Figure 1 is a site plan of the US-50 area near the Seven Corners Shopping Center. This plan shows the key facilities and development in this area. The major features of this plan are described next.

The segment of US-50 between the Seven Corners interchange (at Wilson Boulevard and VA-7) and Patrick Henry Drive was designated as the study section for this project. This segment of US-50 is approximately 2,600 ft long and varies from four to six lanes in width. Traffic on US-50 at the Seven Corners interchange is grade separated from the other traffic at the interchange. The intersection of US-50 and Patrick Henry Drive is controlled by a traffic signal. The speed limit along this segment is 45 mph and operating speeds are slightly higher. The eastbound and westbound lanes are separated by a 3-ft-wide paved island.

Parallel to US-50 to both the north and the south are service roads, which carry local traffic. The service roads are generally two lanes wide and are provided continuously between Patrick Henry Drive and the Seven Corners interchange. There is a pair of slip ramps for each service road that provides access between the service roads and US-50. Traffic volumes on both service roads are significant. The speed limit on the service roads is 25 mph, but operating speeds are generally higher because of the high speed of vehicles exiting US-50 via the slip ramps.

The major commercial development in the study area is the Seven Corners Shopping Center. This center contains two large department stores and more than 70 other stores, shops, and restaurants. North of US-50 at the east and west ends of the study section are two additional shopping centers that contain more than 30 additional stores.

Most of the residential development along the study section is located north of US-50. Three developments that contain a total of more than 800 condominium and apartment units are located in this area. Additional apartment and condominium units are located south of US-50 along Patrick Henry Drive.

The Willston Instructional Center, located north of US-50 adjacent to the residential area, is a vocational school that offers morning, afternoon, and evening classes to non-English-speaking students. Current enrollment in the school is approximately 500 students and the hours of operation are from 9:00 a.m. to 10:00 p.m.

The intersection of US-50 and Patrick Henry Drive

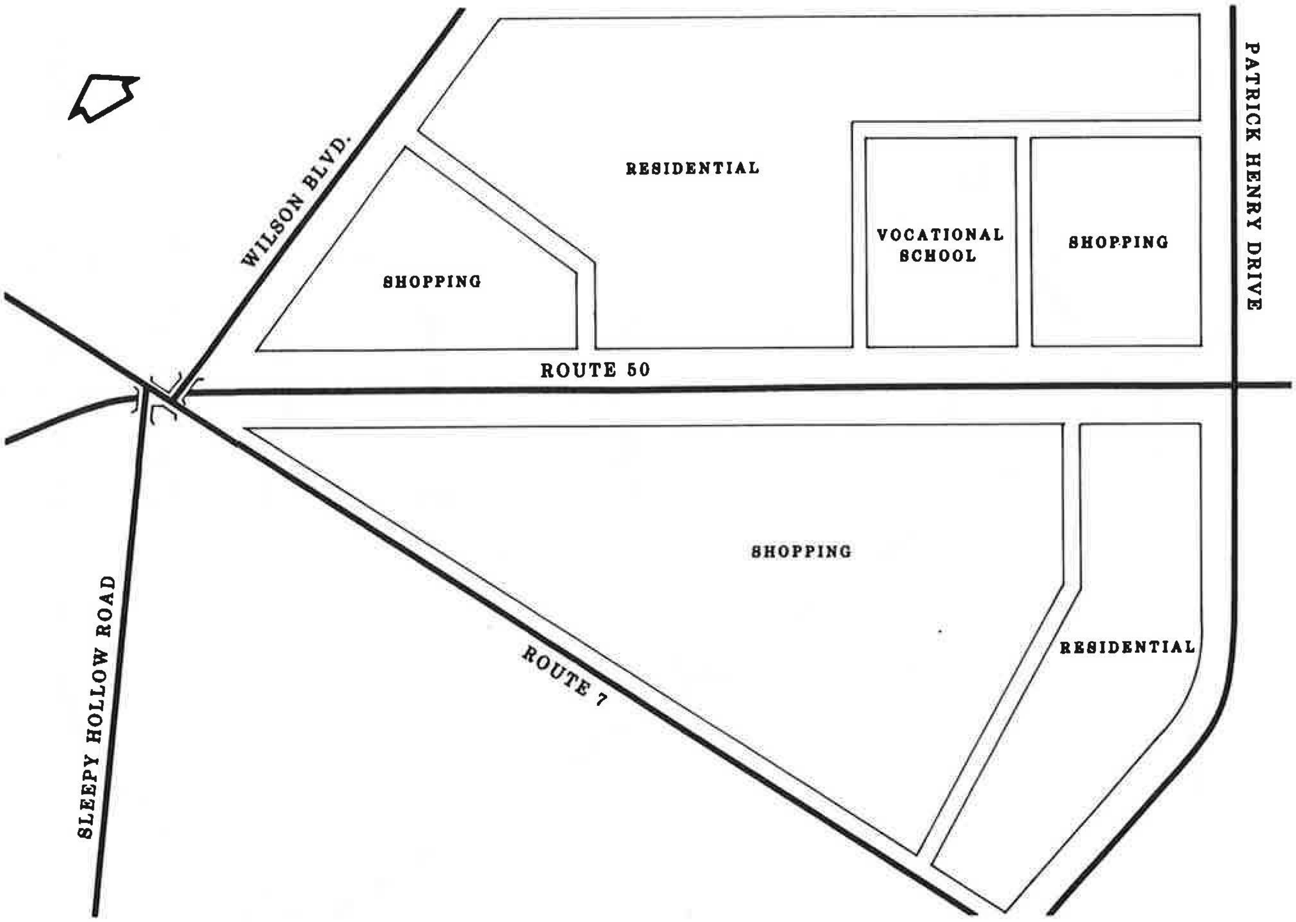

FIGURE 1 Site plan.

