BICYCLE-SAFETY EDUCATION

—FACTS AND ISSUES—

by

Kenneth D. Cross, Ph.D.
Anacapa Sciences, Inc.
Santa Barbara, California

Published by

AAA Foundation for Traffic Safety
8111 Gatehouse Road
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PREFACE

It is estimated that nearly 100 million bicycles are used today by Americans of all ages. Each year, some 1,000 bicyclists are killed and 80,000 are injured in bicycle/motor-vehicle accidents, representing an economic loss of $275 million annually. When you add the total number of bicycle accidents occurring each year which do not involve a motor vehicle, it is estimated that our annual bicycle-accident toll is 1,220 deaths and 727,000 injuries.

Bicycle-safety education programs have been developed over the years without the benefit of important empirical accident data. Dr. Kenneth D. Cross, of Anacapa Sciences, Inc., Santa Barbara, California, is perhaps the nation's foremost investigator and analyzer of bicycle accidents through his work with grants from the U. S. Department of Transportation's National Highway Traffic Safety Administration.

Because of the extensive data base now available on bicycle accidents, it is important that we evaluate our current educational activities for bicyclists at all age levels to redirect, if necessary, our goals and objectives in bicycle-safety education so that local community programs can be strengthened and made more effective in minimizing the losses suffered from bicycle accidents.

The AAA Foundation for Traffic Safety has asked Dr. Cross to present his data and, more importantly, his views on what educational countermeasures can be most effective in meeting the needs in bicycle safety today and in the years to come.

Dr. Cross is eminently qualified to accomplish this task. He has formal training in experimental psychology and has been engaged in applied research for the past 15 years. In addition to his accident studies for the Federal Government, Dr. Cross has worked with state and local governments in the development of bicycle-safety education programs for school-ago children.

It is a privilege for the AAA Foundation for Traffic Safety to make this important work by Dr. Kenneth Cross available to educators and community leaders for their use in improving bicycle-safety education programs.

Sam Yaksich, Jr., Executive Director
AAA Foundation for Traffic Safety

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CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF TABLES

SECTION I
INTRODUCTION

For the 35-year period prior to 1970, bicycle sales in the United States increased at a small and relatively constant rate. Except for a short period during World War II, the annual increase in bicycle sales was due principally to increased usage by juveniles. There has been a steady increase in the size of the juvenile population in the United States and, owing to the increased affluence of most families, an increasing proportion of the juvenile population has been provided a bicycle at an early age. Survey data indicate that by 1968 nearly 90% of all juveniles over seven years of age were bicyclists (Vilardo & Anderson, 1969). A similarly high incidence of bicycling among juveniles was reported in a more recent survey conducted by Chiapecka and his colleagues (1975). Since most juveniles rode bicycles regularly in 1968 (and possibly before), the so-called "bike boom" that commenced in 1969 was due principally to a dramatic increase in the use of bicycles by the teenage and adult populations.

The increased use of the bicycle by teenagers and adults was the result of many interacting factors, but probably the most important single factor was the discovery of the great effeciciency of the lightweight multi-gear bicycle. Beginning in the mid-sixties, an increasing number of adult Americans discovered that the efficiency of the lightweight bicycle enabled them to ride faster and farther than was possible with the heavy, balloon-tire bicycle that most Americans rode prior to that time. Moreover, it was discovered that the head winds and steep gradients that would exhaust riders of standard bicycles could be negotiated with relative ease on a lightweight bicycle.

Given the same constraints on time and physical capacity, the efficiency of the lightweight model bicycle has increased the number of functional trips that can be made on a bicycle and has increased the range of areas where recreational riding is possible. With proper physical conditioning and a good lightweight bicycle, bicyclists are able to travel some of the steepest roadways in the nation. An extreme example of the capabilities of well-conditioned bicyclists riding modern lightweight bicycles is provided by Forester (1975) who described an eight-day trip that traversed every Sierra pass with a roadway over it. The trip, completed by 47 bicyclists, covered 801 miles and a total of 57,900 feet of climb. Forester described the seventh day of the trip as follows:

> The seventh day, it was 65 miles and 5,900 feet of climb to the start of the real climb. Then, after that easy start came the real climb--3,500 feet in nine miles with the grade peaking at 20% for 700 feet, followed by ten miles of descent and 25 miles of desert (Forester, 1975, p. 2.3-7).

Although the bike boom probably would not have occurred if the lightweight bicycle had not been available, it cannot be said that the availability of the lightweight bicycle caused the bike boom. Indeed, lightweight bicycles were in widespread use in many European countries long before they caught the fancy of the American consumer. The most fundamental cause of the bike boom was the emergence of a set of needs that were most fully satisfied by riding a lightweight bicycle. Most adults were motivated to purchase and use a bicycle by the need for a convenient and economical recreational activity or by the need for a more enjoyable form of physical exercise. However, a growing number of both teenagers and adults have been motivated by the desire to curtail their use of motor vehicles. The bicycling advocates of today do not hesitate to point out that the use of bicycles for both recreational and functional trips serves to decrease air pollution, conserve fossil fuel, decrease transportation and parking costs, decrease traffic congestion, and can decrease travel time for relatively short trips in congested areas.

The increasing interest in bicycling has been recognized and promoted by a variety of governmental agencies at all levels and by a variety of commercial and private organizations as well. Many local, state, and federal agencies have officially endorsed bicycling and have supported bicycling through legislative action to guarantee the rights of the bicyclist and to provide resources for research and development programs. Resources have been allocated to promote both safety and the quality of the bicycling experience. Many commercial and civic organizations have contributed their time and resources in promoting the safe use of bicycles; some of the most significant contributions have been made by organizations with no financial interest in bicycling whatsoever.

The increased use of bicycles has benefited society in many ways and the future benefits promise to be even greater. Unfortunately, the societal benefits realized from increased bicycle usage have been partially offset by an increase in the number of deaths and injuries resulting from bicycle accidents. The National Safety Council (1977) reports that the current death rate (number of deaths per 100,000 bicycles in use) is one-thirteenth the rate in 1935; but even so, the annual toll of fatalities and serious injuries resulting from bicycle accidents remains at an intolerably high level. The intolerability of the current level of bicycle-related accidents is evidenced by the fact that hundreds of agencies and thousands of individuals have expended time and resources in attempting to develop ways to reduce the incidence of bicycle accidents. The attempts to reduce bicycle accidents can be grouped into three general approaches: enforcement and adjudication, engineering, and education. Each of these approaches is discussed briefly below.

In recent years, considerable effort has been expended in an attempt to develop a set of bicycle laws and ordinances that are more specific than those of the past. It has been recognized that the rules governing bicycling in traffic cannot meaningfully be defined by simply stating that bicyclists are subject to the same rights and responsibilities as motor-vehicle operators. The excellent work of a panel formed by the National Committee on Uniform Traffic Laws and Ordinances resulted in a thoughtful and comprehensive document that describes the panel's recommendations about uniform bicycle laws and ordinances, and the considerations that led to these recommendations (National Committee on Uniform Traffic Laws and Ordinances, 1975). In addition to the development of more meaningful laws and ordinances, many law enforcement agencies have expended considerable time and resources in developing effective procedures for apprehending violators and in developing deterrents that are both equitable and effective. Contrary to popular belief, police officers derive no pleasure from issuing a bicyclist a citation; in fact, most of them feel that citing bicyclists is the most distasteful and least important part of their job. As a consequence, it has been recognized by many enforcement agencies that a prerequisite of an effective enforcement program is a program to educate patrol officers about the severity of the bicycle-accident problem and the necessity to apprehend and cite bicyclists who violate the laws.

Attempts to reduce bicycle accidents through engineering have taken two forms--improving the design of the bicycle and improving the design of the roadway system. With very few exceptions, both foreign and domestic bicycle manufacturers have long recognized that the continued success of their industry is heavily dependent on producing safe bicycles. Through the years, there have been many design innovations which have increased the safety of the bicycle. To ensure that all bicycle manufacturers comply with generally accepted safety standards, the Consumer Product Safety Commission (CPSC) recently establishe a set of safety standards that define minimum design and performance requirements for all parts of the bicycle and many bicycle accessories as well. These standards were documented in the Federal Register in June of 1974 and became law on January 1, 1975 (Consumer Product Safety Commission, 1974). Although some of the CPSC design standards remain controversial, there is little doubt that the establishment of these standards represents an important benchmark in the continuing effort to enhance safety through bicycle design. Future design innovations that further enhance the safety of the bicycle undoubtedly will be incorporated into CPSC design standards.

As indicated above, a second engineering approach to accident reduction is to design the roadway system to better accommodate bicycles. In the early 1970's, there were few bicycle enthusiasts who were not captivated with the idea of developing a comprehensive system of bicycle facilities that would include: off-street bike paths, on-street bike lanes, signed bicycle routes, grade-separated crossings, special intersection treatments, bicycle-storage facilities, and so on. When viewed in an abstract sense, it appeared that such a system was certain to effect a large reduction in bicycle accidents. However, when this approach to accident reduction was submitted to more careful study, the views on the utility of bicycle facilities became fractionated and a stormy controversy arose. Persons who oppose the construction of bicycle facilities argue that most facilities are unacceptably costly and may create as many safety problems as they solve. Also, some opposition stems from the fear that the construction of bike lanes and bike paths will lead to laws which restrict all bicycle riding to bike lanes and bike paths. Persons who advocate bicycle facilities have come to recognize that they must be carefully designed if they are to reduce accidents, but still believe that safe bicycle facilities can be designed. Moreover, they believe that bicycle facilities will serve to increase bicycle usage and that the benefits of increased bicycle usage is sufficient justification for the construction of bicycle facilities. Readers who are interested in the design and location criteria for bicycle facilities are referred to the works of Fisher et al. (1972); Smith (1975, 1976a, 1976b); and the California Department of Transportation (1978). Those interested in the views of one opponent of bicycle facilities are referred to the work of Forester (1975).

Education is the third general approach to reducing bicycle accidents and is the approach of primary interest for this report. The need for bicycle-safety education has been recognized for many years, probably from the time the first kid was hurt on the first bike. However, until after the onset of the "bike boom," there were only a few organizations that were concerned enough with the bicycle-accident problem to spend their time and resources developing bicycle-safety education materials. The Bicycle Manufacturers Association, formerly the Bicycle Institute of America, is among the organizations that have a long history of developing bicycle-safety education materials.

When the news media began to publicize the dramatic increase in bicycle accidents that accompanied the "bike boom," the public outcry for solutions to the problem led to a great demand for bicycle-safety education materials. A large number of private organizations and governmental agencies responded to this demand. The result was a deluge of safety films, safety posters, pamphlets listing bicycle laws and ordinances, bicycle-safety comic books, and numerous other kinds of one-shot educational materials. The development of these materials was followed shortly by the development of a few comprehensive bicycle-safety education programs, most of which were designed for use in public schools. These early materials and programs have been severely criticized for their simplicity and their failure to address the particular knowledge and skill deficiencies that lead to bicycle accidents. However, to be fair, any criticism of the products of these early efforts must be tempered by an acknowledgment that they were developed under severe time and budgetary constraints and with little empirical data on the causes of bicycle accidents.

The time and budgetary constraints and the lack of information about the causes of bicycle accidents have been perennial problems for persons responsible for the development of bicycle-safety education materials. Although scores of communities have attempted to develop a bicycle-safety education program in recent years, the programs have not been altogether satisfactory because there is no single community that has sufficient time and resources to develop the type of program needed to have a significant impact on the bicycle-accident problem.

The concern about the lack of progress in bicycle-safety education was a primary motive for the organization of a national conference on bicycle-safety education. In May of 1977, the U.S. Department of Transportation and the U.S. Consumer Product Safety Commission co-sponsored the first national conference on bicycle-safety education. The conference--titled BIKE-ED 77--was attended by more than 200 persons from 37 different states. Together, the attendees represented a host of different governmental agencies, commercial organizations, civic groups, professional societies, and bicycle clubs. This large and heterogeneous group was brought together by the common belief that bicycle accidents represent an intolerable problem in the U.S. and that safety education is one of the most cost-effective ways to deal with this problem. Another belief expressed by the sponsoring agencies and endorsed by many of the attendees was that "...a lack of communication among people involved in bicycle safety (education) has fostered a duplication and fragmentation of safety efforts and, in some cases, contributed to the continuation of programs and activities based on misinformation and misunderstandings" (Lawrence Johnson and Associates, 1977, p. 1). The author is in complete accord with this general conclusion. Although this report was commenced prior to the Bike-Ed 77 conference, its objectives and content have been influenced greatly by the recommendations formulated at the conference and subsequently documented by the conference staff.

PURPOSE

The purpose of this document is to provide a compendium of current information that may prove useful to persons engaged in the development, evaluation, or use of bicycle-safety education programs and materials. The document was prepared mainly for persons at the local level who are given the responsibility for developing a bicycle-safety education program and have little or no time to review the literature and conduct research. This document is *not* intended to be a comprehensive review of the literature. Rather, an attempt has been made to identify the topics and issues most relevant to bicycle-safety education and to cite the fewest number of references needed to characterize the current state of knowledge about these topics and issues. It is believed that pointing out important gaps in our knowledge serves an important function, so care has been taken to identify important topics for which little information is available.

OVERVIEW

This report begins with a brief description of what is known about the size and composition of the U.S. population of bicycles and bicycle users (Section II). Data are presented on: bicycle sales and bicycles in use; the size, age distribution, and sex distribution of the bicycle user population; and the purpose and frequency with which bicyclists ride. Section III describes what is known and what is not known about the magnitude of the bicycle-accident problem. Separate subsections are devoted to the discussion of bicycle/motor-vehicle accidents and all other kinds of bicycle-related accidents. The incidence, consequences, and costs are estimated (nationwide) and the probable accuracy of these estimates is discussed. Sections IV and V contain detailed data from a recent study of bicycle/motor-vehicle accidents. Data are presented on the characteristics of the accident-involved operators, the type and condition of the accident vehicles, the type of trip the operators were on when the accident occurred, and the type of location at which the accident occurred. In addition, the accident-generation process is described for 36 different types of bicycle/motor-vehicle accidents. The accident location and the pre-crash actions of both vehicles are illustrated and discussed for the 25 most frequently occurring types of accidents and educational countermeasures are identified for each type of accident. Section VI contains a detailed discussion of educational objectives. This section is devoted mainly, but not exclusively, to the education of bicyclists. A large number of specific educational objectives are recommended and the basis for the recommendation is described. The report is concluded with a summary of the problems and issues that must be resolved before an effective educational program can be developed and implemented.

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SECTION II
BICYCLES AND BICYCLE USERS

This section of the report describes what is known about the size and composition of the U.S. population of bicycles and bicycle users. This information provides a general picture of the size and characteristics of the bicycling population who may require bicycle-safety education.

BICYCLES IN THE UNITED STATES

ANNUAL BICYCLE SALES

An important indicator of the changing trends in bicycling is the number of bicycles sold in the United States each year. Figure 1 shows the number of bicycles sold in the U.S. each year from 1955 through 1977. The annual sales figures shown in Figure 1 include both domestic and foreign-made bicycles. During the years between 1955 and 1970, annual sales increased from slightly under three million to about seven million bicycles per year. The average increase in annual sales during this period was about 200,000 bicycles, but sales did not increase every year. In the three years following 1970, annual sales increased from about seven million to over 15 million bicycles per year. More than 43 million bicycles were sold from 1972 through 1974.

The decrease in bicycle sales in 1975 was even more dramatic than the sales increases in 1971 and 1972. The Bicycle Manufacturers Association reports that the sales decrease of over six million bicycles in a single year was due to the combined forces of

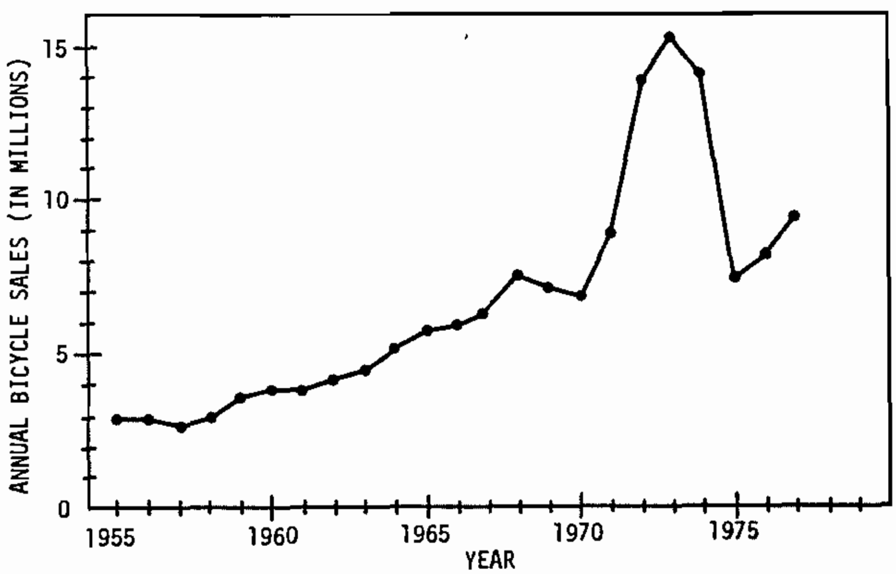

Figure 1. Annual bicycle sales from 1955 through 1977 (Bicycle Manufacturers Association, 1978).

the economic recession, the easing of the fuel shortage, and a temporary saturation of the market (Morse, 1977). Sales increased slightly in 1976 and 1977, and the Bicycle Manufacturers Association anticipates an increase to nearly 10 million in 1978. Although annual bicycle sales have decreased considerably from their peak of over 15 million per year, the "bike boom" cannot be considered at an end with annual sales approaching ten million.

As was stated in Section I, the increase in bicycle usage was due in large part to the increased popularity of the lightweight bicycle. As is shown in Figure 2, the growing popularity of the lightweight bicycle is clearly reflected by the increasing number of lightweight bicycles being sold in the United States. It can be seen that lightweight bicycles accounted for only 12% of the annual sales in 1969. By 1974, nearly three-fourths of all the bicycles sold in the United States were lightweight models. The absolute number and relative proportion of lightweight bicycles sold decreased in 1975, 1976, and 1977; but even so, annual sales exceeded four million in 1975 and 1976 and exceeded five million in 1977.

