the relative hazardousness of a pedestrian crossing by a measure such as conflict rate. If this is desired, then a comparison of data from many other locations is required to produce a measure of hazardousness to pedestrians. Once this is accomplished, a few hours of data collection at a site may produce important information on the relative hazardousness of a crossing, as well as safety deficiencies.

Further investigation is needed to determine the amount of data collection required at a site to provide reliable results. Studies are also recommended to investigate the repeatability of results from one day to the next, and comparisons of results from similar locations are desired to further investigate reliability of this technique.

During this study, it was assumed that pedestrian conflicts are a measure of vehicle-pedestrian accident potential. It was not within the scope of this study to determine the exact relationship that exists between conflicts and accidents. However, this relationship should be investigated; this can be accomplished by comparing pedestrian accident histories with conflict data collected at various locations. Investigations can also be conducted to determine which types of pedestrian conflicts are more hazardous. The results of these studies will assist in providing more concise information from this conflict technique regarding hazards to pedestrians at roadway crossings.

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Causal Factors of Non-Motor-Vehicle-Related Bicycle Accidents

Patricia L. Wheatley and Kenneth D. Cross

The Santa Barbara County Bicycle Safety Project was created in September 1977 and funded through September 1979. The primary area of development in this project involved research into the causal factors of non-motor-vehicle-related bicycle accidents. Many types of accidents fall into this category—bicycles hitting other bicycles, pedestrians, or fixed objects. In addition, bicyclists lose control of their bicycles and fall for many reasons. Although considerable emphasis has been given to bicycle-motor vehicle accidents in the last few years, relatively little attention has been given to the non-motor-vehicle-related bicycle accident. The purpose of the project research has been to provide comprehensive material on the nature and cause of non-motor-vehicle-related bicycle accidents in Santa Barbara County. In addition, the project performed a study on the nature and cause of bicycle-related accidents on separated off-road bicycle facilities in the county. To provide proper perspective on this information, a survey was first taken of the general population of bicyclists in the county.

The Santa Barbara County Bicycle Safety Project was created in September 1977, funded by the California Office of Traffic Safety to the University of California at Santa Barbara. The funding for this project continued through September 1979.

A major emphasis of the Santa Barbara County Bicycle Safety Project, and the topic of this report, was research into the causal factors of non-motor-vehicle-related bicycle accidents. Many accidents fall into this category. For the purposes of this report, all bicycle-related accidents that do not involve a motor vehicle will be referred to as non-motor-vehicle (NMV) accidents.

Bicycle-motor vehicle accident research has received considerable attention over the last few years. On the average, accidents that involve a motor vehicle result in more severe injuries than do NMV accidents. In addition, the study on NMV accidents is difficult because such accidents are rarely reported to any record-keeping agency. In spite of this scarcity of information, it is generally recognized that NMV accidents occur with far greater frequency than do bicycle-motor vehicle accidents. For this reason, the study of NMV accidents was chosen for this project.

Because of the dearth of data on NMV accidents, we decided that a comprehensive survey of the general population of bicyclists might be the only way to obtain information on the full range of NMV accidents.

The purpose of the project research has been to provide comprehensive material on the nature and cause of NMV-related bicycle accidents in Santa Barbara County. In addition, the project performed a study of the nature and cause of bicycle-related accidents on separated off-road bicycle facilities in the county. To provide proper perspective on this information, a survey was first taken of the general population of bicyclists in the county.

Throughout the following narrative, reference will be made to the differences between northern and southern Santa Barbara County. In order to eliminate possible confusion, the following community descriptions are included.

The county of Santa Barbara provides an unusual blend of urban and rural populations. Bounded on the south by the Pacific Ocean, the county lies 148 km (92 miles) northwest of Los Angeles. One-third of the county's area is located in the Los Padres National Forest. A significant portion of the county's 288 000 population resides in the southeastern metropolitan coastal region, including the city of Santa Barbara.

The moderate climate enables continuous outdoor recreation that has increasingly included bicycling. Surveys conducted during the initial research stage of the Santa Barbara County Bicycle Project found that there are 152 528 bicycles and 151 064 bicyclists in Santa Barbara County. Of this number, 96 528 bicyclists live in the southeastern part of the county. A large portion of these bicyclists are adults.

To facilitate the expanded use of bicycles in the southern section of the county, several kilometers of separated bikeways have been and are being built. Santa Barbara County is a pioneer in the area of off-street bikeways.

The coordinating agency, the University of California at Santa Barbara, has a student population of 14 400. The bicycle is the major means of transportation on the university campus. Currently, there are an estimated 10 500 bicycles on campus on any given day. Along with the rise in the bicycling population has been an increase in bicycle accidents. In order to avoid a serious accident problem, a tremendous amount of effort and staff expertise has gone into the development of one of the finest bicycle systems in the nation.

METHOD

The research plan specified four separate surveys: (a) a random postcard survey of county residents, (b) a questionnaire survey of a large sample of bicyclists who reside in Santa Barbara County, (c) an interview survey of those bicyclists who reside in Santa Barbara County, and (d) an interview survey of those bicyclists who had recently been involved in accidents.

Postcard Survey

The objective of the postcard survey was to obtain data on a representative sample of county residents to determine the following:

1. Number of bicycles per household,
2. Number of riders per household,
3. Ages and sexes of the riders,
4. Number of bicycles stolen per household, and
5. Type of area (urban or rural) in which the bicyclists reside.

The prime consideration for the selection of the interview sample was to obtain an unbiased, random sample of county residents. The self-addressed, stamped postcard surveys were then mailed to 8 percent of the persons on the list. A total of 7674 postcards were sent to residences as well as to post office boxes and rural delivery routes. The return cards were number coded so that records could be kept of the return rates for each zip code area in the county.

A total of 1874 postcards were returned, reflecting a 24.4 percent return rate. Results of a subsequent tally of age distributions and household sizes were compared with census data to validate the survey results. The survey returns were consistent with census data in nearly every case, provided that the ages and number of persons per household revealed in the survey is consistent with that of the general population.

To further validate the results and to discover any possible biases in the postcard questionnaire, a telephone survey was conducted after all of the postcards had been returned. Telephone numbers were obtained for a sample of those residents who did not respond by using the telephone company's Cross Reference Directory.

The interviewer asked these residents the same questions as those on the postcard survey. Again, no serious biases were discovered.