is provided with both crosswalks and pedestrian signals. The pedestrian signals are pushbutton activated and are phased with through traffic on Patrick Henry Drive. The current time allotted to pedestrians by these signals is barely adequate for a person walking at a normal speed to cross the seven lanes of US-50 at this location. A 2-ft-wide refuge island is provided in the median for pedestrians who are "trapped" in the intersection when the signal changes. However, this island is rarely used by pedestrians because of its small size.

At the Seven Corners interchange, existing pedestrian facilities are minimal. There are sidewalks through most portions of the interchange area. However, there are no pedestrian crosswalks or signal indications. A pedestrian who desires to walk through the interchange area must cross with the existing traffic signals, the phasing of which is not readily apparent to pedestrians. No improvements to the existing pedestrian facilities at Patrick Henry Drive or the Seven Corners interchange are currently planned.

Pedestrian and Vehicle Volumes

To measure the degree of pedestrian activity and pedestrian-vehicle conflict in the study area, two counts of pedestrian and vehicular traffic volumes were taken, one on a weekday and one on a Saturday. The weekday count covered the hours of 7:00 a.m. to 7:00 p.m. and the Saturday count covered the hours of 8:00 a.m. to 6:00 p.m. Vehicle volumes were recorded using automatic counters. Pedestrian volumes were recorded using several observers who recorded the location of each pedestrian crossing US-50 within the study area, the direction of crossing, the approximate age of the pedestrian, and other pertinent data. Pedestrians crossing at the Seven Corners interchange or at the signal at Patrick Henry Drive were not recorded.

Figure 2 shows the weekday pedestrian and vehicle volumes in the study area. Review of this figure indicates that approximately two-thirds of the total of 631 pedestrians crossing US-50 in the 12-hr period recorded were concentrated at the residential area and vocational school. The highest hourly pedestrian volumes occurred between 3:00 p.m. and 6:00 p.m., which is also when the heaviest vehicle volumes were recorded.

Figure 3 shows the Saturday pedestrian and vehicle volumes in the study area. This figure indicates a generally heavier but more even distribution of pedestrian volumes than does the weekday count. Pedestrian volumes near Patrick Henry Drive and the Seven Corners interchange are heavier than during the week because of heavier use of the nearby shopping facilities. The time distribution of the Saturday pedestrian volumes revealed a fairly constant heavy flow of pedestrians from 1:00 p.m. to 6:00 p.m., again also the time when the heaviest vehicular volumes were recorded. Overall, vehicle volumes are 28 percent lower on Saturday than during the week.

The distribution of pedestrians by age was consistent for both the weekday and the Saturday counts. Adults accounted for approximately 63 percent of the total counted. Teens accounted for approximately 23 percent of the total. The remainder of the pedes-