The decrease in the number of lightweight bicycles being sold is due primarily to a temporary saturation of the market during the period from 1972 to 1974. Also, because there is no widespread shortage of gasoline, there is less pressure on adults to use bicycles rather than motor vehicles. The advent of gasoline shortage or gasoline rationing would almost certainly result in a large and rapid increase in the sale of lightweight bicycles.

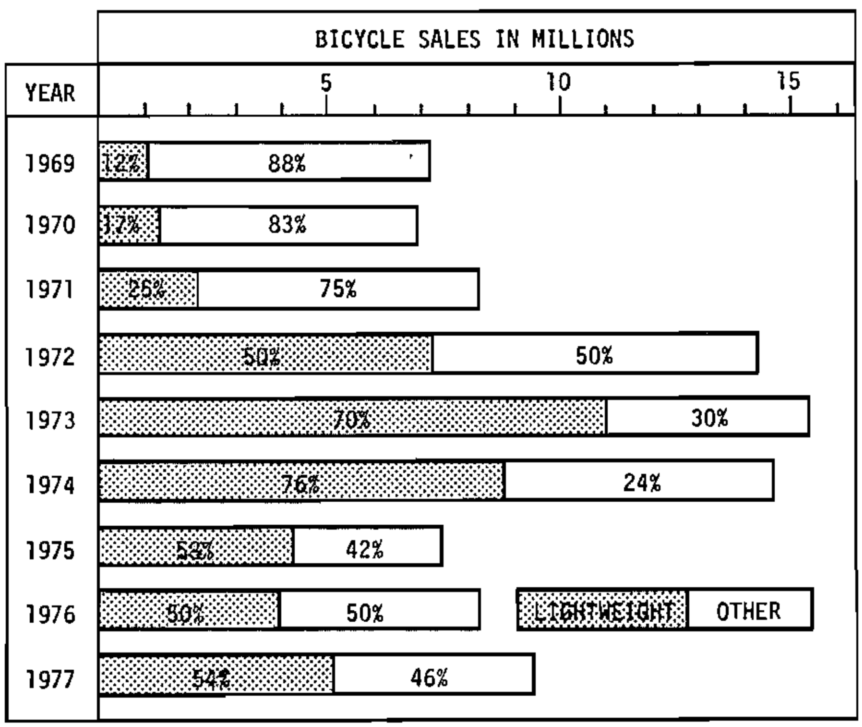

Figure 2. Annual sales of lightweight and other model bicycles from 1969 through 1977.

Another interesting trend in bicycle sales is the increasing popularity of the motocross model bicycle. The motocross bicycle--styled after the motocross motorcycle--is a ruggedly constructed bicycle built for jumping and dirt riding by juveniles. Representatives of the Bicycle Manufacturers Association report that the motocross bicycle, introduced on the market less than three years ago, is selling at an annual rate exceeding 700,000 (Morse, 1977). It will be interesting to see if a bicycle ideally suited to stunting and rough use will have a significant impact on accidents among the juvenile user population.

BICYCLES IN USE

Bicycles in use in the United States has been estimated by both the National Safety Council (1976) and the Bicycle Manufacturers Association (Morse, 1977). The National Safety Council assumes an average bicycle life of ten years, so estimates the bikes in use for a given year by summing the ten-year total domestic production plus imports less exports. Although the Bicycle Manufacturers Association uses a similar estimation procedure ("estimated bike life by a unit sales figure"), their estimates of bikes in use is between five and ten million less than the National Safety Council's estimates.

Figure 3 shows the National Safety Council's estimates from 1935 through 1975 and the Bicycle Manufacturers Association's estimates from 1960 through 1975. Although the agencies differ in their estimates of the absolute number of bicycles in use, they agree that bicycles are being sold at a rate that far exceeds the annual loss due to damage and deterioration. The National Safety Council's estimates show a steady increase from 3.5 million in 1935 to 28.2 million in 1960. Thereafter, the number of bicycles in use increased at an accelerated rate. By 1975, the number of bicycles in use had increased to between 83 million (BMA) and 95 million (NSC).

Judging from the present trends, it is altogether possible that 115 million bicycles may be in use by 1980. The number could be even larger if there is a significant increase in oil prices or if gasoline rationing should become a reality.

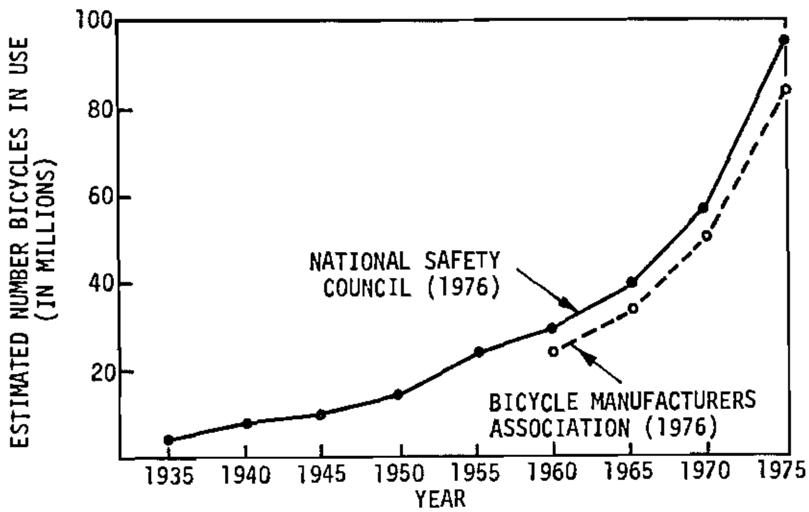

Figure 3. Estimated number of bicycles in use in the United States (1935-1975).

CHARACTERISTICS OF THE BICYCLE-USER POPULATION

Bicycles in use and annual sales estimates reflect trends, but do not provide a precise estimate of the number and types of persons who ride bicycles. A comprehensive nationwide survey to assess the size and composition of the user population has not been conducted. However, several limited surveys have been located that provide some insight into the characteristics of the bicycle-user population.

SIZE OF BICYCLE-USER POPULATION

The size of the bicycle-user population depends on how one defines a bicycle user. Although there is no commonly accepted definition of a bicycle user, most of the recent survey studies have defined the user population as consisting of all persons who have ridden a bicycle at least once during the 12-month period preceding the date of the interview. A total of five studies have been located that estimated the proportion of the total population that rides a bicycle at least once a year. Table 1 shows the sampling areas where the surveys were conducted and the estimated percentage of the total population that qualifies as a bicycle user.

It can be seen in Table 1 that the percentage estimates vary from a low of 26% for Washington, D. C., to a high of 49% for Santa Clara County. The areas with a temporate climate show the largest proportion of bicycle riders (Santa Clara County, California, and Santa Barbara, California). Areas with a more severe climate show a smaller proportion of bicyclists, but the difference is not as great as might be expected. The small percentage of persons who ride bicycles in Washington, D. C., reflects the combined effects of a relatively severe climate and a non-optimal physical environment in which to ride.

Based upon these data, it seems reasonable to estimate that about 40% of the U.S. population--about 90 million persons--ride a bicycle at least once a year. The estimate of 90 million users corresponds closely to estimates of the number of bicycles in use.

TABLE 1

SURVEY ESTIMATES OF THE PERCENTAGE OF THE TOTAL POPULATION WHO RIDE A BICYCLE AT LEAST ONCE A YEAR

SAMPLING AREA	PERCENTAGE OF TOTAL POPULATION
SANTA CLARA COUNTY (Diridon Research Corporation, 1973)	48.0%
SANTA BARBARA COUNTY (Malsin & Silberstein, 1973)	46.8%
STATE OF PENNSYLVANIA (Barton-Aschman Associates, 1975)	40.0%
STATE OF TENNESSEE (Barton-Aschman Associates, 1974b)	36.0%
WASHINGTON, D. C. (Barton-Aschman Associates, 1974a)	26.0%

AGE DISTRIBUTION OF BICYCLE-USER POPULATION

Table 2 shows estimates of the age distribution of the bicycling population in three areas: Washington, D. C., the State of Tennessee, and the State of Pennsylvania. The sources of these data are shown by the references at the bottom of Table 2. It can be seen that the age distributions are nearly the same for Tennessee and Pennsylvania bicyclists. For both states, about one-half of the bicyclists are 15 years of age or younger and about one-fourth are between six and 11 years of age. The bicyclists in Washington, D. C., are somewhat older than those in Tennessee and Pennsylvania. For instance, 57% of the Washington, D. C., bicyclists are older than 19 years of age, whereas only about 40% of the Tennessee and Pennsylvania bicyclists are older than 19 years.

TABLE 2
AGE DISTRIBUTION OF THE BICYCLE-USER POPULATION

	SAMPLING AREA		
AGE	WASHINGTON, D.C.[1]	TENNESSEE[2]	PENNSYLVANIA[3]
< 6	3%	6%	7%
6-11	16%	26%	24%
12-15	13%	17%	19%
16-19	11%	11%	11%
20-23	14%	17%	7%
24-29	19%		8%
30-44	16%	16%	16%
45-59	6%	6%	7%
≥ 60	2%	1%	1%

[1]Barton-Aschman Associates (1974a)
[2]Barton-Aschman Associates (1974b)
[3]Barton-Aschman Associates (1975)

Although juveniles account for only about one-half of the bicycling population, numerous studies show that a very large proportion of all juveniles are bicyclists. Most of the survey studies that have been reviewed indicate that between 80% and 95% of persons between six and 15 years of age are bicyclists (Chlapecka, Schupak, Planck, Kluska, & Dreissen, 1975; Diridon Research Corporation, 1973; Barton-Aschman Associates, 1974a, 1974b, 1975; Maisin & Silberstein, 1973; Vilardo & Anderson, 1969).

SEX DISTRIBUTION OF BICYCLE-USER POPULATION

Because males are more frequently involved in bicycle accidents than females, it is generally assumed that males account for a larger proportion of the bicycle-user population than females. However, no recent evidence has been found to support this assumption. Recent studies by Barton-Aschman Associates (1974b, 1975) show that the bicycling populations in the States of Pennsylvania and Tennessee are composed of about equal numbers of males and females. Moreover, for nearly all age groups, about the same proportion of females ride bicycles as males. The only appreciable difference is that a smaller proportion of females than males ride bicycles after the age of 45 years.

BICYCLE-USAGE PATTERNS

FREQUENCY OF BICYCLE USAGE

For a given geographical area, the frequency with which bicyclists use their bicycles is a function of many factors, such as: ambient temperature, amount of precipitation, average wind velocity, hours of daylight, number and steepness of hills, amenability of the roadway system to bicycle travel, and so on. Since there are few geographical areas that are the same with respect to all the factors that may influence the frequency of bicycling, it is difficult to estimate the absolute frequency of bicycling in one area from data collected in another. For this reason, the reader should exercise caution when attempting to generalize the findings reported below.

Table 3 summarizes the results of two survey studies that were designed to assess frequency of bicycle usage in Tennessee and Pennsylvania as a function of the bicyclist's age. The Tennessee study also tabulated bicycling frequency as a function of bicyclists' sex. The Tennessee study assessed frequency of bicycle usage during a 30-day period in the spring (April-May); the Pennsylvania study assessed the frequency of usage during the month of July and the month of October. The values shown are average calendar days bicycled per bicyclist during the 30-day sampling period.

TABLE 3

MEAN CALENDAR DAYS BICYCLED PER BICYCLIST, SHOWN BY BICYCLIST'S AGE, SEX, SAMPLING AREA, AND MONTH

	TENNESSEE[1] 30-DAY PERIOD APRIL-MAY, 1974			PENNSYLVANIA[2]	
AGE	MALE	FEMALE	AVERAGE	JULY, 1975	OCTOBER, 1974
< 6	17.7	12.2	14.9	22.3	17.3
6-11	19.9	19.5	19.8	21.8	14.4
12-15	19.0	13.8	16.4	19.1	12.7
16-19	10.1	9.3	9.7	13.9	7.3
20-23	6.7	5.7	6.2	7.9	3.3
24-29	6.7	5.7	6.2	9.5	4.3
30-44	4.3	6.2	5.3	8.1	3.0
45-59	6.6	2.8	4.7	7.7	4.2
≥ 60	10.6	3.4	7.0	5.3	3.0
TOTAL	13.2	10.9	12.1	14.8	8.9

[1]Barton-Aschman Associates (1974b)
[2]Barton-Aschman Associates (1975)

NOTE: Averages are based on persons who bicycled during the 12-month period preceding the interview.

Although the total number of bicycling days shown in Table 3 cannot be considered representative for all areas in the United States, the data show patterns of usage that are probably common to most areas. For example, it is believed that the observations listed below would be equally valid for most areas in this country.

- The frequency of bicycle usage is greatest among juveniles under the age of 16.
- The frequency of bicycle usage is consistently greater in the summer than either the spring or fall.
- Bicyclists between 16 and 19 years of age ride about half as often as younger bicyclists and about twice as often as older bicyclists.
- The frequency of bicycle usage tends to remain relatively constant after the age of 19.
- On the average, males ride more often than females (although this is not true for the 30 to 44 years-of-age group, and the difference is insignificant for several other age groups).
- Persons who ride bicycles at all tend to do so relatively often each month.

PURPOSE OF BICYCLING TRIPS

The data presented in Table 4 summarize the purposes for which bicyclists ride; the values represent the proportion of bicycle days for which a bicyclist rode for a given purpose. A bicycle-trip day is defined here as a bicyclist riding for a single purpose on a single day.

TABLE 4
PROPORTION OF ALL BICYCLE-TRIP DAYS AS A FUNCTION OF TRIP PURPOSE AND SAMPLING AREA

	SAMPLING AREA		
TRIP PURPOSE	WASHINGTON, D.C.[1]	TENNESSEE[2]	PENNSYLVANIA[3]
TO WORK	8.5	1.3	3
TO SCHOOL	4.9	2.9	3
PERSONAL BUSINESS	12.9	4.7	9
TO RECREATIONAL ACTIVITY	18.7	10.8	14
TO VISIT FRIENDS	14.8	17.2	21
RECREATIONAL (OVER TWO HOURS)	9.0	7.2	6
RECREATIONAL (UNDER TWO HOURS)	31.4	35.3	44

[1]Barton-Aschman Associates (1974a)
[2]Barton-Aschman Associates (1974b)
[3]Barton-Aschman Associates (1975)

Although percentage values differ somewhat as a function of sampling area, the data reflect the same general trends in all three areas. The majority of trips are purely recreational as opposed to functional, and recreational riding within the neighborhood (under two hours) accounts for the largest proportion of trips--varying from about 31% in Washington, D. C., to over 55% in the State of Tennessee. Longer recreational trips (over two hours) account for a much smaller, but nevertheless significant, number of trips (between six percent and nine percent).

Riding a bicycle to a specific recreational activity or to visit friends are the most frequently occurring types of *functional* trips. The next most frequently occurring functional trip purpose is to conduct personal business. Commuting to work and commuting to school account for a relatively small proportion of all bicycle-trip days, although commuting trips are clearly more prevalent among residents of a metropolitan area (Washington, D. C.) than among the residents of a state as a whole (State of Tennessee and State of Pennsylvania).

Other survey studies have been conducted that have attempted to determine the purposes for which bicyclists ride. The findings of these studies are generally the same as those shown in Table 4, but cannot be compared directly because the trip-purpose categories are not the same. Other information about the purpose for which bicyclists ride can be found in reports by Chiapecka et al. (1975), Maisin and Silberstein (1973), Diridon Research Corporation (1974), Kansas State University (1973), Bivens and Associates (1973), Walsh and Watt (1974), among others.

SECTION III
MAGNITUDE OF THE PROBLEM

The purpose of this section is to discuss what is known and what is not known about the magnitude of the bicycle-accident problem. The first part of the section presents recent data on the incidence, consequences, and costs of bicycle/motor-vehicle accidents. The incidence and consequences of bicycle-related accidents that do not involve a motor vehicle are discussed in the second part of this section. The relative brevity of the second part of this section reflects the paucity of information about the kinds of bicycle-related accidents that are *not* the result of a conflict between a bicycle and a moving motor vehicle.

BICYCLE/MOTOR-VEHICLE ACCIDENTS

Bicycle/motor-vehicle accidents are defined here as accidents that result from an actual collision between a bicycle and a motor vehicle, or a collision with another vehicle or object (including the ground) that was the direct result of actions--by one or both parties--to avoid a collision between a bicycle and a motor vehicle.

INCIDENCE OF BICYCLE/MOTOR-VEHICLE ACCIDENTS

The only systematic data on the incidence of bicycle/motor-vehicle accidents come from record-keeping agencies that tabulate annually the number of traffic accidents that are reported to the police. Each year, the National Safety Council compiles data on the police-reported accidents that occur in a sample of states and uses the sample data to estimate the number of injury-producing accidents that occurred throughout the United States during that year. The National Safety Council reports that bicycle/motor-vehicle accidents have resulted in about 1,000 fatalities and about 40,000 disabling injuries[1] each year since 1972 (National Safety Council, 1977). Although the National Safety Council's estimates are the best available gauge of the incidence of bicycle/motor-vehicle accidents, the estimates are highly conservative because they are based only on police-reported accidents. The findings of several recent studies indicate that a substantial number of bicycle/motor-vehicle accidents that occur each year are *not* reported to the police. For instance:

- A survey of 1,307 motorists in Santa Barbara County revealed that 4.2% of the motorists had been involved in a bicycle/motor-vehicle accident in the recent past, and that only 25% of the accidents were reported to the police (Cross & deMille, 1973).

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[1]The National Safety Council defines a disabling injury as one causing death, permanent disability, or any degree of temporary total disability. Temporary total disability is defined as an injury which renders the injured person unable to perform regular duties on one or more full calendar days after the day of the injury.