A computer mask was designed to enter postcard responses. The following information was computed:

1. Number of accidents for males and females by specific age groups;
2. Number of males, females, and total population of each geographic area;
3. Number of urban, rural, and total residents in each geographic area;
4. Number of male and female cyclists and total number of cyclists;
5. Number of urban, rural, and total number of residents in each age group;
6. Total number of bicycles in each geographic area;
7. Average number of bicycles per household in each geographic area;
8. Average number of bicycles per person in each geographic area; and
9. Total number of bicycles stolen in each geographic area.

Bicycle User Survey

The objective of the bicycle user survey was to obtain population estimates of the riding habits and experiences of Santa Barbara County residents.

A four-page, fold-out survey was designed to include 21 questions, which covered the following areas of interest:

1. Operator characteristics,
2. Rider experience and exposure,
3. Bicycle usage patterns,
4. Bicycle characteristics, and
5. Accident experiences.

The bicycle user survey was taken to elementary, junior high, and senior high schools throughout the county; the University of California; and a two-year college in northern Santa Barbara County. To obtain the adult bicycle-riding populations, surveys were given at the department of motor vehicles in northern and southern Santa Barbara County.

The following is a breakdown of surveys obtained through this effort:

Age Group	North County	South County	Total
Elementary	306	535	841
Junior high school	185	329	514
Senior high school	221	266	487
College	68	317	385
Adults	56	320	376
Total	836	1767	2603

Telephone Surveys

The objective of the telephone interview was to determine the function failure, environmental, psychological, and contributing factors of the particular types of accidents isolated in the bicycle user survey. Ultimately, the similarities and differences between the types of accidents were determined as a result of this interview survey.

All of the bicycle user surveys were reviewed to isolate those that included accidents that took place during the last 24 months as well as those that resulted in either physical injury or property damage. No surveys were included in the telephone interviews unless prior permission from the victim had been secured (this was determined by the victim's signature on the user survey).

At the same time the telephone surveys were being conducted, a bicycle-use survey was being developed by the Santa Barbara County Transportation Study, which was funded by the Federal Highway Administration and the state of California. The Atascadero Creek and Cabrillo surveys were conducted on new separated bike paths in southern Santa Barbara County. At our request, this research team included on their survey a question that asked for the name and phone number of bicyclists who had accidents on separated bikeways. Through these surveys we were able to add to the numbers of documented adult accident experiences on separated bikeways other than on the university campus. After all telephone interviews were completed, the surveys were grouped into accident types. Similarities and trends were evaluated on the basis of the following:

1. Accident types,
2. Sex of victim,
3. Riding experience,
4. Road type and configuration,
5. Speed of the bicyclist,
6. Type of bicycle used,
7. Condition of the bicycle,
8. Amount of property damage, and
9. Other contributing factors.

A total of 206 accident victims were contacted for telephone interviews; 38 telephone surveys were taken from the Atascadero and Cabrillo bikeway surveys.

OVERVIEW OF PROJECT

Information from the postcard survey yielded estimates of the proportion of residents of Santa Barbara County who ride a bicycle at least once per year. The percentage of bicyclists who ride was tabulated by age, sex, and census tract. Information concerning the size and distribution of the entire resident population of Santa Barbara County was obtained from a special census conducted in 1975. This special census yielded data on the size of the resident population by age, sex, and census tract. The size of the bicycling distribution for each subpopulation was obtained by multiplying the number of residents in that subpopulation by the estimate of the percentage of residents within that subpopulation who ride bicycles. This procedure yielded estimates of the size of the bicycling population by age, sex, and census tract.

The postcard survey also yielded data on the percentage of bicyclists who have had at least one accident during the past 12 months. This percentage of bicyclists was tabulated by age, sex, and census tract. The number of bicyclists in each subpopulation was multiplied by the estimates of the percentage of that subpopulation who have had an accident during the past 12 months. This task yielded estimates of the size of the accident population by age, sex, and census tract.

One of the main objectives of this study was to identify the types of NMV accidents that occur and the factors that contribute to each type of accident. The detailed data on accident types and contributing factors were obtained during telephone interviews of accident victims whose names and telephone numbers were identified by the bicycle user survey.

Another product of the bicycle user survey was data on the bicycle usage patterns of Santa Barbara County bicyclists. The primary objective in obtaining information on bicycle usage was to obtain quantitative data to use in comparing the relative exposure of the accident population and nonaccident population. The final index of exposure was estimates by bicyclists of the number of kilometers traveled on a bicycle during an average week. Such exposure data are needed to fully interpret the information on accidents.

When attempting to assess the cost-effectiveness of accident countermeasures, it is useful to be able to compare the estimated cost of countermeasure programs with the magnitude of societal loss that results from accidents. Accident cost data were estimated through a consideration of the accident consequences derived from the telephone survey and information on the average cost of generic types of property damage and injuries.

FINDINGS

Postcard Survey Results

A total of 1874 postcard questionnaires were returned, which provided information on a total of 4674 residents. To assess the representativeness of the sample of residents who responded to the postcard survey, the age distribution of the respondents to the postcard survey was compared with the age distribution of county residents as measured by a special countywide census taken in 1975. Residents younger than 5 and residents older than 65 years of age were underrepresented in the postcard survey, whereas residents whose ages fall between these two extremes were overrepresented slightly. Although these biases are statistically significant, they are exceedingly small for any mailback survey. Discounting the two extreme age groups, a difference between percentage values for the various age groups never exceeds 1.4 percent and, for most age groups, the difference is less than 1 percent.

The representativeness of the postcard data was also assessed by comparing the postcard data and census data in terms of the average number of residents per household. It was found that these two percentage values differed by less than 0.3 percent. Based on these findings, the biases in the postcard survey are so small that they have little effect on the population estimates of the size and distribution of the bicycling population and the accident population.

Careful study of the census data and the data obtained by the postcard survey indicates that the county could be geographically subdivided into two subpopulations, hereafter referred to as North County and South County. The residents who reside within each of these subpopulations are homogeneous, but the residents residing in North County differ in several important respects from the residents who reside in South County. It was also found that bicycle usage by males differed from bicycle usage by females. For these reasons, the size and distribution of the Santa Barbara bicycling population was derived for four subpopulations: North County males, North County females, South County males, and South County females. The number of bicyclists in each age group was derived by multiplying the number of residents in that age group (as indicated by the 1975 census) by the percentage of residents in that age group who identified themselves as bicyclists on the postcard survey. The results of this analytical procedure are presented in Table 1.