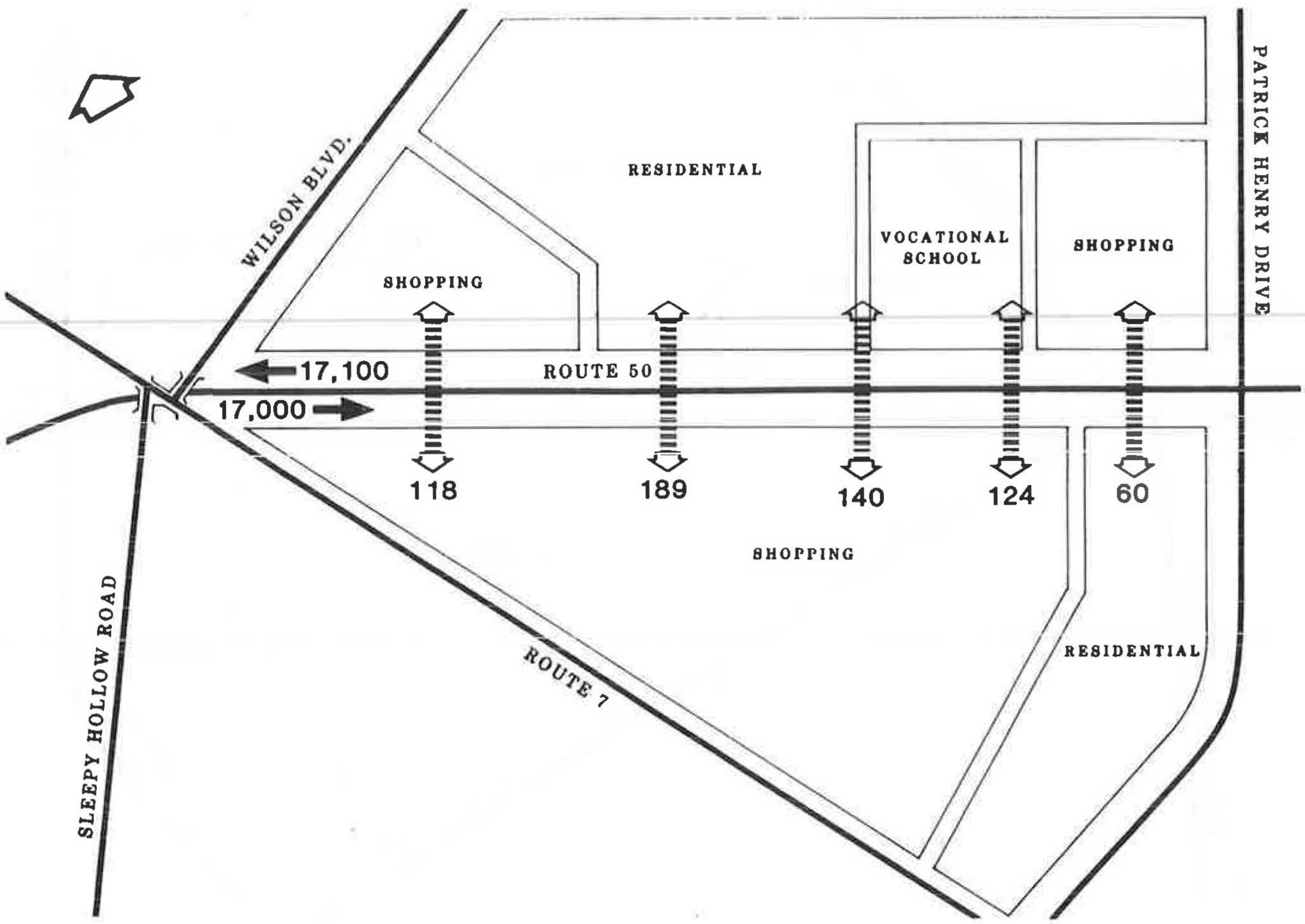

FIGURE 2 Typical weekday pedestrian and vehicle volumes, 7:00 a.m. to 7:00 p.m.

trians counted consisted of small percentages of children, elderly and handicapped persons, and bicyclists.

Pedestrian Delay

To determine the degree of delay that pedestrians currently face in crossing US-50, field measurements of pedestrian delay were taken during four time periods: weekday morning peak, weekday afternoon peak, weekday off-peak, and Saturday. Delay measurements were made by recording the time that pedestrians required to cross US-50 and the two service roads and subtracting the time that the crossing would have required with no traffic present.

Table 1 gives the average delay per pedestrian for each of the four time periods measured. Each of these averages is based on from 20 to 30 field observations. Review of the table indicates that the longest average pedestrian delay, 54.3 sec, was experienced during the weekday afternoon peak period. This result is as expected, because this is when vehicular traffic volumes are heaviest. The average weekday morning peak-period delay is approximately 12 sec less than the afternoon peak-period delay. The weekday off-peak delay and the Saturday delays are less than the average peak delays.

Accidents

Pedestrian accident data for the US-50 study section for the years 1982, 1983, and 1984 were obtained from the Fairfax County Police Department. A total of 14 pedestrian accidents were recorded during this period. The 14 pedestrian accidents recorded resulted in 2 minor injuries, 11 major injuries, and 1 fatality to the pedestrians involved. No injuries to the vehicle occupants involved were recorded. In 9 of the 14 recorded accidents, the pedestrian was held fully or partly responsible for the accident. In 5 of these cases, the pedestrian had been drinking before the accident. Five of the 14 total accidents, 4 of the 5 accidents before which the pedestrian had been drinking, and the fatality occurred at night.

Five of the accidents, including the fatality, occurred at Patrick Henry Drive. In four of these cases, including the fatality, the pedestrian was held at fault for crossing against the signal. In the fifth accident a vehicle ran the signal at Patrick Henry Drive and struck a pedestrian who was in the crosswalk. The remaining nine pedestrian accidents occurred randomly throughout the study area.

IMPROVEMENT ALTERNATIVES

A total of four basic improvement alternatives were considered for this study. These improvement alternatives were based on the conclusions of previous studies and on-site observations. Each of the improvement alternatives considered is described.

No Improvements (no-build)

This alternative consists of maintaining the status quo in the study area; that is, making no improve-