- In a nationwide survey of 23,699 elementary school children, students were required to describe their most serious accident during the past year or, if none, their most serious accident during the past five years. Of the 393 students who indicated that their most serious accident was a bicycle/motor-vehicle accident, only 37% indicated that their accident was reported to the police (Chlapecka et al., 1975).

- In a study by Cross and Fisher (1977), a total of 525 bicyclists and 385 motorists who had been involved in a police-reported bicycle/motor-vehicle accident were asked if they had been involved in any *other* bicycle/motor-vehicle accidents during the past 24 months. It was found that the combined sample of 910 persons had been involved in a total of 47 *other* bicycle/motor-vehicle accidents and that only 27% of these accidents were reported to the police.

Based upon the above findings, it seems reasonable to assume that at least two-thirds of all bicycle/motor-vehicle accidents go unreported. One explanation for the large proportion of unreported accidents is that many bicycle/motor-vehicle accidents result in little or no injury, and it is these inconsequential accidents that are not being reported to the police. Although little is known about the consequences of unreported bicycle/motor-vehicle accidents, some information on this issue was obtained from the data compiled by Chlapecka and his colleagues (1975). A special analysis of Chlapecka's data was performed to determine the consequences of unreported bicycle/motor-vehicle accidents in the sample. The results showed that more than 50% of the unreported accidents were severe enough to require some form of medical treatment (Schupak, 1975). Unfortunately, the data were not in a form that enabled a more precise assessment to be made of the degree of injury sustained by the bicyclists in the unreported accidents.

Although data on the incidence of bicycle/motor-vehicle accidents are meager, it is nevertheless possible to define the general bounds of the problem. Since the National Safety Council's estimates are based on police-reported accidents, it seems reasonable to assume that these estimates--1,000 fatalities and 40,000 disabling injuries--represent the lower limit of the problem. But, what about the upper bounds? First, consider the number of fatalities that occur each year. Because nearly all fatal accidents are reported to the police, the National Safety Council's estimate of 1,000 fatalities per year should be quite accurate. This view is reinforced by the fact that the National Safety Council's estimate of fatalities corresponds closely with estimates of the National Highway Traffic Safety Administration, who publishes a monthly running total of all types of fatal traffic accidents. Next, consider non-fatal but injury-producing accidents. If the survey data cited above are assumed to be representative of the nation, it can be estimated that about one-third of all bicycle/motor-vehicle accidents are reported to the police, and that about one-half of the unreported accidents are injury producing. Using 40,000 as the estimated number of police-reported accidents, it can be estimated that a total of about 80,000 injury-producing bicycle/motor-vehicle accidents occur each year.

BICYCLE/MOTOR-VEHICLE FATALITY RATE

Although there has been a substantial increase in the total number of persons killed each year in bicycle/motor-vehicle accidents, data reported by the National Safety Council indicate that the increase in fatalities has been proportionately less than the increase

TABLE 5

FATALITY RATE PER 100,000 BICYCLES IN USE FROM 1935 THROUGH 1976 (NATIONAL SAFETY COUNCIL, 1977)

YEAR	BICYCLES IN USE* (MILLIONS)	DEATHS	DEATH RATE
1935	3.5	450	12.80
1940	7.8	750	9.59
1945	9.0	500	5.55
1950	13.8	440	3.48
1955	23.1	410	1.78
1960	28.2	460	1.63
1965	38.8	680	1.75
1970	56.5	780	1.38
1971	--	---	--
1972	71.4	1000	1.40
1973	80.0	1000	1.25
1974	90.0	1000	1.11
1975	95.0	1000	1.05
1976	95.0	900	.94

**Bicycles in use for a given year is the ten-year total of domestic production plus imports less exports.*

in bicycles over the last four decades. Table 5 shows the fatality rate per 100,000 bicycles in use from 1935 through 1976 (National Safety Council, 1977). There is a high correlation between the number of bicyclists killed and the number injured each year. So, it can be assumed that the rate for non-fatal accidents would show the same trends reflected by the data in Table 5.

It can be seen in Table 5 that the fatality rate has decreased from a high of nearly 13 in 1935 to less than one in 1976. Since 1955, the annual decrease in the fatality rate has been small in comparison to the previous period. Even so, if the fatality rate had remained the same since 1955, there would have been nearly 1,700 bicyclists killed in 1976 rather than the 900 that were reported. Assuming the number of bicycles in use remains the same, reducing the fatality rate by only 0.1 will result in about 100 fewer deaths each year. Thus, the reduction in fatality rate since 1955 cannot be considered inconsequential.

CONSEQUENCES OF BICYCLE/MOTOR-VEHICLE ACCIDENTS

Although most experts agree that bicycle/motor-vehicle accidents are an important problem, few attempts have been made to assess the consequences of such accidents. A small amount of data is available on the severity of personal injuries and the extent of property damage resulting from bicycle/motor-vehicle accidents. However, the consequences of such accidents go far beyond personal injuries and property damage. Bicycle/motor-vehicle accidents also may result in undesirable consequences for the non-injured party and for persons not directly involved in the accident. Some of these other undesirable consequences are discussed below, following a description of the data on severity of injuries and the extent of property damage.

Personal Injuries

Although it is usually the bicycle operator who is injured, some bicycle/motor-vehicle accidents result in injuries to the motor-vehicle operator or to a passenger of one of the vehicles. Table 6 shows the total number of operators and passengers killed and injured in a sample of 166 fatal and 753 non-fatal accident cases (Cross & Fisher, 1977). It can be seen that the 166 fatal cases resulted in a total of 172 fatalities; the 753 non-fatal cases resulted in 765 persons injured. One case was found in which two bicyclists, who were riding separate bicycles, were killed in the same accident. Also killed were one motorist, one motor-vehicle passenger, and three bicycle passengers. The fatally

TABLE 6

PERSONS KILLED AND INJURED IN A SAMPLE OF 166 FATAL AND 753 NON-FATAL ACCIDENTS

		KILLED	INJURED
VEHICLE OPERATORS	BICYCLISTS	167	720
	MOTORISTS	1	25
VEHICLE PASSENGERS	BICYCLE	3	16
	MOTOR VEHICLE	1	4
COMBINED OPERATORS AND PASSENGERS		172	765

injured motorist and the fatally injured motor-vehicle passenger were riding a motorcycle at the time of the accident and were killed in separate accidents. Study of the 753 non-fatal cases revealed that 3.3% of the accidents resulted in injuries to the motor-vehicle operator, 2.1% of the accidents resulted in injuries to a bicycle passenger, and .5% of the cases resulted in injuries to a motor-vehicle passenger.

In the Cross and Fisher study (1977), information on injury severity was obtained only for the injured bicyclists; injury severity was assessed during face-to-face interviews with a total of 525 bicyclists. It was found that 92% of the bicyclists suffered injuries severe enough to cause them pain and discomfort for at least one day following the accident. The injuries sustained by 55% of the bicyclists were severe enough to prevent them from going to work or school for at least one day; 18% of the bicyclists were hospitalized for one or more days. Based upon the injury data compiled on the sample of 525 bicyclists, a bicyclist who is involved in a non-fatal bicycle/motor-vehicle accident, on the average, can be expected to suffer the following consequences:

- 1.4 days in the hospital;
- 1.4 days in bed at home;
- 4.3 days missed work or school;
- 23.6 days suffering pain or discomfort.

Analysis of the non-fatal injuries revealed that 76.4% of the injuries were body-surface injuries, 17% were skeletal injuries, and six percent were internal non-skeletal injuries. Considering the body-surface injuries first, it was found that abrasions and bruises together accounted for nearly two-thirds of the injuries, and about 11% of the injuries were lacerations. Considering next the skeletal injuries, it was found that 7.5% of the injuries were fractures, 5.6% were sprains, 2.7% were concussions, .9% were dislocations, and .6% were broken teeth. Nearly five percent of the injuries were aches and pains in the muscles and joints, and slightly over one percent were ruptures of subcutaneous tissue, arteries, vessels, or organs.

The distribution of injuries for fatal accidents would certainly be different from the distribution of injuries for non-fatal accidents. Although Cross and Fisher (1977) did not investigate injury type for the fatal cases, other research indicates that the relative frequency of head injuries and internal injuries would be much greater for fatal than for non-fatal accidents. For instance, autopsies performed on 181 bicyclists killed in traffic accidents during the period 1935-1963 (Tonge, O'Reilly, Davison, & Derrick, 1964) showed that brain damage was evidenced in over 80% of the fatalities with an associated skull fracture occurring in 71% of the cases. Injury to abdominal organs was found in over 50% of the victims. Similar findings are reported by Bowen (1970) and by Gissane, Bull, and Roberts (1970).

For each injury identified in the Cross and Fisher study, the bicyclist was asked to define what caused the injury. It was found that 60.4% of the injuries were the result of the bicyclist's impact with the roadway and 24.1% of the injuries resulted from impact with the motor vehicle. It was surprising to find that only 6.2% of the injuries resulted from the bicyclist's impact with the bicycle he was riding. The finding that most injuries are caused by the bicyclist's impact with the roadway suggests that one potentially effective at-crash countermeasure may be training the bicyclist in how to abandon his bicycle or fall in order to minimize injuries.

Property Damage

In the study by Cross and Fisher, the bicyclists and motorists who were interviewed were asked to estimate the cost of repairing their vehicle to its pre-crash condition or, if damaged beyond repair, the replacement cost of the vehicle. For the fatal accidents, estimates of the cost of vehicle damage was obtained from traffic accident reports.

On the average, the cost of the combined damage to vehicles involved in a non-fatal accident was $120: $65 for the bicycle damage and $55 for the motor-vehicle damage. The extent of damage was considerably greater for fatal than for non-fatal accidents. The average cost of the damage to the two vehicles involved in fatal accidents was about $325; the average cost was $100 for the bicycle damage and $225 for the motor-vehicle damage. There were some instances in which the motor vehicle collided with another motor vehicle after having collided with the bicycle. However, no data were obtained on the cost of the damage to other objects or vehicles that were struck by the motor vehicle involved in the bicycle/motor-vehicle accident.

Other Undesirable Consequences

The undesirable consequences of bicycle/motor-vehicle accidents extend far beyond operator injuries and property damage. Whether or not an accident-involved operator is culpable, he or she is nearly always grief stricken at the sight of another person who was injured in the accident. Culpable motor-vehicle operators are often involved in litigation which is both costly and emotionally painful. Relatives and friends of an injured operator also suffer. In addition to the emotional stress associated with an injured loved one, relatives and friends often suffer substantial losses of money and time in caring for the injured operator.

Bicycle/motor-vehicle accidents often are publicized widely--particularly those that result in fatal injuries. It has been suggested that many of the persons who read or hear of bicycle/motor-vehicle accidents conclude that riding a bicycle is simply too dangerous. As a consequence, the occurrence of accidents serves to curtail bicycling in favor of driving. The resulting societal losses due to increased fuel consumption, pollution, and traffic congestion are as real and important as the losses due to injuries and property damage.

COST OF BICYCLE/MOTOR-VEHICLE ACCIDENTS

Implicit in every non-arbitrary decision about safety-education programs is a trade-off of societal costs and societal benefits. In principle, the implementation of a safety-education program can be justified only if the societal benefits resulting from the program outweigh the cost of developing and implementing the program. Thus, if judicial decisions are to be made about safety-education programs to curtail bicycle/motor-vehicle accidents, it is necessary to consider the total societal costs associated with accidents of this type.

TABLE 7

COST OF SOCIETAL LOSSES RESULTING FROM FATAL AND NON-FATAL BICYCLE/MOTOR-VEHICLE ACCIDENTS (POLICE REPORTED)

	AVERAGE COST PER ACCIDENT (DOLLARS)	
COST CATEGORY	FATAL	NON-FATAL
MARKET AND MARKET-PROXY PRODUCTION LOSSES	$171,817	$ 73
HOME, FAMILY, AND COMMUNITY SERVICES PRODUCTION LOSSES	48,281	21
EMERGENCY TRANSPORTATION	55	9
EMERGENCY ROOM TREATMENT	156	85
HOSPITAL CARE	1,030	201
PHYSICIAN'S CARE	328	66
FUNERAL COSTS	987	--
CORONER/MEDICAL EXAMINER	130	--
LOSSES TO OTHERS	3,832	138
LEGAL AND COURT COSTS	4,096	315
INSURANCE ADMINISTRATION COSTS	250	25
ACCIDENT INVESTIGATION COSTS	70	35
VEHICLE DAMAGE	325	130
TOTAL COSTS	$231,357	$1,098

Table 7 lists estimates of the cost of societal losses resulting from fatal and non-fatal bicycle/motor-vehicle accidents that are reported to the police. Most of the cost estimates presented in Table 7 were derived from cost data contained in a recent report on the cost of motor-vehicle accidents (Faigin, 1976). Cost estimates for most losses resulting from traffic accidents differ as a function of the age and sex distributions of the accident population, the average severity of injuries sustained in the accident, and the types of vehicles involved. Therefore, these factors were taken into consideration when estimating the cost of losses resulting from bicycle/motor-vehicle accidents. Information about the age, sex, and injury distributions were taken from the Cross and Fisher (1977) study of bicycle/motor-vehicle accidents. The data and assumptions underlying the cost estimates shown in Table 7 are described and discussed in Appendix A.

It can be seen in Table 7 that the average cost of the societal losses resulting from a fatal accident total $231,357. Assuming 1,000 fatal accidents each year, the total cost of societal losses resulting from fatal accidents exceeds 231-million dollars. The average cost of a non-fatal accident is estimated at $1,098. Although the average cost of non-fatal accidents is far less than for fatal accidents, the total cost of the 40,000 police-reported accidents that occur each year is nearly 44-million dollars. Thus, according to these estimates, the combined cost of fatal and non-fatal accidents exceeds 275-million dollars each year; this estimate does not include the cost of unreported accidents.

No attempt was made to establish a monetary value for such loss as pain and suffering, grief, loss of personal relationships, and so on. Although emotional trauma represents a real and important societal loss, no satisfactory technique has been established for placing a monetary value on such losses.

OTHER BICYCLE-RELATED ACCIDENTS

There are many kinds of bicycle-related accidents other than bicycle/motor-vehicle accidents. Bicycles collide with other bicycles, with pedestrians, and with fixed objects. In addition, bicyclists lose control of their bicycles and fall for a great variety of reasons. For ease of exposition, the class of bicycle accidents that do *not* involve a collision with a motor vehicle will be referred to hereafter as non-motor-vehicle accidents and, for obvious reasons, will be abbreviated as "NMV accidents."

Although it is generally recognized that NMV accidents occur with far greater frequency than bicycle/motor-vehicle accidents, there is surprisingly little data on their incidence, consequences, and causes. This lack of information is the result of at least two factors. First, the limited resources available for research into bicycle accidents have been devoted mainly to the study of bicycle/motor-vehicle accidents rather than NMV accidents. Bicycle/motor-vehicle accidents have been given greater emphasis because, on the average, accidents that involve a motor vehicle result in more severe injuries than NMV accidents. Secondly, the study of NMV accidents is inherently difficult because such accidents are not routinely reported to any record-keeping agency. Medical records maintained by hospitals and physicians contain a great deal of useful information about NMV accidents, but the records are difficult to locate and even more difficult to obtain. Moreover, the study of medical records includes only the accident cases that resulted in injuries severe enough to require professional medical care. Perhaps the only way to obtain information on the full range of NMV accidents that occur is to conduct a comprehensive survey of the general population of bicyclists. Such a survey would be expensive and time consuming, but is sorely needed.

ESTIMATE OF THE INCIDENCE OF NMV ACCIDENTS

Although there is much to be learned about NMV accidents, there are sufficient data available to enable one to confidently conclude that NMV accidents represent a severe problem in the United States. The best data on NMV accidents come from the National Electronic Injury Surveillance System (NEISS). This computerized system was developed by the Consumer Products Safety Commission to continuously monitor product-related injuries treated in the emergency rooms of a selected sample of 119 hospitals at diverse locations throughout the United States.

An analysis of NEISS data for calendar year 1975 revealed that 18% of all bicycle-related fatalities and 94.5% of all bicycle-related injuries were the result of NMV accidents. The remaining 82% of fatalities and 5.5% of injuries were the result of bicycle/motor-vehicle accidents. Since the NEISS data include only the accidents that were treated in a hospital emergency room, it is necessary to somehow extrapolate these data in order to estimate the total number of NMV accidents that occur each year.

One extrapolation method involves the use of data on the annual number of bicycle/motor-vehicle accidents as a basis for estimating the total number of NMV accidents that occur each year. This method assumes that the ratio of bicycle/motor-vehicle accidents versus NMV accidents found in the NEISS data is the same as the ratio for the total population of accidents--whether or not they were treated in an emergency room. The assumptions are as follows: (a) bicycle/motor-vehicle accidents account for 82% of all bicycle-related fatalities, (b) bicycle/motor-vehicle accidents account for 5.5% of all bicycle-related injuries, and (c) about 1,000 fatalities and 80,000 injuries result from bicycle/motor-vehicle accidents each year. With these assumed values, it is possible to set up the following equations:

$$1{,}000 = .82\ (x)$$
$$80{,}000 = .055\ (y)$$

where: x = total number of fatalities
y = total number of disabling injuries

It is a simple matter to solve for the unknowns and arrive at an estimate of about 1,220 for total fatalities and 1,454,000 for total injuries. Subtracting the number of deaths and injuries resulting from bicycle/motor-vehicle accidents from these totals yields an estimate of 220 fatalities and 1,374,000 serious injuries as the annual toll for NMV accidents.

A different extrapolation approach has been used by the National Safety Council. The National Safety Council used the NEISS data and a set of prediction equations to estimate the total number of bicycle-related accidents that were treated in all the hospital emergency rooms in the nation during 1976. Then, the total number of bicycle-related accidents was computed with the assumption that accidents treated in emergency rooms account for 38% of all disabling injury accidents.' This method yielded an estimate of 1,100 fatalities and 460,000 serious injuries. Subtracting the number of deaths and injuries resulting from bicycle/motor-vehicle accidents in 1976 from these totals yields an estimate of 200 fatalities and 420,000 serious injuries from NMV accidents.