Estimates of the size of the bicycling population in Santa Barbara County are shown in Table 1 by geographical area, sex, and age. The bottom row of Table 1 provides estimates of the size of the bicycling population for all ages combined; the three columns on the right-hand extreme of Table 1 show estimates of the size of the entire bicycling population. The reader's attention is directed to the following findings:

1. It is estimated that there are about 179 000 bicyclists in all of Santa Barbara County.
2. About 59 percent of the bicycling population reside in South County and 41 percent reside in North County. For the entire county, about 53 percent of the bicycling population are males and 47 percent are females. The ratio of male to female bicyclists is higher in North County (55 percent males-45 percent females).
3. For females, the 15 - to 19-year-old group contains the most bicyclists, but the 20- to 24-year-old group is only slightly smaller.

The age distribution was found to be typical of the age distributions reported for many other U.S. communities. That is, the relative number of bicyclists increases rapidly after age 5, reaches a peak between ages 10 and 14, and declines steadily thereafter. The age distribution of bicyclists who reside in South County is considerably different from the age distribution of North County bicyclists. In South County, the relative number of bicyclists is greatest for the group aged 20-24; and the group aged 10-14, which was larger than any other in North County, is the fourth largest age group in South County. The large number of young adult bicyclists in South County is partly the result of the large number of college and university students who reside in the Santa Barbara area and partly the result of different bicycle usage patterns by young adults who are not students. Combining North and South County bicyclists results in an age distribution that indicates that the relative size is nearly the same for the groups aged 10-14, 15-19, and 20-24; it also indicates that the groups aged 5-9 and 25-29 are about the same size.

The relative size of the male and female bicycling population is nearly the same for every age group. The only notable difference is that, in North County, a larger proportion of females between the ages of 25 and 40 are bicyclists.

Examination of the differences between the age distributions of North County and South County bicyclists shows that the trends are the same for male and female bicyclists but are more pronounced for female than male bicyclists. The trend, as discussed above, is that the largest age group in North County is the group aged 10-14, whereas the largest age group in South County is the group aged 20-24. Note that about 18 percent of the male bicyclists and more than 23 percent of the female bicyclists in South County are between the ages of 20 and 24. Figure 1 shows in graphic form the age distribution of North and South County bicyclists with male and female combined.

The respondents to the postcard questionnaire were asked to identify for each bicyclist in the household the number of bicycle accidents experienced in the last 12 months. Bicyclists who had experienced a bicycle accident in the past 12 months were grouped together and will be identified hereafter as the accident group. Bicyclists who had had no accidents in the past 12 months were grouped together and will be referred to hereafter as the nonaccident group.

Table 2 shows the age distributions of the accident group and the nonaccident group for North County and South County separately and combined. Age distributions are not shown by sex because the number of individuals in the North County accident group is too small to enable a comparison to be made between the age distribution of male and female accident victims in North County. Moreover, an examination of the age distributions for the male and female accident victims in South County revealed no major differences. Table 2 shows that the age distribution of the North County accident group is bimodal. That is, a secondary peak is reached for the group aged 5-9 and the primary peak is reached at the group aged 15-19. The age distribution of the South County accident group is quite different. It can be seen that nearly 48 percent of bicyclists in the South County accident group are between the ages of 20 and 24. The group aged 15-19 is the next most frequent, accounting for nearly 15 percent of all bicyclists in the accident group. The group aged 10-14 is the third most frequent, accounting for about 14 percent of the bicyclists in the accident group.

Figures 2 and 3 enable an easy comparison of the age distributions for the accident and nonaccident groups; Figure 2 shows the data for North County and Figure 3 shows the data for South County. Figure 2 shows that bicyclists between the ages of 15 and 24 are grossly overrepresented in the accident group; the overrepresentation is greatest for the group aged 20-24. With only three minor exceptions, all other age groups are underrepresented in the accident group. Figure 3 shows that South County bicyclists between the ages of 10 and 24 are overrepresented in the accident group, and that all other age groups are underrepresented in the accident group. The over-representation is only slight for bicyclists in the groups aged 10-14 and 15-19. However, the over-representation of 20- to 24-year-olds in the accident group is extremely large; bicyclists between the ages of 20 and 24 account for only 17 percent of the bicyclists in the nonaccident group, but they account for nearly 48 percent of the bicyclists in the accident group. It is clear from the above findings that accident countermeasures aimed at 20- to 24-year-old bicyclists have the potential for reducing total accidents by a substantial margin. However, as is true in most other communities, substantial accident-reduction benefits can be expected from effective countermeasures aimed at younger bicyclists.

Table 1. Estimated number of bicyclists in north and south Santa Barbara County.

	North County						South County								
	Male			Female			Male			Female			Total Bicyclists		
Age	R	%	B	R	%	B	R	%	B	R	%	B	Male	Female	Combined
<5	4 373	30.2	1 321	3 963	17.1	678	3 735	19.1	713	3 866	24.5	947	2 034	1 625	3 659
5-9	5 230	92.8	4 853	4 914	92.9	4 565	5 045	92.0	4 641	5 154	85.4	4 402	9 494	8 967	18 461
10-14	6 665	98.1	6 538	6 014	91.8	5 521	6 102	99.2	6 053	6 348	98.3	6 240	12 591	11 761	24 352
15-19	6 565	86.3	5 666	5 620	81.1	4 558	8 476	87.9	7 450	9 224	91.2	8 412	13 116	12 970	26 086
20-24	6 985	71.7	5 008	4 342	72.2	3 135	10 589	87.3	9 244	10 605	89.8	9 523	14 252	12 658	26 910
25-29	4 875	68.5	3 339	4 058	73.7	2 991	8 157	87.7	7 154	7 465	85.7	6 398	10 493	9 389	19 882
30-34	3 783	61.9	2 342	4 064	56.9	2 312	5 467	70.7	3 865	5 375	69.7	3 746	6 207	6 058	12 265
35-39	3 887	55.1	2 142	3 827	73.0	2 794	4 170	67.8	2 827	4 366	67.7	2 956	4 969	5 750	10 719
40-44	3 715	60.7	2 255	3 483	54.5	1 898	4 001	71.6	2 865	4 055	49.4	2 003	5 120	3 901	9 021
45-49	3 269	63.6	2 079	3 154	49.1	1 549	3 917	61.8	2 421	4 170	57.6	2 402	4 500	3 951	8 451
50-54	3 074	56.4	1 734	3 098	33.3	1 032	4 112	40.3	1 657	4 624	47.1	2 178	3 391	3 210	6 601
55-59	2 476	36.4	901	2 296	20.0	459	3 442	52.9	1 821	3 831	30.9	1 184	2 722	1 643	4 365
60-64	1 876	36.4	684	1 972	27.6	544	3 006	37.9	1 139	3 791	17.8	675	1 823	1 219	3 042
65-69	1 641	27.3	448	1 580	0.1	2	2 818	30.4	857	4 071	14.6	594	1 305	596	1 901
70-74	1 075	55.6	598	1 065	75.0	799	2 174	27.9	607	3 073	4.0	123	1 205	922	2 127
≥75	1 213	50.0	607	1 676	11.1	186	2 942	3.0	88	5 389	0.1	5	695	191	886
Total	60 704	66.7	40 515	55 126	59.9	33 023	78 153	68.3	53 402	85 407	60.6	57 788	93 917	84 811	178 728