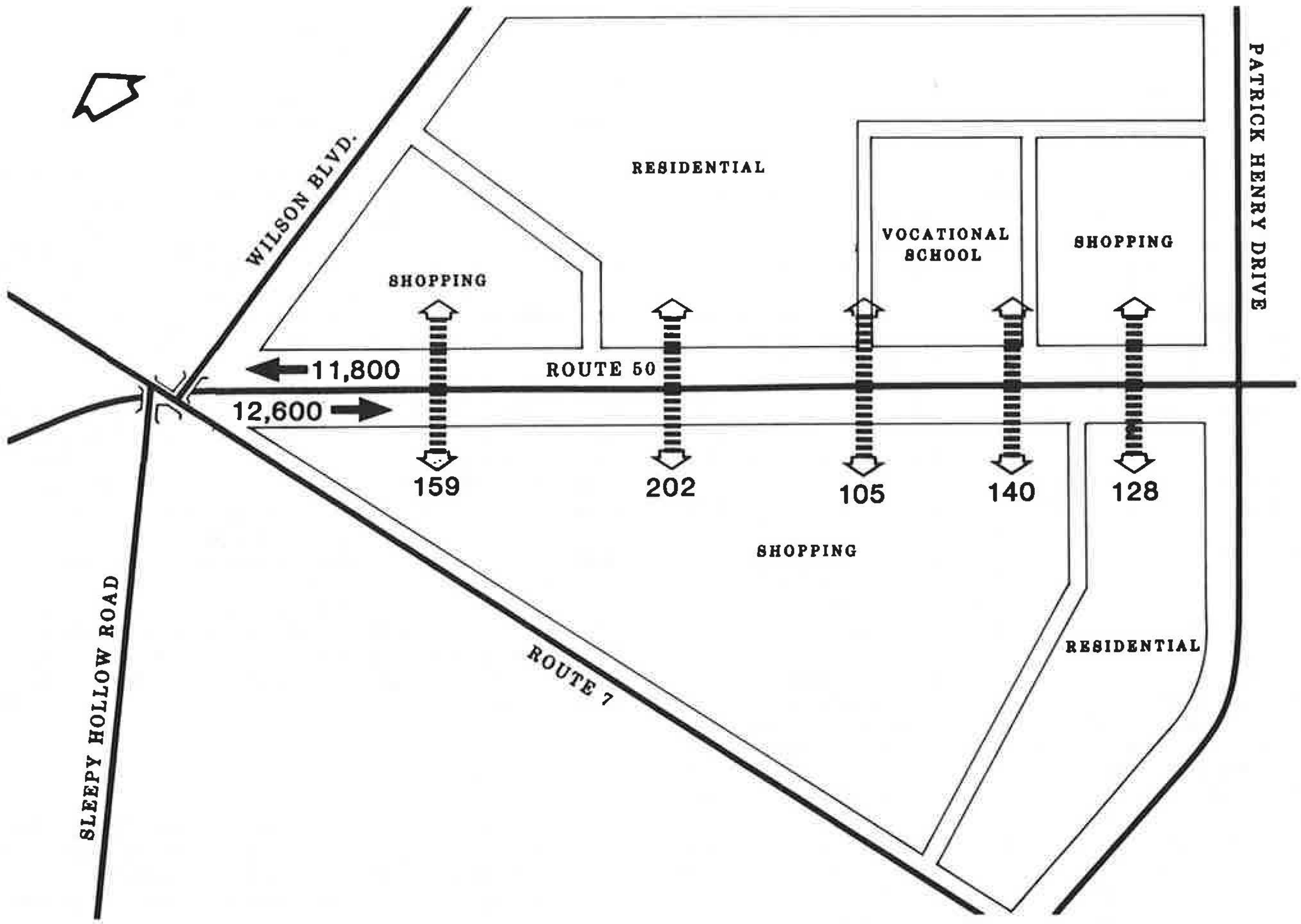

FIGURE 3 Typical Saturday pedestrian and vehicle volumes, 8:00 a.m. to 6:00 p.m.

TABLE 1 Pedestrian Delay (sec)

Time Period	Average Crossing Time	No-Delay Crossing Time[a]	Average Delay
Weekday morning peak	87.3	45.0	42.3
Weekday afternoon peak	99.3	45.0	54.3
Weekday off-peak	73.0	45.0	28.0
Saturday	75.0	45.0	30.0

[a]Calculated using an average crossing distance (for both directions of travel on US-50 and both service roads) of 180 ft and an average walking speed of 4.0 ft per second.

ments to existing pedestrian facilities and allowing pedestrians to continue to cross US-50 at various locations in the study area.

Construct Pedestrian Median Barrier

This alternative consists of constructing a pedestrian barrier, either a fence or some sort of solid barrier, between Patrick Henry Drive and the Seven Corners interchange. The purpose of this barrier would be to prevent pedestrians from crossing US-50 except at Patrick Henry Drive or the Seven Corners interchange. The major benefit of this improvement would be that all midblock pedestrian crossings would be eliminated and so would midblock pedestrian accidents.

Install Pedestrian Signal

This alternative consists of installing a pedestrian signal across US-50 near the center of the study section. This signal would allow through traffic to proceed unless actuated by a pedestrian waiting to cross. Timing of the pedestrian phase of the signal would be limited to the minimum time for a pedestrian to cross to minimize disruption to through traffic on US-50. It also would be necessary to coordinate the operation of this signal with the signals at Patrick Henry Drive and the Seven Corners interchange to minimize disruption to through traffic. This improvement would be accompanied by a pedestrian barrier to force pedestrians to use the signal.

Construct Pedestrian Bridge

This alternative consists of constructing a pedestrian bridge across US-50 near the center of the study section. This improvement would be accompanied by a pedestrian barrier to force pedestrians to use the bridge.

INTERVIEW AND SURVEY RESULTS

To obtain a sample of the attitudes of merchants in the Seven Corners area, in-person and telephone interviews of 20 area store managers were conducted.

Merchants were asked if they thought that construction of a pedestrian barrier along US-50 to prevent pedestrian crossings would hurt their business. Thirty percent of the merchants responded "Yes" to this question.

The merchants were then asked if they thought that installation of a pedestrian signal or construction of a pedestrian bridge across US-50 would help their business. Seventy-five percent of the merchants responded "Yes" to this question. It can be inferred from this response that most of the merchants believe that a signal or bridge would cause more pedestrian trips to be made to the Seven Corners Shopping Center.

Merchants were also asked their opinions of the four improvement alternatives under consideration. Sixty-five percent of the merchants responded that a pedestrian bridge should be constructed. Twenty-five percent of the merchants responded that a pedestrian signal should be installed.