These two approaches yield quite different estimates for both fatalities and disabling injuries. Although it is not known which extrapolation approach is best, it seems reasonable to estimate that NMV accidents account for no fewer than 100 fatalities and one-half million serious injuries each year.

TYPES OF NMV ACCIDENTS

Table 8 shows the relative frequency of three general types of NMV accidents: bicycle-bicycle accidents, bicycle-pedestrian accidents, and collisions with fixed objects or falling. The data shown in Table 8 are from four studies conducted in different geographical areas and covering different bicycling populations. The two studies by Barton-Aschman are probably the most representative because they sampled the full bicycling population within the sampling area. Although the size of the accident sample is small, the

TABLE 8

RELATIVE FREQUENCY OF TYPES OF NMV ACCIDENTS

DESCRIPTION OF SAMPLE AND SOURCE	NUMBER OF ACCIDENTS IN SAMPLE	TYPES OF NMV ACCIDENTS		
		BICYCLE-BICYCLE	BICYCLE-PEDESTRIAN	COLLISION WITH FIXED OBJECT OR FALLING
SURVEY OF GENERAL POPULATION IN THE STATE OF TENNESSEE (Barton-Aschman Associates, 1974b)	47	11%	0%	89%
SURVEY OF GENERAL POPULATION IN THE STATE OF PENNSYLVANIA (Barton-Aschman Associates, 1975)	98	9%	1%	90%
SURVEY OF A SAMPLE OF GRADE-SCHOOL CHILDREN [AGES 7-13] IN 170 SCHOOLS IN 110 CITIES IN 37 STATES (Chlapecka et al., 1975)	5601	11%	1%	88%
ALL ACCIDENTS TREATED IN THE STUDENT HEALTH FACILITY AT THE UNIVERSITY OF CALIFORNIA, SANTA BARBARA, DURING THE PERIOD BETWEEN 1971 AND 1976 (Chung, 1976)	794	42%	6%	52%

consistency in the percentage values shown for the two different states tend to support the reliability of the data. The study by Chlapecka et al. (1975) was limited to school-age children between the ages of seven and 13 years. The accident data refer to the "most serious" accident a child had experienced in the recent past. Chung's data come from a study of medical records for all accidents treated in the student health facility on the campus of the University of California, Santa Barbara (Chung, 1976). Chung examined records for all the accidents that occurred between September 1971 and March of 1976.

It can be seen that the data on the survey of the general population and the survey of grade-school children are quite consistent. For these populations, it can be seen that:

- Bicycle-bicycle accidents account for between nine percent and 11% of all NMV accidents.
- Bicycle-pedestrian accidents account for no more than one percent of all NMV accidents.
- Between 88% and 90% of all NMV accidents result from the bicyclist colliding with a fixed object or falling.

The accidents reported by Chung involved university students and occurred on a university campus that had an excellent system of bikeways during the entire reporting period. It can be seen that the relative frequency of bicycle-bicycle and bicycle-pedestrian accidents in Chung's sample was far greater than for the other three samples; the relative frequency of collisions with fixed objects and falling accidents was less.

Chung reports an NMV accident rate of 20.4 accidents per 1,000 students for the 74-75 school year. If this accident rate is representative of other college and university campuses throughout the nation, it can be estimated that about 136,000 college/university students per year are involved in an NMV accident that results in injuries severe enough to require professional medical treatment. This estimate does not include persons treated in medical facilities other than student health facilities and does not include accidents that result only in minor injuries and/or bicycle damage. Since student health facilities are not included in the sample of NEISS hospitals, the NEISS data may underestimate the total number of serious NMV accidents by as much as 27%.

The NMV accident problem on college and university campuses may be indicative of the problems that may arise in other areas if the volume of bicycle traffic continues to rise. It appears that college and university campuses would provide a fertile research environment for both bicycle-safety education specialists and the traffic engineers who are attempting to develop design standards for future bicycle facilities. Clearly, college and university students must be considered one of the most important target groups for bicycle-safety education programs.

SECTION IV
BICYCLE/MOTOR-VEHICLE ACCIDENTS: DESCRIPTIVE DATA

This section and Section V contain a description of selected findings from a recently completed study of bicycle/motor-vehicle accidents (Cross & Fisher, 1977). The findings of a traditional analysis of descriptive data are summarized in this section. Section V contains a description of frequently occurring types of bicycle/motor-vehicle accidents--referred to as "problem types"--and a discussion of educational countermeasures for the various problem types.

The general objectives of the Cross and Fisher study were to compile data on the causes of bicycle/motor-vehicle accidents and to use the data to identify the full range of countermeasure approaches that have potential for reducing the number of accidents of this kind. The project was national in scope and encompassed both urban and rural accidents.

Although the information presented in Sections IV and V will meet the needs of most readers, it may not be complete and detailed enough to meet the needs of readers who are involved in the development of a new bicycle-safety-education program or in the assessment of existing programs. Persons with such responsibilities are advised to obtain and study a copy of the original report.

METHODOLOGY

Data on bicycle/motor-vehicle accidents were collected in four sampling areas in the United States. The sampling areas were selected to provide maximum coverage of the characteristics of the bicycling population and the environmental conditions in which they ride. The sampling areas, each consisting of several contiguous counties, were located in California (Los Angeles area), Colorado (Denver/Boulder areas), Florida (Tampa/Orlando areas), and Michigan (Detroit/Flint areas). Within each sampling area, a proportionate sample of non-fatal cases was selected from those occurring during each month of calendar year 1975; an attempt was made to select equal numbers of urban and rural accidents at each sampling area. A non-fatal case was rejected from the sample if it was an unwitnessed hit-run accident or if both of the involved operators refused to be interviewed. Because of the small number of fatal accidents that occurred within each sampling area, none were rejected from the sample. Data were compiled on 166 fatal accidents and 753 non-fatal accidents--919 cases in all.

A conceptual model of the accident-generation process was used in defining the data requirements for this study. This model focused on the sequence of functions and events preceding the accident and the factors that influenced the function-event sequence. Data on each accident case in the sample were compiled by trained Field Investigators. Field Investigators compiled and recorded data from several sources, including: the official traffic accident report, observations and measurements taken at the accident site, and detailed interviews with the vehicle operators and persons who witnessed the accident. A structured questionnaire and a detailed scale-drawing of the accident site were used to conduct the operator interviews.

Some questionnaire items were designed to provide information about the characteristics of the operator, his vehicle, and his trip. However, most items were designed to provide detailed information about the accident-generation process. The interview procedures and instruments were designed to provide a clear notion of the pre-crash path of each vehicle, the function failure of each operator, and the combination of factors that were causally related to the function failures.

A classification system was developed and the accident cases were classified into mutually exclusive "problem types." Cases classified into the same problem type exhibited commonality in the following attributes: the traffic context in which the accident occurred, the operators' function failures, and the combination of factors causally related to the function failures.

All data items were analyzed by problem type. In addition, selected descriptive-data items were analyzed for the fatal and non-fatal samples--pooled over problem types. The characteristics of individual problem types and the results of the descriptive-data analyses were examined systematically in an attempt to identify general countermeasure approaches having the potential for reducing the incidence of bicycle/motor-vehicle accidents.

OPERATOR CHARACTERISTICS

SEX

The vehicle operators in the study sample--both bicyclists and motorists--were predominantly males. Furthermore, the proportion of males was greater for the fatal sample than for the non-fatal sample. Seventy-one percent of the non-fatal accidents and 85% of the fatal accidents involved a male *bicyclist*; a male *motorist* was involved in 65% of the non-fatal and 72% of the fatal accidents. It is probable that the overrepresentation of males is due partly to a greater amount of exposure for males--particularly male bicyclists. However, it is also probable that there are some important behavioral differences between male and female bicyclists.

The overrepresentation of male bicyclists may suggest that a bicycle-safety-education program should concentrate principally or exclusively on males. Although it may be true that our educational dollars might be most cost-effectively spent in educating males to the exclusion of females, such an approach would be unfair and shortsighted. The absolute number of accidents involving females is far too large to warrant their exclusion from an educational program. Moreover, because an increasing number of females are becoming interested in bicycling, it can be expected that the differences in male and female involvement in accidents will diminish in the future.

AGE

The age distribution of the motorists in the study sample was found to be highly similar to the age distribution of motor-vehicle operators involved in all other types of traffic accidents. Since the age distribution of accident-involved motorists is well known (see National Safety Council's *Accident Facts*, 1977), the following discussion will be limited to the age distribution of accident-involved bicyclists.

The age distributions of the fatally injured and non-fatally injured bicyclists in the study sample are shown in Figure 4. (It should be noted that accident frequency is plotted for two-year age intervals.) Beginning at age four, accident frequency rises steadily to the age of 12 and remains at this high level through the age of 15. Thereafter, accident frequency declines dramatically and remains at a relatively low and constant level for ages beyond 30 years. The general shape of the curves for fatal and non-fatal accidents is similar, but fatal accidents are more frequent among the very young and the very old bicyclists. About 4.5% of the fatal cases involved a bicyclist younger than six years of age, whereas only two percent of the non-fatal cases involved a bicyclist younger than six years. Similarly, it can be seen that 18.2% of the fatal cases involved a bicyclist older than 35 years of age, and only 4.2% of the non-fatal cases involved a bicyclist older than 35 years. Although not shown in Figure 4, over 10% of the fatalities involved a bicyclist older than 55 years and three percent involved a bicyclist older than 75 years of age. It is of interest to note that the age distributions shown in Figure 4 are quite similar to the age distributions found in a number of other studies

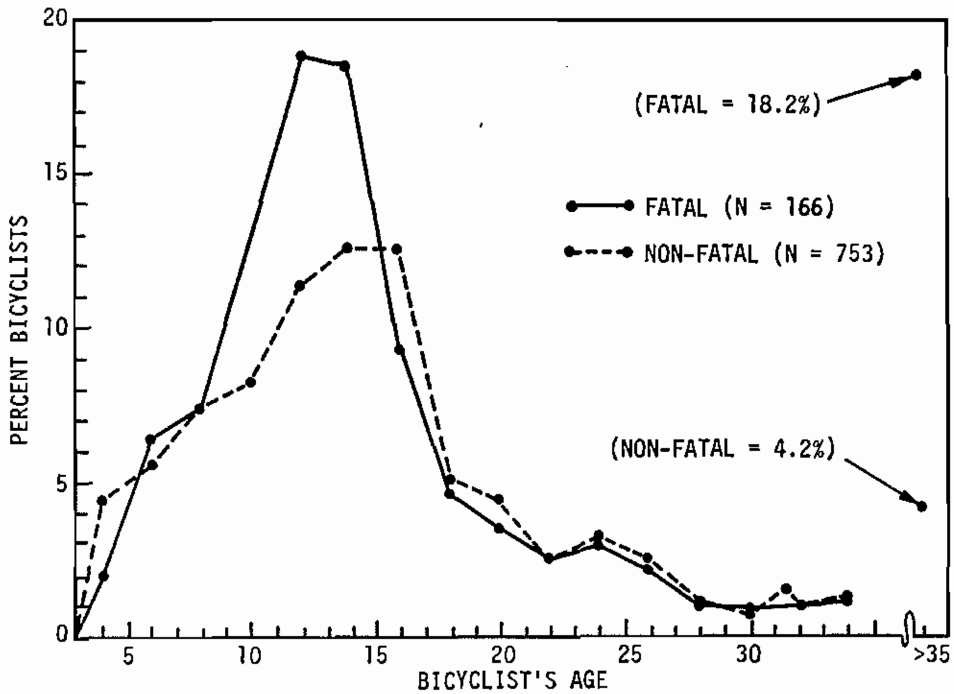

Figure 4. Bicyclist age distributions for fatal and non-fatal accident cases in the study sample.

of bicycle/motor-vehicle accidents, including studies by: the American Automobile Association (1973), the California Highway Patrol (1974), the Virginia Department of Highways (1974), Walsh and Watt (1974), and the Washington State Patrol (1973).

The age distribution of bicyclists in an accident sample is most meaningfully evaluated in terms of the relative exposure for each age group. Although exposure data are not available that take into account the combined frequency and amount of bicycle usage for each age group, Barton-Aschman Associates conducted statewide household surveys to assess the relative proportion of persons within each age group who rode a bicycle at least once during the year preceding the interview. Separate surveys were conducted for the State of Tennessee (Barton-Aschman, 1974b) and the State of Pennsylvania (Barton-Aschman, 1975). The age distributions revealed by these surveys are shown in Table 9 along with corresponding age distributions for the fatally injured and non-fatally injured bicyclists in the study sample.

TABLE 9

COMPARISON OF AGE DISTRIBUTIONS FOR ACCIDENT SAMPLE AND THE GENERAL BICYCLING POPULATION

	ACCIDENT SAMPLE		BICYCLE USERS[1]		
BICYCLIST AGE	FATAL (N=166)	NON-FATAL (N=753)	TENNESSEE (N=3141)	PENNSYLVANIA (N=6372)	COMBINED[2] (N=9513)
< 6	4.2%	*2.0%	5.9%	4.5%	5.0%
6-11	20.6%	*27.5%	25.9%	23.0%	24.0%
12-15	23.1%	*37.1%	17.1%	19.0%	18.4%
16-19	16.9%	13.9%	11.5%	12.2%	12.0%
20-29	13.4%	*12.2%	17.4%	15.8%	16.3%
30-44	*8.5%	*3.8%	15.8%	16.7%	16.4%
45-59	5.4%	*1.8%	6.3%	7.3%	7.0%
≥ 60	*7.9%	1.7%	1.2%	1.2%	1.2%

[1]User data from household surveys completed by Barton-Aschman Associates, Inc., for the Tennessee Departments of Conservation and Transportation (Barton-Aschman, 1974b) and the Pennsylvania Department of Transportation (Barton-Aschman, 1975).

[2]Combined percentage = $\frac{P_1N_1 + P_2N_2}{N_1 + N_2}$

*Proportion differs significantly from the proportion of users (combined Tennessee and Pennsylvania samples) in the corresponding age group ($p < .05$).

An analysis was performed to determine whether the age distribution for either the fatal or non-fatal sample differed significantly from the age distribution of the user population--as measured by the combined sample for Tennessee and Pennsylvania (see column five of Table 9). In columns one (FATAL) and two (NON-FATAL), asterisks were placed beside the percentage values that differed significantly from the corresponding percentage value in column five (user population).

An examination of the data for the fatal sample shows that bicyclists younger than 30 years of age and those between 45 and 59 years of age are involved in fatal accidents in about the same proportion as their numbers in the user population. Bicyclists between 30 and 44 years of age are involved in fatal accidents significantly *less* often than would be expected from their numbers in the user population; bicyclists 60 years of age or older are involved in fatal accidents significantly *more* often than would be expected from the proportion of persons in this age group who ride bicycles. Stated differently, these data suggest that the likelihood of being killed in a bicycle/motor-vehicle accident is *less* than average for bicyclists in the 30-44 age group and greater than average for bicyclists who are 60 years old or older.

Examine next the age distribution for the non-fatal sample. It can be seen that bicyclists between six and 15 years of age are involved in non-fatal accidents more often than would be expected from their numbers; bicyclists younger than six years of age and those between 20 and 59 years of age are involved less often than would be expected from their numbers in the user population. It is of particular importance to note that:

- Accident involvement of 12-15 year old bicyclists is more than twice as great as would be expected from the number of bicycle users in this age group.
- Accident involvement of bicyclists between 30 and 59 years of age is less than one-fourth of that expected from the number of bicyclists in this age group.

The reader must exercise caution when using these data to define the educational target group. The finding that both accident frequency and accident rate is highest among bicyclists between the ages of 12 and 15 may suggest that safety education should be aimed at this age group. However, if safety education did not commence until the age of 12, about one-fourth of all fatal accidents and one-third of all non-fatal accidents will have occurred before the bicyclists receive the education.

DRIVING EXPERIENCE

It was found that most bicyclists and motorists were experienced vehicle operators who operated their vehicles regularly. In addition, most operators were driving/riding a vehicle they were thoroughly familiar with at the time the accident occurred. About 95% of the motorists and bicyclists had more than one year's driving experience and routinely operated their vehicles two or more hours each week. Seventy-five percent of the bicyclists and 93% of the motorists reported that they had driven the accident vehicle at least 50 times before the accident occurred; only seven percent of the bicyclists and three percent of the motorists had driven their vehicle fewer than five times before the accident.

No data have been located that indicate the amount of driving/riding experience that is required to acquire and maintain a reasonable level of vehicle-handling skill. However, it seems reasonable to assume that a relatively high level of vehicle-handling skill can be acquired by most persons in about one year and that this skill can be maintained by operating a vehicle for one or two hours each week. If these assumptions are valid, it can be concluded that few motorists and bicyclists in the non-fatal study sample lacked basic vehicle-handling skill at the time of the accident. In short, these data fail to support the assumption that a large proportion of bicycle/motor-vehicle accidents result from a lack of basic vehicle-handling skill.

PHYSICAL/MENTAL CONDITION

With the exception of intoxication, few operators reported that they were suffering from any type of impairment at the time of the accident. It was found that less than one percent of the bicyclists were impaired by alcohol. However, evidence that the motorist had been drinking was found in 3.5% of the non-fatal accidents and 16.9% of the fatal accidents. Alcohol was judged contributory in nearly every case in which it was found present. Evidence of drug use was found only infrequently, but the type of data collected during this study cannot be expected to provide reliable information about the number of operators who were under the influence of drugs when the accident occurred.

BICYCLISTS' KNOWLEDGE OF THE LAW

For all accidents that resulted from the bicyclist's violation of a traffic law, the bicyclist was questioned in detail about his reasons for violating the law. It was found that the violation was due to ignorance of the law in only one case.

OTHER OPERATOR CHARACTERISTICS

Listed below are other items of information obtained from the interviews with operators in the non-fatal sample. The percentages reported are based on 525 bicyclist interviews and 385 motorist interviews.