Notes: R = number of residents (from 1975 to census data); % = percentage of residents who ride a bicycle (from 1978 postcard survey); and B = estimated number of bicyclists (R x %).

Figure 1. Age distribution of Santa Barbara County bicyclists.

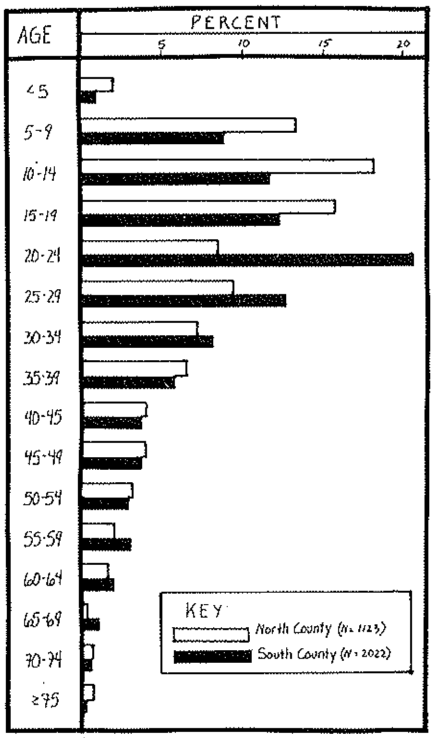


Table 3 gives estimates of the total number of persons in North County and South County who have had at least one accident during the last 12-month period. Estimates were derived for each age group by multiplying the total number of bicyclists in that age group who have reported having an accident during the last 12-month period by census group. Again, the data used to derive these estimates were obtained from the postcard survey and from a special census taken in 1975.

The data in Table 3 reveal several important findings. First, the incidence of NMV accidents in South County is about four times as great as that in North County. A relatively small amount of this difference is attributable to the larger bicycling population in South County than that in North County. Note in Table 3 that the estimated number of bicyclists in North County is 74 000 whereas the estimated number of bicyclists in South County is approximately 105 000. Thus, if the accident rate were the same in North and South County, the number of accidents in South County would be only about 25 percent greater than the number of accidents in North County. It is clear from these results that the accident rate in South County is considerably greater than that in North County. The extent of this difference is made clear by comparing columns 3 and 6 in Table 3. These proportions can be interpreted as accident rates for the corresponding age group. For instance, the number associated with the 10-14 year age group in North County indicates that about 1.46 NMV accidents/100 bicyclists can be expected to occur each year. The largest accident rate for both North County and South County is associated with the group aged 20-24. However, it can be seen that South County bicyclists in this age group experience more than 18 accidents/100 bicyclists, whereas North County bicyclists in this age group experience about 6 accidents/100 bicyclists. The accident rate is higher in South County for 10 of the 16 age groups, and the rate is essentially the same for the remaining six age groups.

Items were included on the postcard questionnaire to obtain information about the number of bicycles in use in Santa Barbara County and the number of bicycles that are stolen each year. The findings are summarized in the table below. The data are shown for urban areas, rural areas, and for urban and rural areas combined.

Item	Urban	Rural	Combined
Total bicycles	2954.00	397.00	3351.00
Mean bicycles per household	1.90	2.16	1.93
Mean bicycles per resident	0.71	0.76	0.71
Mean bicycles per bicyclist	1.05	1.23	1.07
Total bicycles stolen, past 12 months	221.00	18.00	239.00
Bicycles stolen per 1000 in use	74.8	45.3	71.3
Bicycles stolen per 1000 households	142.2	97.3	137.5

DESCRIPTION OF TYPES OF ACCIDENT AND CONTRIBUTING FACTORS

The accident types and the factors that contribute to

Table 2. Age distributions of the accident and nonaccident groups.

	Accident Group						Nonaccident Group					
	North County		South County		Total		North County		South County		Total	
Age	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
<5	1	3.3	0		1	0.5	11	0.9	17	0.9	28	0.9
5-9	5	16.7	13	8.1	18	9.4	226	19.4	165	8.7	391	12.8
10-14	3	10.0	22	13.8	25	13.1	202	17.3	221	11.7	423	13.8
15-19	7	23.4	24	14.9	31	16.2	169	14.6	242	12.8	411	13.4
20-24	6	20.0	77	47.9	83	43.5	88	7.5	342	18.0	430	14.0
25-29	1	3.3	10	6.2	11	5.8	110	9.4	257	13.5	367	12.0
30-34	1	3.3	6	3.7	7	3.7	83	7.1	168	8.8	251	8.2
35-39	2	6.7	2	1.2	4	2.1	72	6.2	124	6.5	196	6.4
40-44	1	3.3	2	1.2	3	1.6	57	4.9	93	4.9	150	4.9
45-49	2	6.7	2	1.2	4	2.1	53	4.5	76	4.0	129	4.2
50-54	0		1	0.6	1	0.5	34	2.9	61	3.2	95	3.1
55-59	0		1	0.6	1	0.5	23	2.0	60	3.2	83	2.7
60-64	0		1	0.6	1	0.5	21	1.8	37	1.9	58	1.9
65-69	0		0		0		8	0.7	20	1.1	28	0.9
70-74	0		0		0		5	0.4	14	0.7	19	0.6
≥75	1	3.3	0		1	0.5	5	0.4	2	0.1	7	0.2
Total	30		161		191		1167		1899		3066	

Figure 2. Comparison of age distribution of North County accident and nonaccident groups.