Because residents of the condominiums and apartments located north of US-50 would be the primary beneficiaries of any pedestrian improvements in the study area, a mail-back survey was conducted to determine these residents' pedestrian trip patterns, concerns, and attitudes toward various improvement strategies. A total of 536 survey forms were distributed, of which 162 (30 percent) were returned.

Eighty-six percent of the survey respondents stated that they or members of their household currently regularly make walking or bicycle trips across US-50. The most frequent trip purpose identified by survey respondents was shopping (59 percent). Other responses such as catching the bus and dining also were specified.

Respondents were asked to identify the location at which they normally crossed US-50. Choices of the Seven Corners interchange, Patrick Henry Drive, and the five midblock areas where pedestrian counts were recorded were provided. The answers to this question indicated a close correlation to the pedestrian volumes observed in the field.

Survey respondents were asked if they thought that the location where they normally crossed US-50 was dangerous. Ninety-six percent of those who currently cross US-50 answered this question "Yes." Thus there is near unanimity that crossing US-50 anywhere in the study section is dangerous.

Respondents who currently make trips across US-50 were asked whether they would make fewer trips if a pedestrian barrier were installed to prevent pedestrian crossing except at Patrick Henry Drive and the Seven Corners interchange. Forty-two percent of the respondents answered that they would continue to make the same number of trips. The remaining respondents would reduce their number of trips by varying degrees. Twenty percent of the respondents would completely eliminate their walking trips across US-50 if a barrier were installed. The average trip reduction per pedestrian who currently crosses US-50 would be approximately 8.1 trips per week, which equates to about a 19 percent reduction in total trips across US-50.

Mail-back survey respondents were also asked whether they would use a pedestrian-actuated signal if one were provided near the center of the study section. Seventy-five percent of the respondents indicated that they would use such a signal. Of the respondents who would use such a signal, 55 percent further stated that the presence of the signal would cause them to make more walking trips across US-50. Survey responses quantified this increase at about 6 percent of the total pedestrian trips across US-50.

Respondents were then asked whether they would use a pedestrian bridge if one were constructed. Ninety-three percent of the respondents replied that they would use such a bridge. Of the respondents who would use a pedestrian bridge, 69 percent further stated that the presence of a bridge would cause them to make more trips across US-50. Survey responses quantified this increase at about 12 percent of the total pedestrian trips across US-50.

Overall, the results of the mail-back survey indicate that respondents favor construction of a pedestrian bridge more than a pedestrian signal and that they would make more additional trips with a pedestrian bridge than with a pedestrian signal. Persons who already make trips across US-50 would make fewer trips if a pedestrian barrier were constructed.

In addition to the mail-back survey, a series of pedestrian interviews was conducted to further measure pedestrian response to both existing conditions and improvement alternatives. A total of 50 interviews were conducted along the entire length of the study section during various times of the day. Pedestrians who stated that they had already completed a mail-back survey were excluded from the interviews.

Questions asked during the interviews were similar to but less extensive than those asked in the mail-back survey. Responses to the questions indicated a close correlation with the distribution of answers given by respondents to the mail-back survey. Interview results indicated that a large majority of interviewees thought that it was dangerous to cross US-50. Interviewees also responded positively to both the pedestrian signal and pedestrian bridge alternatives and indicated that they would make more walking trips if either alternative were implemented. Interviewees also indicated that if pedestrian access across US-50 were blocked, they would make slightly fewer trips.

ECONOMIC ANALYSIS

The economic analysis procedure previously described was applied to the Seven Corners study area. The costs and benefits of the various components of the economic analysis were determined as described next.

Facility Costs

Construction Costs

These costs were determined by using standard cost estimate techniques using an assumed scope for each alternative. For all alternatives it was assumed that a median fence or full median barrier would be installed between Patrick Henry Drive and the Seven Corners interchange. This assumption was made because construction of a median barrier to channelize pedestrian traffic would be a desirable improvement for all of the alternatives studied. It was further assumed that each alternative would include improvements to the existing sidewalk system to provide pedestrians a complete path to desirable crossing points. For the pedestrian signal alternative, it was assumed that a pedestrian-actuated signal would be installed with an overhead or time-based interconnect to adjacent signals. For the pedestrian bridge alternative, it was assumed that the bridge would be constructed near the residential area north of US-50 and extend over both service roads and US-50. The approximate construction costs for each alternative are given in Table 2.

Maintenance and Operating Costs

These costs were determined by contacting various local agencies and obtaining maintenance and operating cost information for similar facilities. A summary of these costs is given in Table 2. The cost of operating and maintaining the fence or barrier is composed primarily of repairing portions of the fence or barrier damaged by accidents or vandalism. This cost would be higher for a fence because it would be more easily damaged than a median barrier. The oper-

TABLE 2 Construction, Operating, and Maintenance Costs ($)

Alternative	Construction Cost	Annual Operating and Maintenance Cost
No-build	0	0
Median fence	70,000	3,000
Median barrier	180,000	1,000
Pedestrian signal and median fence	120,000	4,000
Pedestrian signal and median barrier	230,000	2,000
Pedestrian bridge and median fence	560,000	6,000
Pedestrian bridge and median barrier	670,000	4,000

ating and maintenance cost of the pedestrian signal includes electricity costs and average annual costs for repair of signal equipment. The operating and maintenance cost of the pedestrian bridge includes the estimated annual cost of removing snow from the bridge; electricity costs for lighting on the bridge; and repair of lighting fixtures, railings, screens, and so forth.