- Nineteen percent of the bicyclists and 54% of the motorists reported that they had received formalized training in the operation of a motor vehicle prior to the accident.
- Fifty-seven percent of the bicyclists and 52% of the motorists reported that they had read the laws and ordinances governing bicycles prior to the time the accident occurred.
- Twenty-one percent of the bicyclists and 96% of the motorists possessed a valid motor-vehicle operator's license at the time of the accident. Most of the motorists who did not possess a valid motor-vehicle operator's license were juveniles who were riding motorcycles at the time of the accident.
- Six percent of the bicyclists reported that they ride a bicycle as part of their job (does not include commuting).
- Twenty-five percent of the motorists reported that they drive a motor vehicle as part of their job (does not include commuting).
- Eight percent of the bicyclists reported that they had received some form of formalized training in operating a bicycle prior to the accident.
- Forty-one percent of the bicyclists reported that they commute to school or work on a bicycle.
- Seventeen percent of the motorists reported that they ride a bicycle at least occasionally.

- Eight percent of the bicyclists and one percent of the motorists reported having had at least one bicycle/motor-vehicle accident (other than the one that was being investigated) during the past 24 months. Only 27.7% of the "other" bicycle/motor-vehicle accidents were reported to the police.

- Twenty-two percent of the bicyclists reported that they could have chosen an alternate route to their destination that was safer than the route they were on when the accident occurred.

VEHICLE CHARACTERISTICS

VEHICLE TYPE

The type of motor vehicle involved in the accident was usually recorded on the official traffic accident report form, but the specific type of bicycle was seldom reported. For this reason, information about motor-vehicle type was obtained for nearly every case in both the fatal and non-fatal samples; information on bicycle type was obtained only for the non-fatal cases in which the bicyclist was interviewed.

Bicycle Type

The relative frequency with which different types of bicycles were ridden by male and female bicyclists in the non-fatal sample is shown in Table 10. Also shown is the distribution of bicycle types for the combined (male and female) sample. Considering the combined sample, it can be seen that most bicyclists were riding a lightweight bicycle at the time the accident occurred and that a smaller, but significant, number were riding a standard or middleweight bicycle. About five percent of the bicyclists were riding a highrise bicycle; less than two percent were riding another type of bicycle (child tricycle or big wheel,[2] adult tricycle, folding or collapsible bicycle, tandem bicycle, or custom design).

TABLE 10

TYPE OF BICYCLE RIDDEN BY MALE AND FEMALE BICYCLISTS IN THE NON-FATAL SAMPLE

BICYCLE TYPE	MALE		FEMALE		COMBINED	
	N	%	N	%	N	%
LIGHTWEIGHT	186	*51.0*	80	*50.3*	266	*50.8*
STANDARD/MIDDLEWEIGHT	148	*40.5*	74	*46.5*	222	*42.4*
HIGHRISE	23	*6.3*	4	*2.5*	27	*5.1*
OTHER	8	*2.2*	1	*.6*	9	*1.7*
TOTAL	365	*100*	159	*100*	524	*100*

[2]Accidents involving child tricycles and "big wheels," are clearly underrepresented in this sample. Discussions with representatives of Dunlap and Associates (Blomberg, 1977) revealed that accidents involving tricycles and big wheels are usually reported as pedestrian accidents. For a large sample of pedestrian accidents that occurred in Los Angeles, it was found that tricycle and big wheel accidents together accounted for about two percent of *all* pedestrian accidents and five percent of all *child* pedestrian accidents.

A comparison of the distributions of bicycle type for males and females shows that nearly identical percentages of males and females (about 50%) were riding a lightweight bicycle. A standard or middleweight bicycle was ridden by a slightly larger percentage of females (46.5%) than males (40.5%), whereas a slightly larger percentage of males than females were riding a highrise or "other" type bicycle. Statistical tests revealed that *none* of the differences between corresponding percentage values were statistically significant ($p < .05$). Therefore, these data suggest that there are no important differences in the types of bicycles ridden by male and female accident victims.

There have been few survey studies that attempted to assess the relative number of bicycles of each type that are in use by the general bicycling population. Most surveys that have addressed the issue of bicycle type are limited to only one segment of the population (school-age children, college students, etc.) or are outdated. One recent study has been located that surveyed the general population in Santa Clara County, California (Diridon Research Corporation, 1973). The distribution of bicycle types revealed by this survey is shown in Table 11 along with the distribution of bicycle types for the study sample. It can be seen that lightweight bicycles are overrepresented in the accident sample, and that all other bicycle types are underrepresented. Although no data are available on the distribution of bicycle types in use within the areas from which the accident sample was drawn, it is unlikely that the number of lightweight bicycles in use within the sampling areas would be greater than the lightweights in use within Santa Clara County, California, where the adult ridership is very high. For this reason, the data shown in Table 11 suggest that a disproportionate number of bicycle/motor-vehicle accidents involve lightweight bicycles. Although it is possible that accident rate would be constant across bicycle types if exposure (type, frequency, and amount of riding) was held constant, it is also possible that accident rate is higher for lightweight bicycles because the average speed is far greater than for other types of bicycles.

TABLE 11

DISTRIBUTION OF BICYCLE TYPES FOR THE STUDY SAMPLE (NON-FATAL CASES) AND A RECENT HOUSEHOLD SURVEY

BICYCLE TYPE	STUDY SAMPLE (N=524)	HOUSEHOLD SURVEY[1] (N=3187)
LIGHTWEIGHT	51%	32%
STANDARD/MIDDLEWEIGHT	42%	52%
HIGHRISE	5%	12%
OTHER	2%	4%

[1]Diridon Research Corporation, 1973.

Motor-Vehicle Type

The distributions of motor-vehicle type for the fatal and non-fatal samples are shown in Table 12. The parenthetical values adjacent to the name of the vehicle type represent the percentage of total vehicle registrations for the associated vehicle type (National Safety Council, 1976). For instance, 77.5% of all vehicles registered in the United States are passenger cars, 18.4% are trucks, and so on.

As would be expected, most of the motor vehicles involved in bicycle/motor-vehicle accidents are passenger cars. It can be seen that about 80% of the fatal accidents and

TABLE 12

TYPE OF MOTOR VEHICLE DRIVEN BY MOTORISTS IN THE FATAL AND NON-FATAL SAMPLES

VEHICLE TYPE	FATAL N	FATAL %	NON-FATAL N	NON-FATAL %
PASSENGER CAR (77.5%)	126	*79.8*	658	*88.1*
TRUCK (18.4%)	30	*19.0*	70	*9.4*
Pickup or Van	24	*15.2*	61	*8.2*
Other Truck	6	*3.8*	9	*1.2*
MOTORCYCLE (3.7%)	1	*.6*	18	*2.4*
BUS (.4%)	1	*.6*	1	*.1*
TOTAL	158	*100*	747	*100*

[1]Parenthetical values show percentage of total vehicle registrations for the associated vehicle type.

88% of the non-fatal accidents involved a passenger car (a significantly larger percentage of non-fatal than fatal accidents involved a passenger car [p <.01]). Comparison of the distribution for the study sample with the distribution of all registered motor vehicles shows that passenger cars are only slightly overrepresented in the fatal sample but are overrepresented in the non-fatal sample by more than ten percent. Although the reasons for this overrepresentation of passenger cars in bicycle/motor-vehicle accidents is not known for certain, the most probable reason is that passenger cars are more often driven in the areas where bicycle density is greatest.

Table 12 shows that trucks are involved in a proportionately greater number of fatal accidents (19%) than non-fatal accidents (9.4%). More than 80% of the trucks were pickups or vans; the remainder were larger types of trucks. These data suggest that the likelihood of fatal injuries increases as a function of the size of the vehicle. For instance, dividing the proportion of fatal cases by the proportion of non-fatal cases yields a ratio of .9 for passenger cars, 1.9 for pickups and vans, and 3.2 for larger types of trucks. However, because of the small number of cases involving a truck, these data can only be considered suggestive.

Only one fatality resulted from a collision between a bicycle and a motorcycle. Motorcycles were involved in a proportionately greater number of non-fatal accidents (2.4%). Although motorcycles were involved in bicycle/motor-vehicle accidents less often than would be predicted from their numbers, it is possible that the accident rate per mile driven may be greater than for other types of motor vehicles.

The small number of bicycle/motor-vehicle accidents involving a bus was somewhat surprising. Considering the width of a bus and the types of areas in which they travel, it seems reasonable to expect a greater number of bicycle-bus accidents than was revealed by the sample. This result is probably a function of the skill of the bus drivers and a recognition by bicyclists that buses constitute a serious threat.

VEHICLE CONDITION

The bicyclists who were interviewed were asked to identify both the safety equipment and the vehicle defects for the bicycle they were riding at the time of the accident. To minimize the effects of recall, checklists of safety equipment and defects were provided. The motorists who were interviewed were asked to identify equipment defects for the motor vehicle they were driving at the time the accident occurred. A checklist was also used to assess motor-vehicle defects.

Bicycle Safety Equipment

Bicyclists were asked to identify the safety equipment that was on the bicycle they were riding when the accident occurred and to indicate whether or not the items they checked were in good working order. The bars in Figure 5 indicate the proportion of bicycles in the non-fatal sample that were equipped with the associated safety item. The shaded portion of the bar indicates the proportion of cases in which the item was defective.

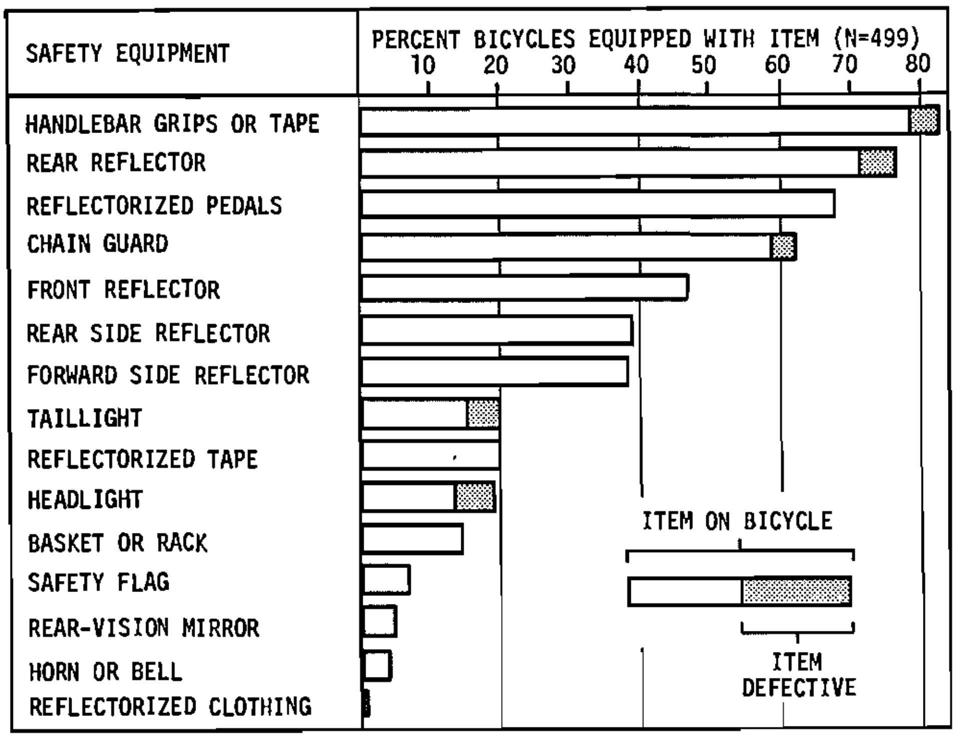

Figure 5. Safety equipment on the bicycles in the sample of non-fatal accidents.

It can be seen that the vast majority of bicycles were not equipped with all the safety items that most experts consider essential for safe riding and, in some cases, that are required by law. Only four of the safety-equipment items were found on the majority of bicycles: handlebar grips or tape (83%), rear reflector (76%), reflectorized pedals (68%), and chain guard (62%). Although a front reflector and a forward and rear side reflector are required by law, it can be seen that only about 47% of the bicycles were equipped with a front reflector and about 38% were equipped with a forward and rear side reflector. Twenty percent or fewer of the bicycles were equipped with the remaining safety items. It is interesting to note that although about 20% of the bicycles were equipped with a taillight and headlight, about five percent of all taillights and headlights were defective or otherwise inoperable at the time the accident occurred. It is also of interest to note that only seven percent of the bicycles were equipped with a safety flag and that less than five percent were equipped with a rear-vision mirror (this percentage includes head-mounted rear-vision mirrors).

It might be argued that although many bicycles are not equipped with the necessary lighting equipment, such ill-equipped bicycles are not often ridden at night. For this reason, the availability of lighting equipment was tabulated separately for daytime and nighttime accidents. This tabulation is shown in Table 13. It can be seen that the proportion of bicycles equipped with the various lighting equipment was similar for the daytime and nighttime accidents. The proportions differed significantly only for reflectorized clothing where it was found that a significantly larger percentage of bicyclists involved in nighttime accidents were wearing reflectorized clothing ($p < .05$). However, the absolute number of bicyclists who were wearing reflectorized clothing at the time of the accident was so small that this difference has little practical significance.

TABLE 13

LIGHTING EQUIPMENT ON BICYCLES INVOLVED IN DAYTIME AND NIGHTTIME ACCIDENTS (NON-FATAL ACCIDENT SAMPLE)

	PERCENT BICYCLES EQUIPPED WITH ITEM	
LIGHTING EQUIPMENT	DAYTIME ACCIDENTS (N=477)	NIGHTTIME ACCIDENTS (N=52)
REAR REFLECTOR	72.7%	67.3%
REFLECTORIZED PEDALS	73.1%	63.3%
FRONT REFLECTOR	44.4%	40.4%
REARWARD SIDE RELFECTOR	36.7%	38.5%
FORWARD SIDE RELFECTOR	35.4%	40.4%
TAILLIGHT	19.7%	21.1%
REFLECTORIZED TAPE	19.1%	15.4%
HEADLIGHT (OPERATIONAL)	19.1%	13.5%
REFLECTORIZED CLOTHING	.2%	1.9%

These data would be most meaningful if it were possible to compare the safety equipment on bicycles in the accident sample with the safety equipment on the general population of bicycles in the sampling areas. Unfortunately, no data have been located that enable one to estimate the percentage of bicycles in the general population that are equipped with the safety items investigated in this study. However, based upon casual observations, it is believed that bicycles in the accident sample would not differ significantly from those in the general population.

As is discussed in more detail later, lighting equipment and devices to increase the daytime conspicuity of the bicycle (safety flags, for example) are clearly the most crucial items of safety equipment. Other items are either present on most bicycles or, if absent, seldom contribute to bicycle/motor-vehicle accidents.

Bicycle-Equipment Defects

During the interviews, the bicyclists were first asked to indicate on the checklist the equipment that was defective at the time of the accident, and then were asked to indicate whether the defect contributed to the accident in any way. The bars in Figure 6 indicate the proportion of bicyclists who reported the presence of the associated defect. The shaded portion of the bar indicates the proportion of cases in which the defect was present and judged contributory by the bicyclist.

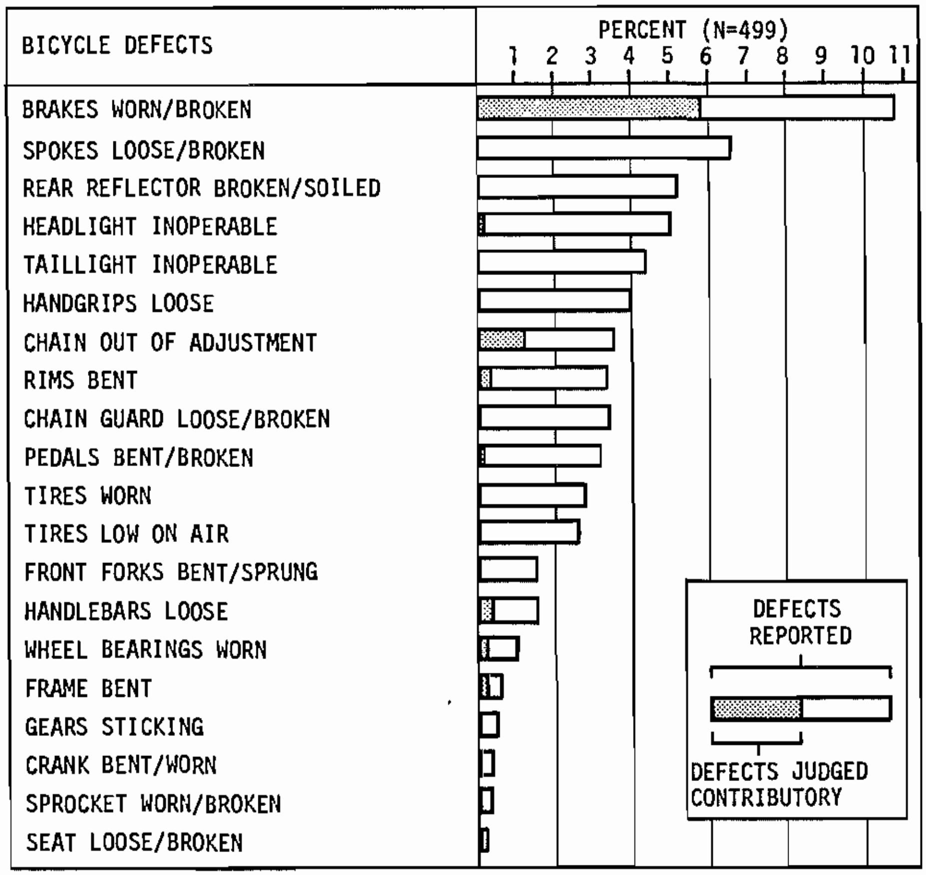

Figure 6. Bicycle defects reported and defects judged contributory by bicyclists in the non-fatal accident sample.