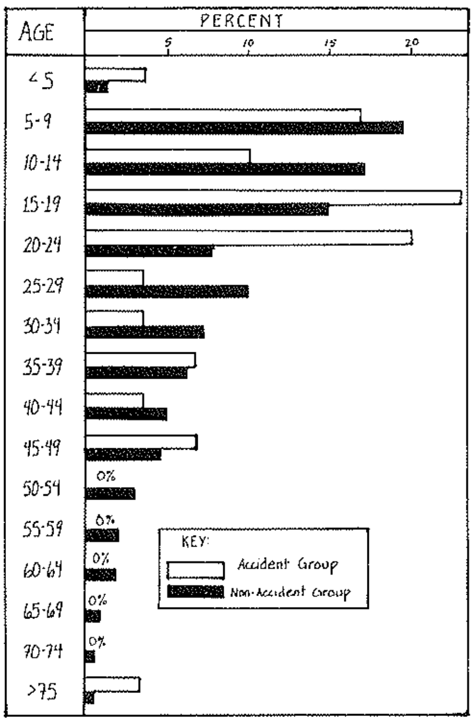
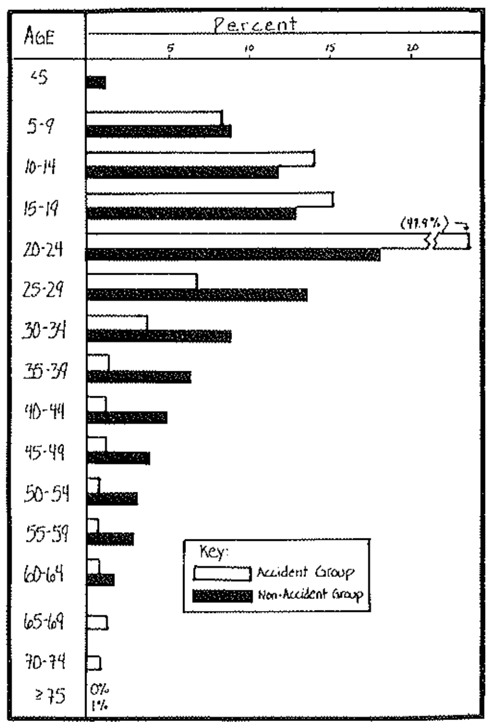


Figure 3. Comparison of age distribution of South County accident and nonaccident groups.



accidents were defined from a study of the data compiled from the telephone interviews with the accident victims. Eight of the 206 accident cases investigated proved to be bicycle-motor vehicle accidents, so the following results are based on interviews with 198 bicyclists who recently were involved in NMV accidents. The information obtained for each case was studied by three members of the project staff. Each staff member made independent judgments about the factor that precipitated the accident and the one or more factors that contributed to the accident. Differences in judgments about precipitating factors and contributing factors were resolved through discussion.

An attempt was made to contact virtually every bicyclist in the user survey who reported having had a recent NMV accident. Many bicyclists, especially young adults, could not be located because of an address change. For this reason and others, the sample of bicyclists interviewed cannot be considered representative of the total accident population in Santa Barbara County. To correct for the biases in the telephone survey data, the age distribution of the sample of bicyclists in the telephone survey was multiplied by weighting factors such that the age distribution for the telephone survey matched the age distribution of the accident population in Santa Barbara County, as revealed by the postcard survey. This age distribution is shown in Table 2 and discussed above. The weighting factors

Table 3. Estimates of the total number of persons in North County and South County who have had at least one accident during the last 12-month period.

	North County Bicyclists			South County Bicyclists		
Age	Number	Had Accident (%)	Estimated Number of Accidents	Number	Had Accident (%)	Estimated Number of Accidents
<5	1 999	8.33	167	1 660	0.00	0
5-9	9 418	2.16	203	9 043	7.30	818
10-14	12 059	1.46	176	12 293	9.05	1112
15-19	10 224	3.98	407	15 862	9.02	1431
20-24	8 143	6.38	520	18 767	18.38	3449
25-29	6 330	0.90	57	13 552	3.75	468
30-34	4 654	1.19	55	7 611	3.45	263
35-39	4 933	2.70	133	5 783	1.59	92
40-44	4 153	1.72	71	4 868	2.11	103
45-49	3 628	3.64	132	4 823	2.56	123
50-54	2 766		0	3 835	1.61	62
55-59	1 360		0	3 005	1.64	49
60-64	1 228		0	1 814	2.63	48
65-69	450		0	1 451		0
70-74	1 397		0	730		0
≥75	793	16.67	132	93		0
Total	73 535		2053	105 190		8018

used for each of the age groups is shown in the following table:

Bicyclist's Age	Weighting Factor
<5	1.00
5-9	4.60
10-14	2.30
15-19	1.18
20-24	7.13
25-29	2.32
30-34	7.40
>35	1.00

As the accident types are discussed in the following pages, two percentage values are given for each type of accident. One percentage value indicates the proportion of accidents in the unweighted sample that is accounted for by that accident type. The other percentage value indicates the percentage of accidents in the weighted sample that is accounted for by that accident. When percentage values for the weighted and unweighted sample are approximately the same, it can be concluded that that accident type is relatively independent of bicyclists' age; or, stated differently, accidents of that type are experienced by bicyclists of different ages.

Class A Accidents—Collision or Near Collision With a Moving Object

All of the accidents included in class A involved the collision of a bicyclist with another moving object or a bicyclist falling or colliding with a fixed object while attempting to avoid a collision with a moving object. Class A accidents were subdivided into the four accident types listed in the table below. Class A accidents accounted for slightly more than 28 percent of the NMV accidents in the weighted sample.

Accident Description	Sample (%)	Weighted Sample (%)
Type 1—Collision or near collision with another bicycle	19.1	21.2
Type 2—Collision or near collision with animal	1.5	1.5
Type 3—Collision or near collision with pedestrian	1.0	4.6
Type 4—Fell or struck fixed object when evading collision with motor vehicle	2.0	1.0
Total class A (N = 47)	23.6	28.3

Type 1: Collison with Another Bicycle

The table above shows that accident type 1 accounts for slightly more than 21 percent of the NMV accidents in the weighted sample. (Hereafter all percentage values cited in the text refer to the weighted sample.) Type 1 accidents can be divided into five distinctly different subtypes, based on the factor that precipitated the accidents. The subtypes are listed below along with the percentage of all type 1 accidents that were accounted for by that subtype.