User Benefits and Costs

Accident Benefits and Costs

The primary reason for consideration of the various improvement alternatives in this study is to improve pedestrian safety in the study area by reducing pedestrian accidents. To evaluate the user benefit of this accident reduction for various alternatives, costs were assigned to various accident types using the data in the previously described study from Texas (1) adjusted for inflation.

During the past 3 years there have been 13 injury accidents and 1 fatal pedestrian accident in the study section. Nine of the injury accidents occurred at midblock locations. The remaining 5 accidents, including the fatality, occurred at Patrick Henry Drive. Thus there is an average of 3 accidents per year at midblock locations and 1.7 accidents per year at Patrick Henry Drive. The overall fatality rate is 1/14 or 7.1 percent of all pedestrian accidents. This is in close agreement with the overall fatality rate of 9.3 percent in the Texas study.

For the median fence or barrier alternative, it was assumed that the 3 midblock pedestrian accidents per year would be eliminated. However, according to survey and interview responses, this alternative would approximately double the existing pedestrian traffic at Patrick Henry Drive. Thus it would be expected that pedestrian accidents at Patrick Henry Drive would double, to an average of 3.4 per year. The net pedestrian accident savings would be 3.0 - 1.7 = 1.3 accidents per year.

The pedestrian signal alternative would also be expected to eliminate the 3 midblock accidents per year. However, studies have shown that addition of a signal can be expected to produce various types of accidents. In an urban setting, pedestrian accidents can be expected to occur at a rate of 0.14 accidents per million entering vehicles and rear-end accidents at a rate of 0.28 accidents per million entering vehicles (2). These are the two types of accidents that would likely occur at the proposed pedestrian-actuated signal. Total entering vehicles for the new signal location would be the total average daily traffic on US-50 (35,700) multiplied by 340, a commonly used multiplier that accounts for reduced vehicle traffic on weekends and holidays (5), for a total of 12,138,000 entering vehicles per year. The expected number of pedestrian accidents would be 0.14 x 12.138 = 1.7 and the expected number of rear-end accidents would be 0.28 x 12.138 = 3.4. Note that the number of expected pedestrian accidents is equivalent to the number of pedestrian accidents currently experienced at Patrick Henry Drive. The net annual result of a pedestrian signal installation on US-50 would be 3.0 - 1.7 = 1.3 fewer pedestrian accidents and 3.4 additional rear-end accidents.

The pedestrian bridge alternative also is expected to eliminate the 3 midblock pedestrian accidents per year. However, this alternative also is expected to increase pedestrian traffic at Patrick Henry Drive by approximately 18 percent. It is assumed that this increase in pedestrian traffic would result in an equal increase in pedestrian accidents or 0.18 x 1.7 = 0.3 pedestrian accidents per year. Thus the accident savings for the pedestrian bridge alternative would be 3 - 0.3 = 2.7 pedestrian accidents per year.

The total accident costs for various accident types are given in the 1984 Texas report. These costs include direct costs, such as property damage, medical, legal, lost time, and funeral costs. The costs also include indirect costs, such as production and consumption losses for persons injured and killed, accident investigation costs, and insurance administration costs. The total accident cost for rear-end accidents in urban areas is $3,900. The total average accident cost for pedestrian accidents, assuming a 7.1 percent fatality rate, is $59,800. These costs have been adjusted for inflation using the Consumer Price Index. Using these costs, Table 3 gives a summary of the total accident cost savings for the various alternatives considered. Review of this table indicates that the pedestrian bridge alternative would result in the greatest accident cost savings, about $161,000 per year. The median fence or barrier and the pedestrian signal would result in accident cost savings of approximately $78,000 and $64,000, respectively. The no-build alternative, of course, results in no accident cost savings.

Vehicle Delay Benefits and Costs

The only alternative that would significantly affect vehicle delay in the study section would be the pedestrian signal alternative. To evaluate the magnitude of this delay, the procedures outlined in the 1977 AASHTO red book (4) were used. These procedures consider the effect of a traffic signal in four areas: cost of vehicle acceleration and deceleration to and from a stop, cost of vehicle idling, cost of drivers' and passengers' time during acceleration

TABLE 3 Accident Benefits

Alternative	No. of Pedestrian Accidents Reduced per Year	Cost per Pedestrian Accident ($)	Savings ($)	No. of Rear-End Accidents Increased per Year	Cost per Rear-End Accident ($)	Savings ($)	Total Savings ($)
No-build	0	59,800	0	0	3,900	0	0
Construct median fence or barrier	1.3	59,800	77,740	0	3,900	0	77,740
Install pedestrian signal	1.3	59,800	77,740	3.4	3,900	−13,260	64,480
Construct pedestrian bridge	2.7	59,800	161,460	0	3,900	0	161,460

and deceleration, and cost of drivers' and passengers' time during idling.