Although a significant proportion of the bicycles were defective, few of the defects were judged contributory by the operator. The one exception to this observation is defective brakes. Nearly 11% of the bicyclists reported that their brakes were defective at the time of the accident, and over half of them indicated that their defective brakes contributed to the accident. The researchers' assessment of the contribution of bicycle defects did not always correspond with the judgment of the bicyclists. In a significant number of cases, it was found that the accident was imminent by the time the bicyclist first attempted to brake; so the defective brakes were judged non-contributory, even though the bicyclists believed that the brake defect did, in fact, contribute to the accident.

The main implication of these findings is that programs to eliminate bicycle defects, with the possible exception of defective brakes, cannot be expected to make a significant impact on the number of bicycle/motor-vehicle accidents that occur. This conclusion is supported by the findings of a study by the Virginia Department of Highways (1974) in which a bicycle defect was found to be a contributory factor in less than three percent of all bicycle/motor-vehicle accidents.

Motor-Vehicle Condition

It was found that nearly all motor vehicles in the sample were properly equipped and free of defects when the accident occurred. This finding corresponds closely with the findings of other studies which indicate that less than one percent of all bicycle/motor-vehicle accidents involve a defective motor vehicle (see Waller and Reinfurt, 1969; Washington State Patrol, 1973).

CHARACTERISTICS OF ACCIDENT TRIP

TRIP PURPOSE

About 80% of the bicyclists and 96% of the motorists were on a utilitarian trip to a specific destination when the accident occurred. Approximately equal numbers of bicyclists were traveling for the following purposes: shopping or errands (22%), commuting to a place of recreation (21%), visiting friends (19%), and commuting to school or work (19%). Although only 18% of the accidents occurred while the bicyclist was on a recreational trip with no destination, household surveys have revealed that between 50% and 60% of all bicycle trips are of this type.

The most common trip purposes for motorists include: shopping or errands (41%), commuting to school or work (29%), visiting friends (14%), and commuting to a place of recreation (13%).

TRIP LENGTH

Most operators were on a relatively short trip when the accident occurred. The median one-way trip length was 1.1 miles for bicyclists and 5.8 miles for motorists. Less than five percent of the bicyclists were on a trip exceeding a one-way length of 3.4 miles; less than five percent of the motorists were on a trip that exceeded about 30 miles, one way.

DAY OF WEEK

The accidents in the study sample did not exhibit the weekend rise that is typical for other types of traffic accidents. In fact, the frequency of non-fatal accidents was less on Saturday and Sunday than on any day of the week. For all practical purposes, there is no day of the week that is clearly more or less important than any other day.

TIME OF DAY

Figure 7 shows the distributions of fatal and non-fatal accidents in the study sample by time of day. Also shown (solid circles) is the distribution of all motor-vehicle accidents by time of day (National Safety Council, 1976). It can be seen that the distribution of bicycle/motor-vehicle accidents is similar but somewhat more pronounced than the distribution of all motor-vehicle accidents. That is, there is a minor peak during the morning rush hours between 7:00 and 9:00 AM and a major peak during the evening rush hours between 3:00 and 7:00 PM.

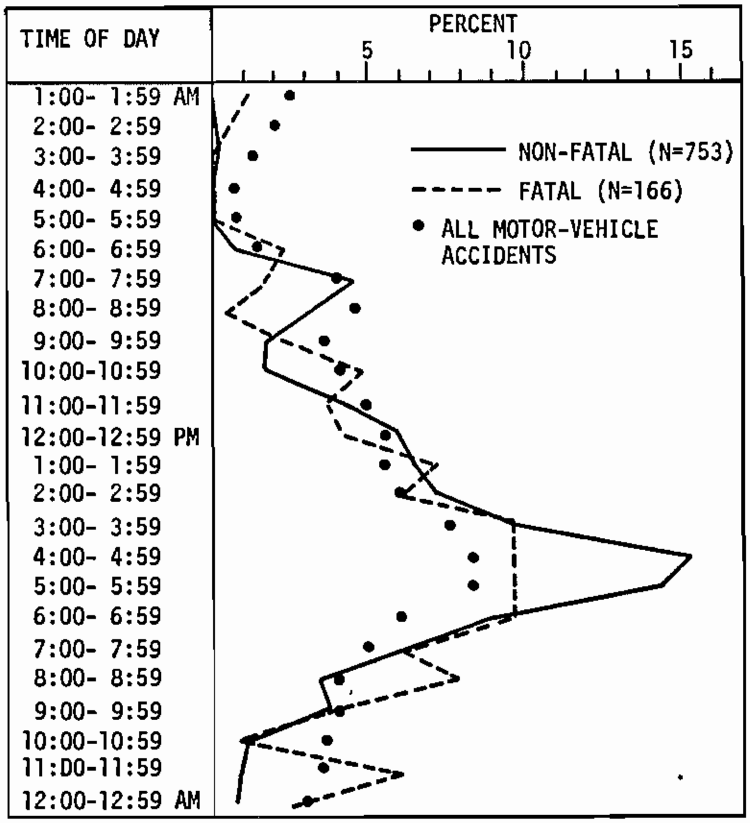

Figure 7. Distributions of fatal and non-fatal accidents by time of day.

The distributions of fatal and non-fatal accidents differ in two important respects. First, a relatively smaller proportion of fatal than non-fatal accidents occur during the evening rush hours. While the absolute number of fatal accidents is greatest during these hours, the likelihood of a fatal accident apparently does not increase as a simple function of exposure. Secondly, the relative proportion of fatal accidents occurring after 8:00 PM is almost surely due to darkness. As will be shown later, the types of accidents that occur during darkness are more likely to result in fatal injuries to the bicyclist.

Nearly identical distributions of accidents as a function of time of day are reported by Waller and Reinfurt (1969), Walsh and Watt (1974), and the Washington State Patrol (1973). All three of these studies show a secondary peak during the morning rush hours and a major peak during the evening rush hours. Furthermore, the reported percentage values are nearly identical to one another and to the percentage values for the non-fatal accidents presented in this study.

LIGHTING CONDITIONS

About 17% of all accident trips were made during darkness. However, it was found that a significantly greater proportion of fatal (30%) than non-fatal (10%) accidents occurred during darkness. These findings provide strong support for the contention that the likelihood of sustaining fatal injuries from a bicycle/motor-vehicle accident is significantly greater when the accident occurs at night.

In addition to a greater likelihood of fatal injuries at night, it is probable that accident rate is also far higher at night. Although no data have been located that provide an accurate estimate of the amount of all bicycle riding that is done during darkness, casual observation and discussions with a large number of bicyclists indicate that night riding accounts for no more than three or four percent of most bicyclists' total riding time.

WEATHER CONDITIONS

Most of the accident trips were made during conditions of fair weather. A small, but significant, number of accidents occurred when rain was falling (three percent of the non-fatal cases and six percent of the fatal cases). Only a fraction of one percent of the cases occurred when it was snowing, during a period of heavy fog, or in an area with blowing sand or dust.

CHARACTERISTICS OF ACCIDENT LOCATION

URBAN VERSUS RURAL ACCIDENTS

Law enforcement agencies most commonly differentiate urban and rural areas in terms of either the incorporation status of the area or the number of inhabitants who reside within a built-up area. As a consequence, many accidents that are officially designated as rural occur in densely populated residential communities located in the unincorporated fringe of a large population center. Similarly, some accidents officially designated as urban occur in areas that are truly rural in character.

To avoid the ambiguity associated with the official designation, the accidents were classified as urban or rural based upon information obtained from the on-site inspections. Accidents usually were classified as rural if they occurred in an area where (a) the posted speed limit was 45 MPH or more, (b) there were no curbs or sidewalks adjacent to the roadway, (c) street lights were not present at the intersections, and (d) at least 50% of the area within one-half mile radius of the accident site was open. Cases that did not meet all four of these classification criteria were classified as urban.

A comparison of the official designations and the designations based upon the on-site inspections revealed the following:

- 90.9% of the fatal accidents in incorporated areas are correctly classified as urban.
- 67.2% of the fatal accidents in unincorporated areas are correctly classified as rural.
- 96.2% of the non-fatal accidents in incorporated areas are correctly classified as urban.
- 41.4% of the non-fatal accidents in unincorporated areas are correctly classified as rural.

According to the National Safety Council (1976), (a) 60% of the fatal accidents occur in incorporated areas, and 40% occur in unincorporated areas; (b) 80% of the non-fatal accidents occur in incorporated areas, and 20% occur in unincorporated areas. These data are based upon police reports, so are subject to the biases discussed above. Therefore, the above estimates of the magnitude of this bias were used to adjust the National Safety Council's estimates of the distribution of incorporated and unincorporated accidents. The adjusted estimates are shown below:

	FATAL	NON-FATAL
URBAN	68%	89%
RURAL	32%	11%

These data leave no doubt that the likelihood of sustaining fatal injuries is greater for accidents that occur in rural areas. It is also probable that accident *rate* is higher in rural areas, but it will be necessary to obtain data on the relative amount of riding that is done in urban and rural areas in order to assess the differences in accident rate.

PROXIMITY TO OPERATOR'S RESIDENCE

Most accidents occurred in close proximity to the operator's residence. The median distance between the accident site and the operator's residence was .6 miles for bicyclists and 2.6 miles for motorists. These findings, along with the finding that most operators had driven through the accident site many times before the accident occurred, enable one to confidently conclude that lack of familiarity with the accident site is seldom a factor in bicycle/motor-vehicle accidents.

POSTED SPEED LIMIT

The majority of accidents occurred on roadways with a posted speed limit of 30 MPH or less. However, the likelihood of fatal accidents was found to be positively correlated with the posted speed limit for the roadway on which the accident occurred. The distribution for non-fatal accidents showed that over 80% of the non-fatal accidents occurred on roadways with a posted speed limit of 35 MPH or less. In contrast, more than half of all fatal accidents occurred on roadways with a speed limit greater than 35 MPH; less than one-third of the fatal accidents occurred on roadways with a posted speed limit of 25 MPH or less.

LATERAL AND VERTICAL CURVATURE OF ROADWAY

It was found that one or both operators' pre-crash path was on a laterally curved roadway in only 3.6% of the cases. About seven percent of the motorists and ten percent of the bicyclists were traveling on a measurable hill at the time of the crash or shortly before. For motorists, equal numbers were traveling uphill and downhill. However, a significantly larger proportion of the bicyclists were traveling downhill than uphill. This finding undoubtedly is due to the higher speeds bicyclists travel when riding downhill, and indicates that, on the average, accident risk is greater when traveling downhill. Riding downhill at an excessive speed was judged contributory in about six percent of the cases.

ROADWAY-SURFACE DEFECTS

About 12% of the accidents occurred on a roadway with one or more significant defects. However, roadway-surface defects were found to be contributory in less than three percent of the cases.

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SECTION V
BICYCLE/MOTOR-VEHICLE ACCIDENTS: PROBLEM TYPES AND EDUCATIONAL COUNTERMEASURES

Bicycle/motor-vehicle accidents exhibit great diversity in the situations in which they occur and the reasons for which they occur. When every case is viewed as a unique event, the universe of bicycle/motor-vehicle accidents presents an overwhelmingly complex picture to even the most capable researcher. The nature of the problem, and therefore approaches to reducing the problem, simply cannot be comprehended without structuring the universe of accidents in some meaningful way. The traditional approach to structuring information about accidents is to examine the distribution of data one or two variables at a time. The descriptive data presented in Section IV typifies the traditional analytic approach. This approach is useful and necessary, but descriptive data seldom provide the type of structure that stimulates innovative ideas about accident countermeasures.

Another approach to structuring a complex universe of objects or events is to develop a classification scheme that enables one to subdivide the universe of cases into mutually exclusive "sets" by grouping together objects or events that exhibit commonality in one or more of their attributes. Classification schemes have been developed and used since the days of the early Greeks (Crowson, 1969), and much of the progress in the physical and biological sciences can be attributed to this tool for scientific inquiry (Sokal, 1974). More recently, classification schemes have been developed and successfully used in the study of pedestrian accidents (Snyder & Knoblauch, 1971) and alcohol-related motor-vehicle accidents (Perchonok, 1975).

This section describes the results of a classification of bicycle/motor-vehicle accidents. To convey the full range of similarities and differences among accident cases, a hierarchical classification system was developed that consisted of problem *classes*, *types*, and *subtypes*. Problem classes reflect commonality at the most general level. Problem types represent variations of accidents within the same class, and subtypes represent variations of accidents within the same type. Problem types generally provide the most useful definition of a problem for which specific countermeasures can be tailored; but for some kinds of countermeasures, problem classes or problem subtypes may constitute a more meaningful problem definition.

ORGANIZATION AND CONTENT

For ease of exposition, problem types within the same class are discussed together in a separate subsection. Each subsection begins with a brief description of the distinguishing characteristics of the problem class and the similarities and differences among the problem types within that class. Then, each problem type and subtype in the class is described in turn.

The descriptions of Problem Types 1 through 25 are accompanied by perspective drawings that illustrate the traffic contexts in which the accidents occur and the proximal pre-crash paths of both vehicles. Some drawings illustrate two or more subtypes of the same problem type. The illustration of subtypes is accomplished by showing a separate set of vehicles (a bicycle and a motor vehicle) for each subtype. Each illustration shows the percentage of fatal and the percentage of non-fatal accidents accounted for by the problem type that is illustrated. When two or more subtypes are illustrated, percentage values are shown in close proximity to each vehicle set. These values show the percentage of cases *within the problem type* that is accounted for by each subtype; the combined percentage values for the subtypes shown on each illustration total 100%. Although the illustrations provide a useful aid in understanding how accidents of a given type occur, the reader is cautioned against using the illustrations to draw inferences about the characteristics of the roadway(s), the presence or absence of visual obstructions, the exact impact points, the exact collision points, and so on. The problem-type descriptions for each class are followed by a discussion of the educational countermeasures that appear to have potential for reducing the incidence of one or more problem types within that class.

CLASS A PROBLEM TYPES: BICYCLE RIDEOUT--DRIVEWAY, ALLEY, AND OTHER MID-BLOCK

Table 14 lists the generic titles of the four Class A problem types and shows the proportions of cases in the fatal and non-fatal samples that were classified into each problem type. The proportion of cases in the total class is shown at the bottom of the table.

TABLE 14

PROBLEM CLASS A--BICYCLE RIDEOUT: DRIVEWAY, ALLEY, AND OTHER MID-BLOCK

		FATAL (N=166)	NON-FATAL (N=753)
TYPE 1	BICYCLE RIDEOUT: RESIDENTIAL DRIVEWAY/ALLEY, PRE-CRASH PATH PERPENDICULAR TO ROADWAY	6.7%	5.7%
TYPE 2	BICYCLE RIDEOUT: COMMERCIAL DRIVEWAY/ALLEY, PRE-CRASH PATH PERPENDICULAR TO ROADWAY	2.4%	3.2%
TYPE 3	BICYCLE RIDEOUT: DRIVEWAY/ALLEY APRON, PRE-CRASH PATH PARALLEL TO ROADWAY	2.4%	2.5%
TYPE 4	BICYCLE RIDEOUT: ENTRY OVER SHOULDER/CURB	3.6%	2.5%
TOTAL CLASS (N: FATAL = 25; NON-FATAL = 105)		15.1%	13.9%

All Class A accidents occurred at a mid-block location shortly after the bicyclist entered the roadway from a driveway, alley, or over a curb or shoulder. In almost every case, the bicyclist entered the roadway without slowing, stopping, or searching for oncoming traffic. Because of the bicyclist's suboptimal pre-crash course (path and/or speed), the motorist had insufficient time to avoid the accident once the bicyclist became visible and the bicyclist's intended path became apparent to the motorist. The function failures and contributing factors are similar for the four Class A problem types. The main differences among the problem types are the type of location at which the bicyclist entered the roadway, the factors that served to limit the operator's preview time,[3] and the bicyclist target group.

PROBLEM-TYPE DESCRIPTIONS

Problem Type 1 (6.7% Fatal; 5.7% Non-Fatal)

Figure 8 illustrates the traffic context and critical actions for Problem Type 1. Accidents of this type occur when the bicyclist rides straight out of a residential driveway or alley and collides with a motor vehicle approaching from the left or right. Figure 8 shows that 72% of the collisions occurred in the first half of the roadway (the half nearest the point at which the bicyclist entered the roadway); the remaining 28% occurred in the second half of the roadway.

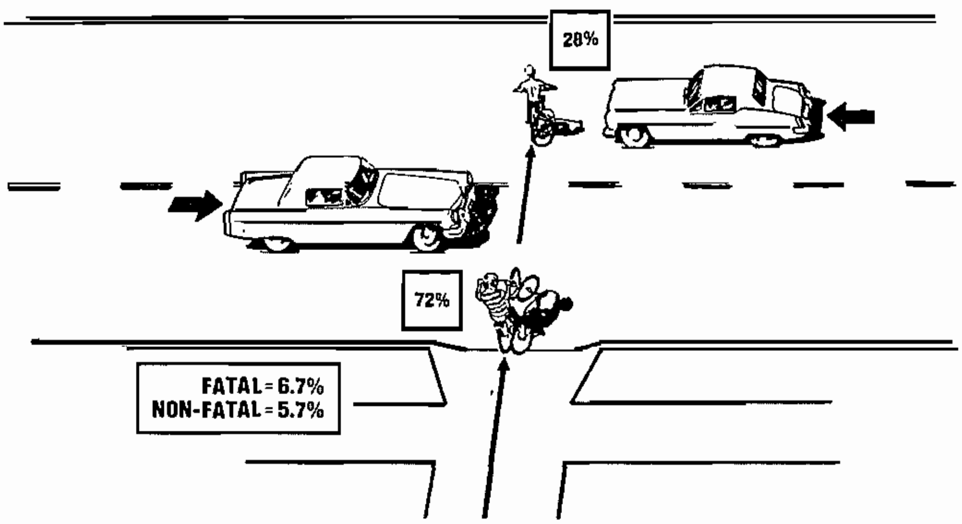


Figure 8. Illustration of Problem Type 1, *Bicycle Rideout: Residential Driveway/Alley, Pre-Crash Path Perpendicular to Roadway.*

Problem Type 1 includes only the bicycle rideout accidents that occurred at the junction of a roadway and a residential driveway (48%), a residential alley (33%), or a driveway serving a rural residence (19%). Seventy-nine percent of the cases occurred on a two-lane[4] urban street with light traffic and a posted speed limit of 25 MPH or less; 19% occurred on a two-lane rural roadway, and two percent occurred on an urban street with more

[3]The term "preview time" is used here to refer to the time available between the point at which the operator first observed the other vehicle and the point at which the collision occurred.