Subtype 1—misjudged the intentions of the other bicyclist—63 percent;

Subtype 2—obstructed view of another bicyclist—13 percent;

Subtype 3—distracted, not looking in direction of other bicyclist—8 percent;

Subtype 4—misjudged the space required to overtake and pass—8 percent; and

Subtype 5—game playing or stunting—8 percent.

All of the accidents classified into subtype 1 involved a bicyclist who observed the other bicycle soon enough to avoid the accident, but failed to do so because he or she misjudged the intentions of the other bicyclist. Subtype 1 accidents most commonly involved two or more bicyclists who were riding together, either abreast or in tandem. The accidents occurred when one of the bicyclists unexpectedly turned, slowed speed, failed to turn, or failed to slow. An unexpected turn was the most common type of misjudgment.

A smaller, but nevertheless important, number of subtype 1 accidents involved bicyclists who were not riding together but were approaching one another on either an orthogonal path or a parallel path. In most of these cases, both bicyclists misjudged the intentions of the other.

All subtype 2 accidents occurred when one bicyclist's view of the other was obstructed until the bicycles were in such close proximity that the accident could not be avoided. In all cases, the bicycles approached one another on orthogonal paths. The objects that obstructed the bicyclist's view were vegetation or parked motor vehicles.

All the bicyclists in subtype 3 were distracted and, therefore, were not searching in the direction of the other bicyclist. All subtype 4 accidents resulted from a bicyclist's misjudgment about the space required to overtake and pass another bicyclist. That is, one bicyclist attempted to overtake and pass another bicyclist at a point where there was insufficient space to do so safely. All subtype 5 accidents occurred when two or more bicyclists were game playing or stunting.

Type 2: Collision or Near Collision with Animal

Nearly every book on bicycle riding warns of the hazards associated with animals chasing bicyclists or unexpectedly dashing into the bicyclist's path. The table shows that collisions or near collisions with animals accounted for only 1.5 percent of the NMV accidents in the weighted sample. The low incidence of this type of accident may be due to the fact that most, and perhaps all, communities in Santa Barbara have leash laws for dogs. It would be interesting to compare the incidence of this accident type in Santa Barbara County with the incidence in one or more communities that do not have a leash law.

Type 3: Collision or Near Collision with Pedestrian

A collision or near collision with a pedestrian accounted for only 1 percent of the accidents in the unweighted sample but accounted for nearly 5 percent of the accidents in the weighted sample. This difference is due to the fact that this accident type more often involves older riders than younger riders. The incidence of bicycle-pedestrian accidents in the telephone survey was too small to make a definitive statement about how and why they occur. However, information obtained from bicyclists who were riding on one of the two main separated bicycle paths in Santa Barbara indicates that the incidence of bicycle-pedestrian accidents increases dramatically when separated bike paths are used by pedestrians and bicyclists. It was found that 3.8 percent of the bicyclists interviewed on the bike paths had recently been involved in an accident with a pedestrian on one of the two main paths in the city of Santa Barbara. The data indicate that bicycle-pedestrian accidents most frequently occur when the pedestrian turns unexpectedly as he or she is being overtaken from the rear by a bicyclist. This type accident is particularly common when the pedestrian is roller skating or riding on a skateboard.

In summary, the telephone survey indicated that bicycle-pedestrian accidents are not as frequent as other types of accidents on the public streets. However, the evidence from the bike path surveys indicates that bicycle-pedestrian accidents may increase dramatically when bicyclists and pedestrians are permitted to use the same separated bike path. Other support for this contention comes from data on the incidence of bicycle-pedestrian accidents on college and university campuses.

Type 4: Fell or Struck Fixed Object When Evading Collision with Motor Vehicle

Many bicycle enthusiasts claim that numerous accidents occur when bicyclists fall or strike fixed objects as a result of their attempt to avoid a collision with a motor vehicle. This claim is not supported by the data compiled during this study. As is shown in the table, type 4 accidents accounted for only 1 percent of the NMV accidents in the weighted sample. It is possibly that the incidence of type 4 accidents may be far greater in other communities within Santa Barbara County. However, we hypothesized that the bicycle enthusiasts' claim that this type of accident occurs frequently is based on the incidence of near accidents rather than the incidence of actual accidents.

Class B Accidents: Fell or Collided with Stationary Object After Losing Control of Bicycle

As its title implies, all class B accidents occurred when the bicyclist lost control of the bicycle and fell or collided with a fixed object. The accident types and subtypes within class B are differentiated in terms of the factors that led to the loss of control. As is shown in the table below, class B accidents accounted for 61 percent of the accidents in the weighted sample.

Accident Description	Sample (%)	Weighted Sample (%)
Type 5—Lost control because of irregular road surface	22.6	22.6
Type 6—Lost control when performing stunts	6.5	3.6
Type 7—Lost control due to vehicle handling deficiency	13.6	12.6
Type 8—Lost control when carrying object in hands	3.0	1.4
Type 9—Lost control because object caught in moving part of vehicle	11.1	13.8
Type 10—Lost control because of other bicycle failure or defect	8.0	7.1
Total class B (N = 129)	64.8	61.1

Type 5: Lost Control Because of Irregular Road Surface

The data indicate that nearly 23 percent of all NMV accidents involve a bicyclist who lost control of the bicycle because of an irregularity in the road surface on which he or she was riding. Type 5 accidents can be further divided into subtypes based on the type of road surface irregularity that led to the loss of control. The type 5 subtypes are listed below along with an indication of the proportion of all type 5 accidents accounted for by each subtype.

Subtype 1—wet pavement—12 percent;
Subtype 2—sand, gravel, or dirt on paved surface—30 percent;
Subtype 3—tire hit large rock or other debris—20 percent;
Subtype 4—crack, bump, or hole in paved surface—30 percent;
Subtype 5—sewer grate—2 percent;
Subtype 6—rut or bump in unpaved surface—5 percent; and
Subtype 7—railroad track—2 percent.

Speed was judged to be a contributing factor in 49 percent of all type 5 accidents. In about one-half of the cases in which speed was judged to be a contributing factor, the bicyclist was riding down a hill. The effect of speed manifested itself by reducing the amount of time the bicyclist had available to respond to the irregularity of the road surface, increased the bicycle's sensitivity to road surface irregularities, or both. In 37 percent of the type 5 accidents, the bicyclist observed the irregularity of the road surface soon enough to have slowed speed or steered around the irregularity. In these cases, the bicyclist's failure to change speed or path was due to misjudgment of the effect of the irregularity on the bicycle's performance. In short, the bicyclist failed to perceive the irregularity as an accident hazard. In the remaining cases, the bicyclist failed to observe the road surface irregularity until it was too late to initiate effective evasive action. As indicated above, the bicyclist's failure to observe the irregularity soon enough to respond was often due, in part, to the bicycle's high speed.