To perform the calculations, the existing pedestrian counts were examined to determine the demand on a pedestrian signal during various periods of the day assuming a uniform pedestrian arrival rate. A 100-sec signal background cycle corresponding to the signal cycle at Patrick Henry Drive was also assumed. The curves contained in the AASHTO red book were used to determine expected stopping and idling delay and costs using a conservative $1.22 per hour (calculated by using the $0.48 per hour of minor vehicle-person delay contained in the AASHTO red book, assuming a vehicle occupancy of 1.25, and adjusting for inflation using the Consumer Price Index) as the time value of vehicle delay. The results of this calculation indicate a vehicle delay cost of approximately $213,000 per year. This cost is probably slightly overstated because uniform pedestrian arrivals were assumed, but it should still be clear that installation of a signal would result in a major cost to the vehicular users of US-50.

Pedestrian Delay Benefits and Costs

Each of the alternatives except the no-build alternative would have an effect on pedestrian delay in the study section. The median fence or barrier alternative would have the most profound effect because it would force pedestrians to walk to Patrick Henry Drive or the Seven Corners interchange to cross US-50. Installation of a pedestrian signal or construction of a pedestrian bridge would also affect pedestrian delay.

To evaluate the effect of the various alternatives on pedestrian delay, the pedestrian count data were used to estimate the number of pedestrians desiring to cross US-50 at various locations. The distance from each location to the nearest crossing point for the various improvement alternatives was then calculated. An average walking speed of 4 ft per second was used to calculate the average pedestrian delay from the various locations for various alternatives. This average delay was multiplied by the total number of pedestrians desiring to cross at a particular location to obtain the total pedestrian delay. An average pedestrian delay of 50 sec was assumed to occur at the Seven Corners interchange, the new pedestrian signal, and the Patrick Henry Drive signal. The effects of using the stairs at the new pedestrian bridge were included in the calculations as were the effects of expected increased or decreased pedestrian activity for various alternatives. When the total pedestrian delay for each alternative had been calculated, existing pedestrian delay, calculated from existing count data and delay measurements, was subtracted. The resulting delay total was expanded to a yearly figure for total hours of additional pedestrian delay for each alternative. A time value of $0.97 per hour of pedestrian delay (calculated by using the $0.48 per hour value of minor person delay contained in the AASHTO red book and adjusting for inflation using the Consumer Price Index) was used to convert hours of delay to an annual cost. Table 4 gives the total additional hours and cost of pedestrian delay for each alternative. Review of Table 4 indicates that all of the alternatives, except the no-build alternative, result in an increase in pedestrian delay. Not surprisingly, the median fence or barrier alternative causes the greatest increase in pedestrian delay, 19,200 hours ($18,624). The pedestrian signal and pedestrian bridge alternatives cause 11,600 hours ($11,252) and 11,400 hours ($11,058) of additional pedestrian delay, respectively.

TABLE 4 Pedestrian Delay Costs

Alternative	Annual Hours of Pedestrian Delay	Unit Cost of Pedestrian Delay ($)	Total Cost ($)
No build	0	0.97	0
Median fence or barrier	19,200	0.97	18,624
Pedestrian signal	11,600	0.97	11,252
Pedestrian bridge	11,400	0.97	11,058

Summary of Facility Costs and User Costs and Benefits

To complete the annual cost comparative evaluation of each alternative, the annual costs and benefits were summed. In this process, the useful lives for various types of alternatives contained in the FHWA publication, "Manual on Identification, Analysis and Correction of High Accident Locations" (4) were used. The useful lives chosen were as follows:

- Median fence--10 years,
- Median barrier--15 years,
- Pedestrian signal--15 years, and
- Pedestrian bridge--30 years.

These useful lives would indicate that in a 30-year period (the shortest period for which the alternatives can be compared) the median fence would be replaced twice and the median barrier and pedestrian signal once. An interest rate of 12 percent compounded continuously was selected for use in calculating life-cycle costs of each alternative.

Table 5 gives the total annual costs for each of the alternatives considered. Review of this table indicates that construction of a pedestrian bridge produces the greatest amount of annual benefit (negative costs), followed by construction of a median fence or barrier, the no-build alternative, and installation of a pedestrian signal that actually results in a greater facility and user cost than the existing situation.

INTANGIBLE BENEFITS AND LIABILITIES

Five types of intangible benefits and liabilities were assessed for this study and are described in this section.

Increased or Decreased Vehicle Trips

This potential benefit or liability would likely affect each of the alternatives except the no-build alternative. Results of the pedestrian interviews and mail-back surveys indicate that pedestrians would make fewer walking trips across US-50 if a median fence or barrier were installed and more walking trips if a pedestrian signal or bridge were installed. It is likely that some of this increase or decrease in walking trips would result in a converse decrease or increase in automobile trips. This increase or decrease in automobile trips would affect traffic congestion and vehicle delay on streets near the study section.

Increased or Decreased Commercial Patronage

Because each of the alternatives except the no-build alternative would result in a change in the total number of pedestrian trips, it is possible that some portion of this increase or decrease in walking trips would cause changes in patronage of the businesses

TABLE 5 Summary of Economic Evaluation ($)

	Annualized Construction Cost	Maintenance Cost	Accident Reduction Benefits	Vehicle Delay Costs	Pedestrian Delay Costs	Total Annual Cost
No-build	0	0	0	0	0	0
Median fence	12,773	3,000	−77,740	0	18,624	−43,343
Median barrier	27,499	1,000	−77,740	0	18,624	−30,617
Pedestrian signal and median fence	20,412	4,000	−64,480	213,000	11,252	184,184
Pedestrian signal and median barrier	35,139	2,000	−64,480	213,000	11,252	196,911
Pedestrian bridge and median fence	77,012	6,000	−161,460	0	11,058	−67,390
Pedestrian bridge and median barrier	91,738	4,000	−161,460	0	11,058	−54,664

in the study area. If, for example, a median fence or barrier were constructed, it is possible that some pedestrians would be discouraged from making shopping trips across US-50 because of the increase in pedestrian delay. Likewise, a pedestrian signal or bridge might encourage more shopping trips due to the greater accessibility of the shopping areas.