[4]Unless stated otherwise, all the roadways referred to throughout this section are two-way roadways.

than two lanes. Accidents of this type occurred almost exclusively during daytime hours, and the frequency of occurrence was greatest in the afternoon; 95% of the cases occurred during the daytime and 84% occurred between 2:00 PM and 7:00 PM.

A visual obstruction was a contributing factor in 63% of the accidents; parked motor vehicles and vegetation were the most common types of obstructing objects. When the operators' views were not obstructed, the accident was usually the result of one or both operator's failure to search in the direction of the other vehicle until an accident was imminent. In about nine percent of the cases, the motorist observed the bicyclist early enough to have avoided the accident but proceeded with the assumption that the bicyclist would slow or stop before entering the roadway.

The motorist's failure to search in the bicyclist's direction was usually due to his expectation that all traffic entering the roadway from intersecting driveways and alleys would yield the right of way. In short, the motorist did not search in the bicyclist's direction because he saw no necessity to do so in that traffic context. The factors that contributed to the bicyclist's failure to search are more numerous and complex. The most common contributing factors revealed by the interviews include:

- Distracted by riding companion or pedestrian (26%),
- Distracted by play activity (19%),
- Distracted by factors other than play or interaction with another person (16%),
- Assumed area would be void of traffic (19%), and
- Assumed riding companion would search (13%).

Accidents of this type nearly always occurred close to the bicyclist's home; many occurred as the bicyclist was exiting the driveway serving his own residence. Consequently, most bicyclists were thoroughly familiar with the physical and operational characteristics of the accident location. Mainly because of his familiarity with the area, the bicyclist did not consider either the environment or his actions to be particularly hazardous. Therefore, risk *assessment* rather than risk *acceptance* must be considered an important factor for Problem Type 1. Although the bicyclists' actions would be perceived as risk-taking behavior by adults, it would be misleading to suggest that the bicyclists who were involved in this type of accident were any more willing to engage in risk-taking activities than the general population of bicyclists in the same age group.

Problem Type 1 involved bicyclists who were younger than those involved in any other problem type. The median age of the bicyclists was 9.8 years, and about five percent were five years of age or younger. Fewer than five percent of the bicyclists were 16 years of age or older.

Problem Type 2 (2.4% Fatal; 3.2% Non-Fatal)

As is shown in Figure 9, Problem Type 2 occurred in much the same way as Problem Type 1. The distinguishing characteristic of Problem Type 2 is that all the collisions occurred at the junction of a roadway and a *commercial* driveway (75%) or alley (25%). That is, the bicyclist rode *straight out* of a commercial driveway or alley into the approaching motor vehicle's path.

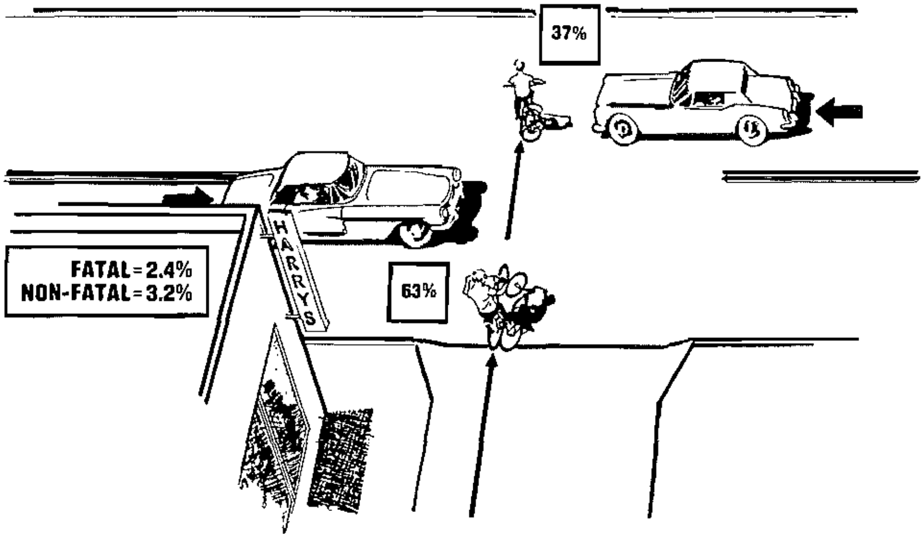


Figure 9. Illustration of Problem Type 2, *Bicycle Rideout: Commercial Driveway/Alley, Pre-Crash Path Perpendicular to Roadway.*

(NOTE: The building was drawn in the above illustration to indicate that this type of accident occurs at the junction of a *commercial* rather than a residential driveway/alley. Although a building sometimes obstructed the operator's view in accidents of this type, buildings were not the most frequent type of obstructing object.)

The accidents occurred with about equal frequency on two-lane urban streets (54%) and urban streets with more than two lanes (42%). But, in either case, the roadway was usually carrying moderate to heavy traffic at the time the accident occurred. Accidents of this type nearly always occurred during the daytime (96%) and the frequency was clearly greatest between 2:00 PM and 5:00 PM (58.4%).

In 39% of the cases, the motorist's preview time was critically limited by a visual obstruction. Parked motor vehicles, fences, and walls were the most common types of visual obstructions. The remaining 61% of the cases occurred even though the visibility conditions were good and the operators had a clear view of the other vehicle long before the collision occurred. About eight percent of the motorists observed the bicyclist in time to have avoided the accident but incorrectly assumed that the bicyclist would stop or turn at the junction. In about 42% of the cases, however, the motorist failed to search in the direction of the clearly visible bicyclist because he assumed that all traffic entering the roadway from intersecting driveways would yield to him.

The bicyclist's suboptimal course and his failure to search were the result of a wide range of different factors. The most common are listed below.

- Distracted by play activity (23%),
- Distracted by riding companion (23%),
- Competing needs--need to catch up with riding companion (15%), and
- Competing needs--need for excitement generated by high speed (15%).

There were few cases in which the presence of information overload could clearly be established from the interview data. That is, few bicyclists believed that their information processing capacity was severely taxed by the information processing requirements that existed at the time of the accident. Even so, it is believed that a substantial portion of the bicyclists were heavily loaded (if not overloaded) by the task of entering a heavily trafficked, multiple-lane roadway, and that information overload or attentional conflict often contributed to the bicyclist's search failure.

Although the bicyclists involved in Type 2 accidents were usually juveniles, there was a substantial number who were in their late teens or older. The median age of the bicyclists for this problem type was 13.8 years; five percent of the bicyclists were seven years of age or younger and five percent were 25 years of age or older.

Problem Type 3 (2.4% Fatal; 2.5% Non-Fatal)

Problem Type 3 is similar in many respects to Problem Types 1 and 2. As is illustrated in Figure 10, the distinguishing characteristic of Problem Type 3 is that the bicyclist entered the roadway from a *parallel sidewalk* by way of a *driveway apron*. About three-fourths of the collisions occurred in the near lane(s) and one-fourth occurred in the far lane(s). Problem Type 3 includes accident cases that occurred at either a residential or a commercial driveway, but most accidents (89%) occurred at a residential driveway. (In this respect, Problem Type 3 is most similar to Problem Type 1.) Eighty-four percent of the collisions occurred on a two-lane residential street; the remaining 16% occurred on a roadway with more than two lanes. Eighty-nine percent of the accidents occurred during the daytime; 63% occurred between 2:00 PM and 7:00 PM.

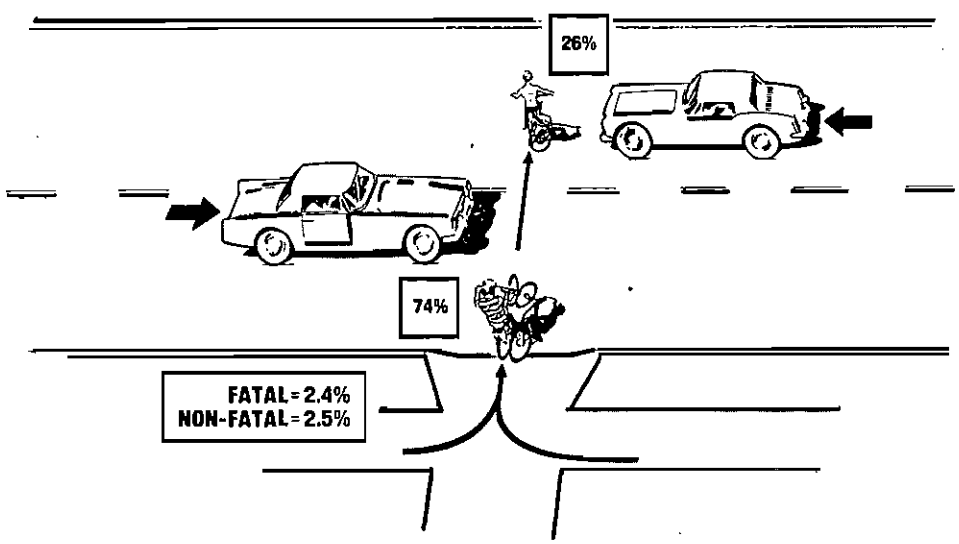


Figure 10. Illustration of Problem Type 3, *Bicycle Rideout: Driveway/ Alley, Pre-Crash Path Parallel to Roadway.*

Like the previous two problem types, there were many cases (47%) in which the bicyclist's pre-crash course combined with visual obstructions to limit the motorist's preview time to such an extent that there was no chance to avoid the accident once the bicyclist emerged from behind the obstructing object. In 22% of the cases, however, the motorist observed the bicyclist early enough to have avoided the accident, but incorrectly assumed that the bicyclist would continue riding on the sidewalk. In 17% of the cases, the bicyclist was visible, but the motorist failed to search in his direction because he assumed that all intersecting traffic would yield to him.

Even when visual obstructions were present, there were many instances in which the bicyclist could have observed the motor vehicle early enough to have avoided the accident. Thus, search failures accounted for 72% of the bicyclist's precipitating function failures. Most of the bicyclists' search failures were due to the presence of some type of distractor. The most frequent distractors were interacting with another person (36%), play activity (27%), and non-traffic-related mental activity (18%). In 18% of the cases, the bicyclist failed to search because he incorrectly assumed that a riding companion would search for hazards and select a safe course through the accident area.

The bicyclists who were involved in Type 3 accidents were slightly older than those involved in Type 1 accidents but were younger than those involved in Type 2 accidents. For Problem Type 3, the median age of the bicyclists was 11.5 years; about five percent of the bicyclists were five years of age or younger and about five percent were 16 years of age or older.

Problem Type 4 (3.6% Fatal; 2.5% Non-Fatal)

All Type 4 accidents occurred shortly after a bicyclist entered the roadway over a curb (74%) or shoulder (26%) at a mid-block location. Thirty-seven percent of the bicyclists stopped or slowed before entering the roadway; the remaining bicyclists made no attempt to slow their speed. As is shown in Figure 11, the bicyclist's pre-crash path was sometimes parallel to the roadway (42%) and sometimes perpendicular to it (58%). This type of accident most often occurred on a two-lane urban street (74%), but occasionally occurred on an urban street with more than two lanes (10%) or on a rural roadway (16%). Ninety-five percent of the accidents occurred during the daytime; 68% occurred between 3:00 PM and 6:00 PM.

The motorist's preview time was critically limited by visual obstructions in 41% of the cases; a parked motor vehicle was the most common type of visual obstruction. In 32% of the cases, the motorist observed the bicyclist well in advance and could easily have avoided the accident had he known that the bicyclist would enter the roadway. In the remaining 21% of the cases, the motorist failed to search in the bicyclist's direction and therefore failed to observe the bicyclist (clearly visible) until it was too late to avoid the accident.

The objects that obstructed the motorist's view also obstructed the bicyclist's view in many instances (26%), but in the majority of cases, the bicyclist made no attempt to search in the motorist's direction before entering the roadway (53%). Of the factors that were found to contribute to the bicyclists' function failures, 67% were found to be distractions of one type of another. A wide range of distractors were revealed by the data, but there was no single type of distractor that was clearly more important than any other.

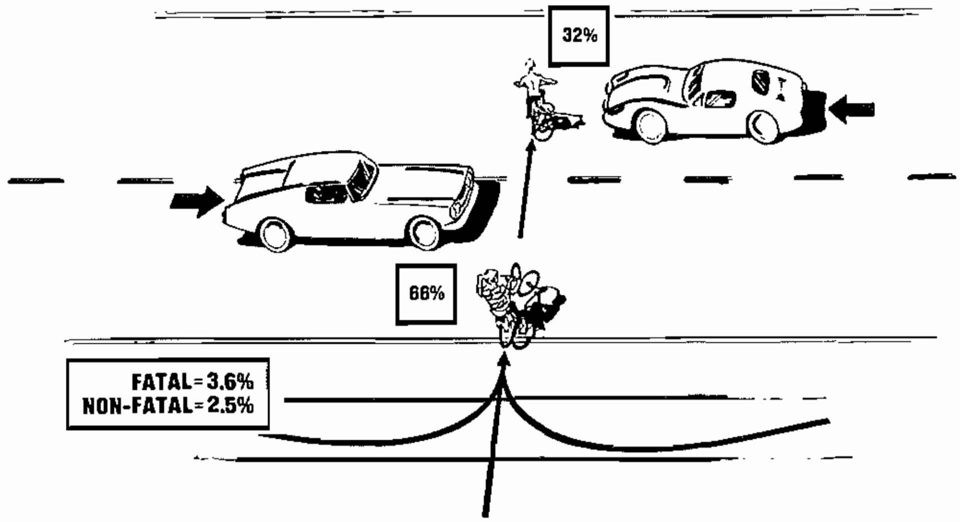


Figure 11. Illustration of Problem Type 4, *Bicycle Rideout: Entry Over Shoulder/Curb.*

Surprisingly, there were few bicyclists who reported that they were distracted by the act of riding over the curb or shoulder. It seems almost certain that most bicyclists' attention would be focused on the curb/shoulder they are preparing to ride over; the closer the bicyclist's position to the curb/shoulder, the more his scan would be directed downward. Thus, although not directly supported by the data, it seems reasonable to assume that the bicyclist's failure to search was often due, in part, to the distractions inherent in the act of riding over a curb or shoulder.

EDUCATIONAL COUNTERMEASURES FOR CLASS A PROBLEM TYPES

It seems clear that the education and training of motorists and bicyclists would prove effective in reducing the incidence of all four problem types within Class A. However, it is also possible that educating and training could prove effective for the parents of juvenile bicyclists, law enforcement officers, and bicycle-design engineers. The objectives of an education and training program for each of these groups is discussed briefly below.

Bicyclists

If education and training of bicyclists is to be effective in reducing Class A accidents, it must be administered at a very early age--preferably in kindergarten and certainly not later than the fourth grade. For instance, consider the age of the bicyclist for Problem Type 1. The data show that more than five percent of the Type 1 accidents involved bicyclists who were five years of age or younger, and 25% of the cases involved bicyclists who were younger than eight years of age. The age of the 5th and 25th centile bicyclist for the other three Class A problem types is only one or two years older than for Problem Type 1. Clearly, the requirement to impart, to very young children, the knowledge and skills necessary to avoid Class A accidents represents a formidable task.

There were very few instances in which a bicyclist rode into a motor vehicle's path because he misjudged the motor vehicle's approach velocity. Therefore, it seems reasonable to assume that most Class A accidents would be avoided if the bicyclist could be taught to stop at the edge of the roadway and search carefully for oncoming motor vehicles. In fact, substantial gains would probably be achieved if the bicyclist could merely be induced to stop at the junction or slow his speed considerably, thereby giving the motorist sufficient time to observe the bicyclist and initiate evasive action. To counter Class A accidents, an ideal educational program for young bicyclists would accomplish at least the following:

- Modify bicyclists' assessment of the risk associated with entering *any* roadway at *any* mid-block location.
- Teach the bicyclist to search for and recognize all types of visual obstructions and the exact behavioral sequence to follow when obstructing objects are present.
- Teach the bicyclist the importance of momentary distractions and how to cope with them.
- Teach the bicyclist the proper behavioral sequence when entering the roadway when visual obstructions are *not* present.
- Teach the bicyclist about the typical scan patterns of motorists in this traffic context.
- Teach the bicyclist to recognize his own lack of conspicuity even when clearly visible to an approaching motorist.

Motorists

This study revealed no indication that the motorists who were involved in Class A accidents were atypical in their skills or their concern for safety. Even so, it is possible that some accidents of this type could be avoided if the general motoring public was informed of the frequency with which Class A accidents occur, where they occur, and the reasons for which they occur. The main objectives of an education and training program for the general motoring public would be to:

- Modify motorists' search patterns in a manner that would increase the likelihood of detecting bicyclists who are riding on the sidewalk or in intersecting driveways.
- Modify motorists' expectations about bicyclists emerging from behind visual obstructions suddenly and without warning.
- Induce motorists to modify their speed and path through high-hazard areas.

Bicyclists' Parents

The education of parents of bicyclists in the target group could result in parents assuming more responsibility for the bicyclists' training and, more importantly, a greater degree of parental control of where and how young bicyclists are permitted to ride. Casual observation indicates that most parents generally recognize that riding a bicycle may be dangerous for very young children, but few parents appear to have a clear understanding of the types of locations where bicycle/motor-vehicle accidents occur or the types of bicyclist actions that most often lead to such accidents. It is altogether possible that misinformed parents may be giving their children instructions that are counterproductive. For instance, the instruction to "ride close to home" may cause the bicyclist to ride in an area that is less safe than available alternative areas.