Type 6: Lost Control When Performing Stunts

Three-quarters of type 6 accidents occurred when a young bicyclist was riding over a jump. It is interesting to note that in every one of these cases, the bicyclist was riding a Motocross bicycle. In the remaining cases, the bicyclist was attempting a wheelie, riding a serpentine course, or riding over a curb. These three accident subtypes accounted for about 25 percent of type 6 accidents and occurred with about equal frequency.

Type 7: Lost Control Due to Bicycle-Handling Deficiency

The preceding table shows that more than 12 percent of the NMV accidents in the weighted sample resulted directly from a deficiency in the bicyclist's vehicle-handling skill. As the term is used here, vehicle-handling skill deficiency refers to an inadequate level of skill to safely perform the maneuver that the bicyclist was attempting just prior to the accident. That is, a bicyclist may have a bicycle-handling skill deficiency even though his or her bicycle-handling skills are far better than those of the average bicyclist. Type 7 accidents can be divided into subtypes based on the maneuver that the bicyclist was attempting when the accident occurred. The accident subtypes are listed below along with an indication of the percentage of type 7 accidents accounted for by each subtype.

Subtype 1—high-speed braking—24 percent;
Subtype 2—high-speed turning—16 percent;
Subtype 3—high-speed steering—28 percent;
Subtype 4—normal-speed braking—8 percent;
Subtype 5—normal-speed turning—8 percent; and
Subtype 6—normal-speed steering—16 percent.

Bicyclists involved in subtypes 1 through 3 were at least as skilled as the average bicyclist in the age group. Conversely, bicyclists involved in subtypes 4 through 6 were judged to have far less bicycle-handling skills than the average bicyclist of the same age. Some of the type 7 accidents involved an irregularity in the roadway surface, such as wet pavement or gravel. However, it was judged that the accident was precipitated by the skill deficiency rather than by the roadway surface irregularity.

Type 8: Lost Control When Carrying Object in Hands

Type 8 accidents occurred relatively infrequently, accounting for only 1.4 percent of the accidents in the weighted sample. One-half of these accidents resulted from the bicyclist's inability to slow or stop by manipulating caliper brakes with only one hand. The other type 8 accidents resulted from a bicyclist's inability to steer and maintain balance when carrying an object in one hand. The incidence of type 8 accidents is surprisingly low in light of the number of bicyclists who are seen riding 10-speed bicycles and have only one hand available for steering and braking.

Type 9: Lost Control Because Object Caught in Moving Part of Bicycle

Type 9 accidents accounted for nearly 14 percent of the accidents in the weighted sample. Type 9 accidents can be divided into subtypes based on the object that became lodged in a moving part of the bicycle. The subtypes of accident type 9 are as follows:

Subtype 1—pant leg caught between chain and sprocket—32 percent;
Subtype 2—passenger's hand or foot caught in spokes—23 percent;
Subtype 3—object hanging from handlebars lodged in front wheel or spokes—27 percent;
Subtype 4—chain lodged between spokes and frame—5 percent; and
Subtype 5—miscellaneous—13 percent.

Type 10: Loss of Control Because of Bicycle Defect or Failure

Subtypes 4 and 5 of accident type 9 involved a bicycle failure. They were classified in accident type 9 because the failure resulted in an object being lodged in a moving part of the bicycle. It can be argued that these accidents should be classified in type 10 rather than type 9. Type 10 accidents can be divided into subtypes based on the part of the bicycle that was defective or that failed. This classification resulted in the identification of seven subtypes, each of which occurred with about equal frequency.

Subtype 1—defective brakes,
Subtype 2—loose handlebars,
Subtype 3—wet brakes,
Subtype 4—bicycle frame broke,
Subtype 5—gears slipped,
Subtype 6—chain broke, and
Subtype 7—front wheel was loose.

High speed was a factor in 41 percent of all type 10 accidents. That is, it was judged that the bicycle failure would not have resulted in a loss of control if the bicyclist had been riding at a reasonable speed.

Class C: Bicyclist Collided with Stationary Object with Subsequent Loss of Control

The table below shows that class C accidents accounted for only 10.4 percent of those in the weighted sample.

Accident Description	Sample (%)	Weighted Sample (%)
Type 11—Bicyclist's view of object was obstructed	1.0	1.3
Type 12—Degraded visibility	1.5	0.4
Type 13—Bicyclist not searching ahead	9.1	8.7
Total class C (N = 22)	11.6	10.4

Type 11 and type 12 accidents resulted from the bicyclist's view of the object being obstructed (1.3 percent) or obscured (0.4 percent) by degraded visibility conditions. These results indicate that few NMV accidents result from a bicyclist's inability to observe a fixed object until an accident is imminent. The distinguishing characteristic of type 13 accidents is that the bicyclist failed to observe the object struck because he or she was not searching in the direction he or she was traveling. Eighty percent of type 13 accidents involved the collision of a bicyclist with the rear of a parked motor vehicle. In over one-half of these accidents, the bicyclist was interacting with a riding companion who was riding abreast or behind the bicyclist. In the remaining cases, the bicyclist was communicating with a passenger, searching to the rear for overtaking traffic, or throwing a newspaper. These three accident subtypes occur with about equal frequency.

RELATIONSHIP BETWEEN ACCIDENT LIKELIHOOD AND EXPOSURE

The bicyclists who completed the questionnaire in the user survey were asked to indicate the number of kilometers per week they travel on school trips, trips to and from work, trips to visit friends and relatives, shopping and errand trips, trips traveling to a specific place of recreation, and recreational trips that have no specific destination. There was no expectation that these items would yield precise information on the absolute number of kilometers per week ridden for each of these purposes. However, it was reasoned that such items would yield data in which the bias is constant for bicyclists in the same age group and, therefore, would enable a comparison to be made of the relative exposure of bicyclists in the accident group and those in the nonaccident group.

A computer program was written to compute for each bicyclist in the user survey the estimated distance traveled for all trip purposes combined. The computer program then divided the bicyclists into age groups and, for each age group, divided the bicyclists into an accident group and a nonaccident group. The distribution of kilometers traveled per week was studied in the median and interquartile range for each population; the subpopulation was computed.