Increased or Reduced Land Values

Increased or reduced accessibility of shopping and other facilities may positively or negatively affect land values in the residential areas near the study section. Depending on its appearance, the presence of a pedestrian bridge could also have a negative affect on land values, particularly of those properties directly adjacent to it.

Increased or Reduced Air Pollution and Noise

The only alternative that would have a significant effect on air pollution and noise in the study area would be the installation of a pedestrian signal. Air pollution and noise caused by idling and stopping vehicles would be increased, particularly in the area near the signal.

Positively or Negatively Affected Area Aesthetics

Each of the alternatives except the no-build alternative would probably negatively affect the aesthetics of the study area. A median fence or barrier would act as a visual barrier and could become an eyesore if not properly maintained. A traffic signal also would be an intrusion into the overall appearance of the area. A pedestrian bridge would have the largest aesthetic effect on the area. The bridge itself would be a visual intrusion and, depending on its design and appearance, it could severely detract from the aesthetics of the study area.

Table 6 gives a summary of the likely effects of the intangible benefits and liabilities of each of the improvement alternatives. The more detailed analysis of intangible benefits and liabilities in the Seven Corners study resulted in the pedestrian signal alternative being the preferred alternative followed by the pedestrian bridge alternative, the no-build alternative, and the pedestrian barrier alternative, respectively.

TABLE 6 Summary of Intangible Benefits and Liabilities

	Alternatives			
	No-Build	Median Fence or Barrier	Pedestrian Signal	Pedestrian Bridge
No. of vehicle trips	No effect	Negative	Positive	Positive
Commercial patronage	No effect	Negative	Positive	Positive
Land values	No effect	Negative	Positive	Positive and negative
Air pollution	No effect	No effect	Negative	No effect
Noise	No effect	No effect	Negative	No effect
Aesthetics	No effect	Negative	Negative	Negative

SUMMARY OF ANALYSIS OF ALTERNATIVES

Table 7 gives the ranking of the various improvement alternatives in terms of the pedestrian interview and mail-back survey responses, the economic analysis, and the intangible costs and benefits. Review of this table indicates that the pedestrian bridge alternative is preferred in the users' opinions, from an economic standpoint, and from an overall standpoint, assuming an equal weighting of the three evaluation components. In the study on which this paper is based, the pedestrian bridge alternative was recommended as the preferred alternative. Alternative sites for the bridge were evaluated and a detailed set of recommendations and design criteria was developed. Fairfax County has subsequently accepted these recommendations, and the pedestrian bridge is currently being designed.

TABLE 7 Overall Alternative Rankings

	Pedestrian Interviews and Mail-Back Surveys	Economic Analysis	Intangible Costs and Benefits	Average Rank
No-build	3	3	3	3.0
Median fence or barrier	4	2	4	3.3
Pedestrian signal	2	4	1	2.3
Pedestrian bridge	1	1	2	1.3

SUMMARY AND CONCLUSIONS

An evaluation methodology has been presented for grade-separated pedestrian facilities that includes consideration of qualitative factors in the form of resident, merchant, and pedestrian interviews and surveys and an assessment of intangible benefits and liabilities and quantitative factors in the form of an economic analysis including both facility and user costs and benefits. The individual procedures described, though not new, have been combined in an effective evaluation procedure. For the application presented, the pedestrian bridge alternative would likely have been rejected in a less comprehensive analysis because of its relatively high cost. However, after applying the evaluation procedure described, construction of a pedestrian bridge clearly became the preferred alternative. The evaluation described is repeatable and is applicable to many types of similar projects.

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Abridgment

Occupant Restraint Use in the Traffic Population: 1984 Annual Report

MICHAEL E. GORYL and MICHAEL J. CYNECKI

ABSTRACT

This paper is a report on the 1984 findings from four independent studies designed to monitor occupant restraint and helmet use for various segments of the traffic population. This study is sponsored by NHTSA and is a continuation of earlier NHTSA studies. The report is based on field observations collected during a 12-month period from January through December 1984. During this period the use of occupant restraints including both safety belts and child safety seats was observed for more than 238,000 drivers and passengers in more than 206,000 passenger vehicles in 19 cities across the nation. Helmet usage was also recorded for operators and passengers of more than 14,000 motorcycles. These study results are not intended to be cross-sectionally representative of restraint use across the country; they are intended to be a measure of restraint use over time, sampled at select metropolitan areas throughout the United States. The observational studies are described.

This paper is a report of findings from four independent studies on occupant restraint and helmet use for various segments of the traffic population. Field observations, collected in 19 U.S. cities from January through December 1984, are the basis for this report. The four studies and their findings are as follows:

1. Driver safety belt use: A total of 130,207 drivers stopped at traffic signals were observed in 1984. Safety belt use during the last data collection period (July to December) was 15.3 percent.
2. Passenger safety belt and child safety seat use: Findings are based on 108,076 passengers observed at shopping mall exits. Child safety seat usage (for infants and toddlers) increased throughout

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