Our findings indicate that the 25th centile bicyclist rides about 5.6 km per week (3.5 miles per week), the 50th centile bicyclist rides about 14.3 km (8.9 miles) per week, and the 75th centile bicyclist rides slightly more than 25 km (16 miles) in an average week. The trends are completely consistent with the hypothesis that accident likelihood increases with exposure, as measured by the number of kilometers traveled per week. For every age group, the accident group reported traveling more kilometers per week than the bicyclists of the same age in the nonaccident group. Similarly, the kilometers traveled per week, like the incidence of NMV accidents, increases consistently to the 20- to 24-year-old group. Unfortunately, there was an insufficient number of older bicyclists to determine whether exposure, like accident frequency, decreases with age beyond age 24.

CONSEQUENCES OF NMV ACCIDENTS

In order to estimate the cost of the total societal losses from NMV accidents, the following procedure was used. Cost were divided into four major areas:

1. Doctor, dentist, and hospital costs;
2. Cost of bicycle damage;
3. Cost of other property damage, such as damaged clothing and books; and
4. Cost of days lost from school or work as a result of the NMV accident.

Although the bicyclists were questioned about the number of days in which they were partially disabled or suffered pain and discomfort, no attempt was made to estimate the cost of partial disability or pain and suffering. The method used to estimate the dollar loss associated with each of the four categories is as follows.

Medical Costs

Most of the estimates of medical costs were derived from cost data contained in a recent report on the cost of motor vehicle accidents (1). Note that the cost estimates quoted in Faigin's report are consistently low because of the inflated cost of medical care that has occurred since the report was published; however, no more accurate cost estimates could be located. Thus, the following costs were assumed for medical care:

1. Emergency-room treatment—$85,
2. Hospital care—$100 per day, and
3. Doctor's care—$20 per visit.

When surgery or dental work was needed, the cost estimates used were those reported by the accident victim.

Bicycle and Other Property Damage

At the time of the telephone surveys, few persons were aware of the dollar cost of damage to their bicycle. In numerous cases, the person simply failed to repair the damage, or the bicyclist or a parent repaired the damage as well as possible. In order to obtain information with which to estimate the cost of bicycle damage, local expert bicycle repairpersons were surveyed to obtain their estimates of the cost of parts and labor to repair various types of damage.

For property damage other than that sustained by the bicycle, the cost estimates used in the analyses were those provided by the bicyclist.

Cost of Days Lost from Work or School

The cost of a day missed from work was assumed to be $65. This value was computed by Faigin in 1976 (1) and is undoubtedly higher today. The cost of a day lost from school was assumed to be $5. This value was suggested by Cross in 1978 (2) in a discussion of the cost of bicycle-motor-vehicle accidents.

Average Costs and Total Losses

By using the cost estimates described above, it was determined that the average cost of a NMV accident was $106. In an earlier part of this section, it was estimated that 2053 North County bicyclists and 8018 South County bicyclists had at least one NMV accident during the past 12 months. Thus, the annual cost of NMV accidents is estimated to be about $218 000 in North County and about $850 000 in South County or about $1 070 000 for the county as a whole.

These cost estimates must be considered highly conservative in that they make no allowance for pain and suffering. Although emotional trauma represents a real and important societal loss, no satisfactory technique has been established for placing a monetary value on such a loss. In addition, no consideration has been given for the time lost by friends or relatives who care for an injured bicyclist. Moreover, the cost estimates cited above were based on the number of bicyclists who had one or more accidents during the past 12 months. Since some bicyclists have more than one bicycle accident during any 12-month period, the cost estimates cited above should be multiplied by the ratio of total accidents divided by total accident victims. Finally, the cost estimates must be considered conservative because the assumed costs of medical care and days lost from work or school are based on 1975 dollars rather than 1979 dollars.

CONCLUSION

The annual societal cost of NMV accidents has been conservatively estimated at $1 070 000 for Santa Barbara County. This is the first time a documented estimate of cost has been made to confirm the magnitude of this problem. With this documentation of cost, the need has been established for a remedy.

Whenever a decision is being made concerning the development of safety education programs, a balance between societal cost and societal benefit must be made. The cost of education can only be justified if the potential societal benefits outweigh the costs. We think that a societal loss of this magnitude justifies extensive educational development.

Never before have Americans been as energy conscious as they have in recent times. Bicycle use has become a logical alternative to fuel-consumptive vehicles. Consequently, more bicycles are now on the road than ever before. With this increased bicycle use has come a desperate need for bicycle safety education. In the current political climate, individual states as well as the federal government are placing high priority on the development of facilities that will encourage bicycle use for transportation. Without balancing education with this acceleration, we could be creating a tremendous safety problem while striving to save energy.

By using research projects that have defined major accident causes, it will be possible to direct meaningful safety education to adults as well as children.

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Determination of the Characteristics of Bicycle Traffic at Urban Intersections

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A study of bicycle traffic at urban intersections was conducted to determine the characteristics representative of this mode. The study was undertaken to address information deficiencies recognized during efforts to develop a multimodal-intersection-simulation model. The study focused on the arrival patterns, approach speeds, and crossing gap-acceptance characteristics of bicycle traffic. Traffic data were collected from a number of intersection locations operating under multimodal demand, which included motor vehicle, pedestrian, and bicycle modes. A video recording procedure was used to record and subsequently retrieve information relative to the various events of interest. Statistical analysis of the data was conducted to establish the characteristics of bicycle traffic arrivals, approach speeds, and crossing gap acceptance. The analysis of arrival data revealed that a negative exponential distribution represented a reasonable model for low-to-medium volumes of bicycles. Other arrival models were noted to be applicable in some cases, but the negative expontential was preferred because of its universality and simplicity. Approach speeds were noted to range from 3.4 to 39.6 km/h (2.1 to 24.6 mph), with the distribution of speeds corresponding to a normal curve. Analyses of bicycle speeds on different facilities and the impact of bicycle lane traffic on automobile speeds were performed. Last, an analysis of crossing gap acceptance revealed that the distribution of accepted gaps corresponds to a log normal function. The results of the study are presented and the applicability of the findings discussed. Recommendations are made for improving the procedures used and conducting further investigations.

The sale and use of bicycles for both utilitarian and recreational travel has grown since the mid 1960s (1-3). Transportation professionals, in recognition of this trend, had begun to give serious attention to the bicycle mode by the mid 1970s. Many programs were initiated to plan, design, and implement facilities for bicycle travel (4-7).