The main objective of a parent-education program is to inform parents of the frequency with which Class A accidents occur, how they occur, and why they occur. If parents are to be effective in educating their children, they must have a clear understanding of the function failures and contributing factors that lead to an accident. It is particularly important that parents understand that quiet neighborhood streets and thorough familiarity with the area do not ensure the bicyclist's safety.

Law Enforcement Officers

Educating patrol officers about the importance of Class A accidents and the reasons for which they occur could prove useful in curtailing the behavior that leads to these types of accidents. That is, an understanding that many bicycle/motor-vehicle accidents occur as the bicyclist enters the roadway would increase the likelihood that an officer would observe and issue citations to bicyclists who enter the roadway in an unsafe manner. However, an education and training program for law enforcement officers must be preceded by the passage of ordinances that make unsafe entry into the roadway unlawful.

Bicycle Designers

A first step in the development of methods to increase the vertical dimension and conspicuity of bicycles would be to educate bicycle-design engineers about the need for such devices. Thus, persons who are involved directly or indirectly with bicycle design should be educated on the importance of Class A accidents and the nature of the accident-generation process for these types of accidents.

CLASS B PROBLEM TYPES: BICYCLE RIDEOUT--CONTROLLED INTERSECTION

Table 15 lists the problem types within Class B and shows the relative frequency with which they occurred. The distinguishing characteristic of all Class B problem types is that the bicyclist entered a controlled intersection in an unsafe and usually unlawful manner. In all Class B accidents, the motorist and bicyclist were traveling on orthogonal legs of the intersection.

TABLE 15

PROBLEM CLASS B--BICYCLE RIDEOUT: CONTROLLED INTERSECTION

		FATAL (N=166)	NON-FATAL (N=753)
TYPE 5	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGN	7.8%	10.2%
TYPE 6	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, SIGNAL PHASE CHANGE	.6%	3.1%
TYPE 7	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, MULTIPLE THREAT	2.4%	2.0%
OTHER CLASS B	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, OTHER	1.2%	1.7%
TOTAL CLASS (N: FATAL = 20; NON-FATAL = 128)		12.0%	17.0%

PROBLEM-TYPE DESCRIPTIONS

Problem Type 5 (7.8% Fatal; 10.2% Non-Fatal)

Problem Type 5 includes "bicycle rideout" accidents that occurred at a signed intersection. The approach leg traveled by the bicyclist was controlled by a "stop" sign in 96% of the cases and a "yield" sign in only four percent of the cases. The approach leg on which the motorist was traveling was uncontrolled, except for three percent of the cases which occurred at an intersection controlled by a four-way stop sign. Eighty-two percent of the bicyclists entered the intersection without slowing or stopping; 18% slowed significantly or stopped at the intersection before riding into the path of the oncoming motor vehicle. About six percent of the motorists were traveling at a speed that exceeded the posted limit, but in the remaining cases, the motorist's speed was judged to be well within the normal range.

Seventy-five percent of the cases occurred at the junction of a pair of two-lane streets. In 17% of the cases, the motorist was traveling on a four-lane street and the bicyclist was traveling on a two-lane street. The remaining cases occurred at the junction of a pair of four-lane streets (4%) or at the junction of a pair of two-lane rural roadways (4%). Most accidents occurred during the daytime (94%) and they occurred with about the same frequency throughout the period between 7:00 AM and 7:00 PM.

Figure 12 shows that 22% of the bicyclists were riding facing traffic prior to the accident. Riding facing traffic was an important contributing factor because it decreased the likelihood that the bicyclist would be detected by the motorist in this situation. But, the most critical factor was the bicyclist's failure to slow or stop at the junction. That is, riding facing traffic contributed to the accident only because the bicyclist failed to stop at the junction.

It can be seen in Figure 12 that almost two-thirds of the collisions occurred before the bicyclist reached the center of the roadway. This finding can be attributed to the fact that motorists approaching from the left, in the near traffic lane(s), have very little time to initiate evasive action once it becomes apparent that the bicyclist does not intend to stop. Motorists approaching from the right have more time to respond because the bicyclist must travel across an entire traffic lane before he intersects the motor vehicle's path.

Seven percent of the cases classified into Problem Type 5 were "multiple-threat" accidents--a variation of Problem Type 5 that is not portrayed in Figure 12. In these cases, a motorist observed the bicyclist and slowed or stopped to let him pass. The bicyclist observed the motorist slow or stop, assumed it was safe to cross the roadway, and proceeded into the intersection where he collided with a second motor vehicle. Every case of this type occurred in California where motorists are accustomed to yielding the right of way to pedestrians. Apparently, the motorists in these cases treated the bicyclist as a pedestrian rather than as a vehicle operator.

The motorist's view of the bicyclist was obstructed in about 31% of the cases--usually by vegetation. It was surprising to find that parked motor vehicles obstructed

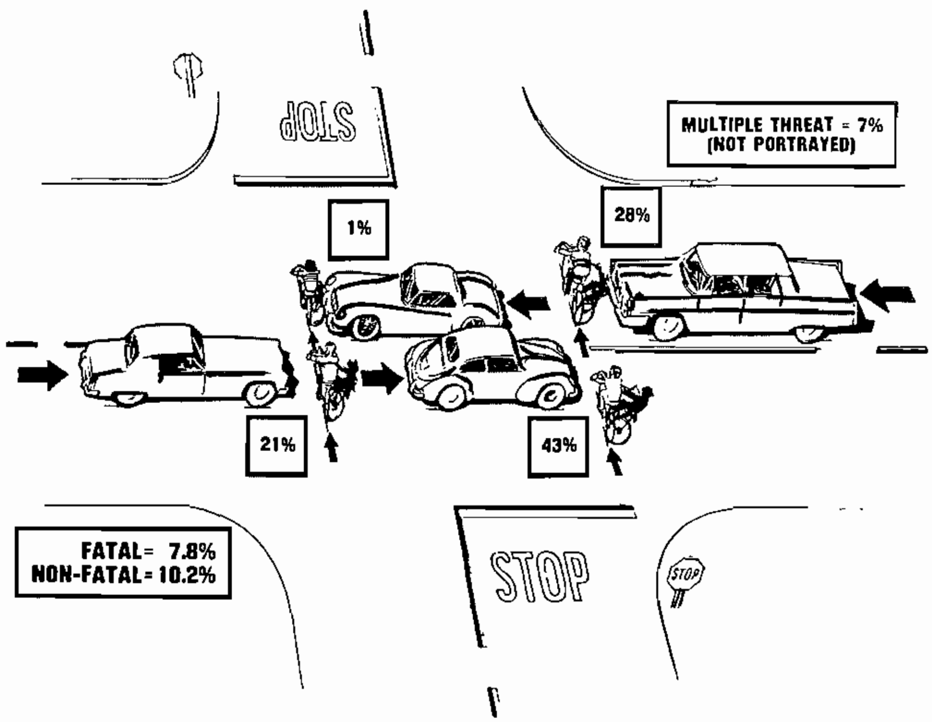


Figure 12. Illustration of Problem Type 5, *Bicycle Rideout: Intersection Controlled by Sign.*

the operator's view in only three percent of the cases. About five percent of the motorists failed to detect the approaching bicyclist because of darkness, inadequate bicycle lighting, or both. In all of the cases that involved obstructions or degraded visibility, it was judged that the motorist's preview time was critically limited and that the accident was imminent at the point at which the bicyclist could first have been observed/ detected.

The motorist had sufficient preview time to have avoided the accident in the majority of cases. The motorist failed to search in the direction of the bicyclist (clearly visible) in about 40% of the cases. The motorist's search failure was usually because he assumed that all intersecting traffic would yield the right of way to him, or because the bicyclist was riding in an unexpected location (wrong side of street). In 13% of the cases, the motorist observed the bicyclist soon enough to have avoided the accident, but failed to initiate evasive action because he assumed the bicyclist would slow, stop, or turn at the intersection.

The bicyclist's speed control at the intersection is a critical factor in explaining his role in Type 5 accidents. The classification of cases in terms of the bicyclist's speed control at the junction revealed the following variations or subtypes for Problem Type 5:

- Bicyclist stopped and concluded it was safe to proceed (13%),
  --Multiple treat (7%)
  --Other (6%)
- Bicyclist slowed significantly and concluded it was safe to proceed (5%), and

- Bicyclist failed to slow (82%).
  --*Attempted to stop but could not (7.8%)*
  --*No attempt to slow or stop (74%)*

The bicyclist's function failures are discussed for each of these variations of Problem Type 5.

First, consider the accidents in which the bicyclist stopped at the junction and concluded that it was safe to proceed (13%). More than half of these accidents were multiple-threat accidents (described above); the remainder involved a bicyclist who failed to search properly (3%) or who misjudged the motor-vehicle's approach speed (3%). Next, consider the cases in which the bicyclist slowed significantly and concluded it was safe to proceed (5%). These accidents were due to the bicyclist's failure to search effectively or his failure to take into account the presence of visual obstructions.

Finally, consider the accidents in which the bicyclist clearly failed to slow his speed. In 7.8% of the cases, the bicyclist *attempted* to stop at the junction but was unable to do so because of a skill deficiency, defective brakes, wet caliper brakes, wet pavement, or a combination of these. The bicyclist in these cases misjudged his ability to manipulate the brakes or misjudged stopping distance under the conditions that existed at the time of the accident. In 74% of the cases, the bicyclist made *no attempt* to stop or slow prior to entering the intersection. The interview data clearly show that the bicyclist's failure to stop or slow at the intersection was *not* the result of his failure to observe the stop sign. The accidents nearly always occurred at an intersection through which the bicyclist had ridden many times before the accident, so most bicyclists knew perfectly well that a sign was present at that location. Furthermore, it is clear that the bicyclist's failure to stop was not the result of ignorance of the law. Even the youngest bicyclist admitted knowing that the law requires bicyclists to stop for stop signs and to yield the right of way at intersections controlled by a yield sign. So, failure to observe traffic signs and ignorance of the law definitely are not important contributing factors for Problem Type 5.

Of the bicyclists who failed to slow or stop, it was judged that nearly 70% could have avoided the collision if they had searched in the direction of the motor vehicle prior to entering the intersection. In the remaining cases, because of the combined effects of the bicyclist's speed and an obstructed view, it was judged that the bicyclist could not have avoided the accident at the point where the motor vehicle first could have been observed. The bicyclist's failure to slow or stop and his failure to search must be explained in terms of the following factors:

- Operator distractions (41%),
  --*Interacting with riding companion or pedestrian (31%)*
  --*Play activity (3%)*
- Faulty expectations/assumptions (32%),
  --*Assumed area would be void of traffic (most cases probably)*
  --*Expected riding companion to select safe course (9%)*
- Competing needs (25%), and
  --*Need to conserve time (14%)*
  --*Need for excitement generated by high speed (7%)*
- Information overload (17%).

Although a variety of factors contributed to the bicyclist's failure to stop at the intersection, it appears that faulty risk assessment was an overriding factor in most cases. This opinion is based upon three facts. First, most accidents occurred at a relatively safe-appearing intersection; in most cases, the operators were traveling residential roadways on which both traffic volume and operator speeds were low. Secondly, most accidents occurred at an intersection that the bicyclist had ridden through many times before the accident--probably without stopping in many instances. Third, the bicyclists' self-ratings provided no indication that their actions were due to a high willingness to accept risks. For these reasons, it seems reasonable to assume that the overriding reason for most bicyclists' failure to stop was their expectation that the roadway would be void of traffic. Although few bicyclists admitted to this fact during the interviews, it is to be expected that bicyclists would be reluctant to report such an unrealistic expectation.

Although bicyclists of all ages frequently fail to stop or slow at signed intersections, Type 5 accidents nearly always involved a juvenile bicyclist. The median age of the bicyclists involved in this type of accident was 11.8 years; less than 25% of the bicyclists were older than 14 years of age and about five percent of the bicyclists were older than 18 years of age.

Problem Type 6 (.6% Fatal; 3.1% Non-Fatal)

All accident cases classified into Problem Type 6 occurred at a signalized intersection. Eighty-three percent of the accidents occurred as the bicyclist was crossing an intersecting street with four or more traffic lanes. Although the majority of these accidents occurred during the daytime, 17% occurred during darkness. About 70% of all Type 6 accidents occurred during the period between 1:00 PM and 7:00 PM.

The distinguishing characteristic of Problem Type 6 is that the bicyclist entered the intersection as the signal phase was changing and failed to clear the intersection before the signal turned red. In all cases, the motorist entered the intersection after the signal controlling his approach had turned green. Problem Type 6 does not include cases in which the bicyclist entered the intersection more than one or two seconds after the onset of the red-signal phase. In addition, Problem Type 6 does not include "multiple-threat" accidents. Multiple-threat accidents were classified into Problem Type 7 and are described below. As is shown in Figure 13, 38% of the collisions occurred before the bicyclist reached the center of the roadway he was crossing; the remaining 62% occurred in the second half of the roadway the bicyclist was crossing.

In 78% of the cases, the motorist failed to search in the bicyclist's direction until it was too late to avoid the accident. In the remaining cases, the motorist either (a) searched adequately but failed to detect the bicyclist because of darkness, inadequate bicycle lighting, or both (4%), or (b) searched for and detected the bicyclist soon enough to have avoided the accident but assumed the bicyclist would stop or slow before entering the motor vehicle's path (13%). The motorist's failure to search in the bicyclist's direction was due partly to his faulty assumption that all intersecting traffic would yield to him and partly to information overload. It is clear that the motorist's information-

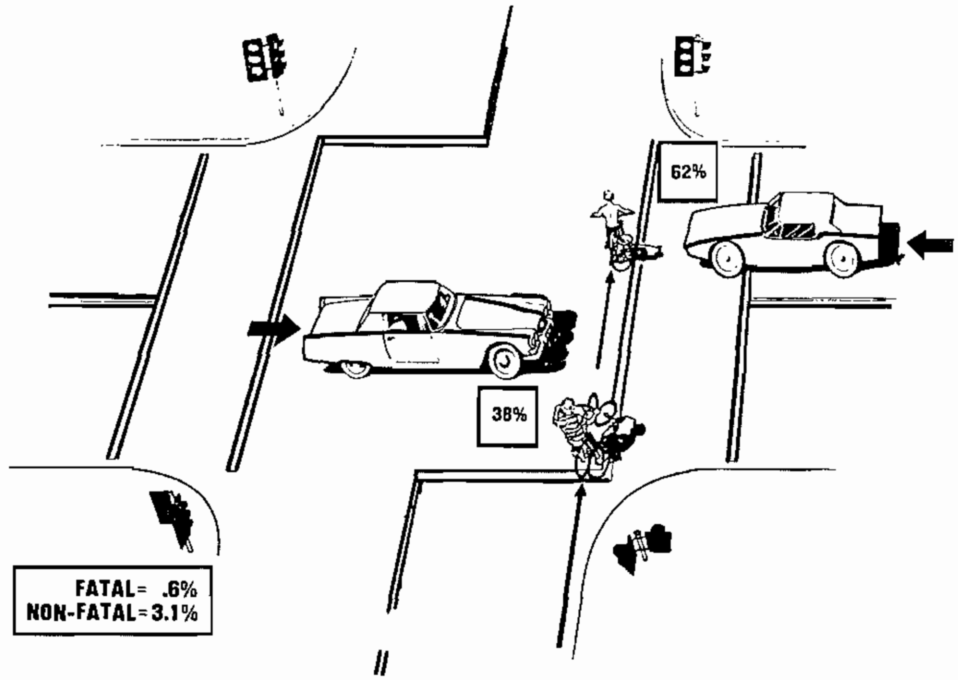


Figure 13. Illustration of Problem Type 6, *Bicycle Rideout: Intersection Controlled by Signal, Signal Phase Change.*

processing capacity was heavily loaded by the requirement to watch the signal, search for pedestrian and vehicle traffic, control the speed and position of his vehicle, and so on.

Nearly 57% of the bicyclists failed to search in the direction of the motor vehicle until an accident was imminent; 30% of the bicyclists observed the motor vehicle but assumed it would stop or remain stationary until the intersection was clear. Only four percent of the accidents were due to an action failure by the bicyclist. The evidence available for this problem type indicates that some bicyclists failed to stop at the intersection because they were unaware that the signal had changed since they last checked it. Other bicyclists knew that the signal had changed but assumed they could clear the intersection before the termination of the amber phase. However, because admitting to trying to beat the red light is more incriminating than admitting to a failure to notice the signal phase change, it is not possible to estimate accurately the relative proportion of the bicyclists who made each type of error. However, it was found that 16% of the bicyclists were following a riding companion whom they assumed would search for hazards and select a safe course.

Because of the complexity of the traffic context and the usually high speed of the bicyclist, it is assumed that information overload contributed to the bicyclist's failure to carefully monitor the traffic signal, to search for approaching traffic, or both.

The relatively low incidence of fatal accidents for Problem Type 6 is due to the low motor-vehicle speeds at impact. Because the collision occurred as the signal phase was changing, the motorist was either accelerating from a stopped position or, more commonly, had slowed to a low speed for the red signal and accelerated when the signal turned green a moment before the collision.

About half the bicyclists involved in Type 6 accidents were juveniles, and half were young adults or adults. The median age of the bicyclists was 16.1 years; about 15% were 18 years of age or older. Only five percent of the bicyclists were younger than 11 years of age. As a group, the bicyclists involved in Type 6 accidents were considerably older than those involved in any of the problem types discussed previously.

Problem Type 7 (2.4% Fatal; 2.0% Non-Fatal)

Problem Type 7 is highly similar to Problem Type 6 with respect to target location, target period, and the nature of the bicyclist's pre-crash course. Problem Types 6 and 7 differ in one important respect. For Problem Type 7, the bicyclist's decision to proceed across the intersection was influenced by the presence of other motor vehicles that were stopped at the intersection, apparently waiting for the bicyclist to pass. The nature of the accident-generation process for Problem Type 7 is illustrated in Figure 14. It can be seen that 14% of the accidents occurred in the first half of the roadway and involved a bicyclist who was riding facing traffic. The remaining 86% of the cases occurred in the second half of the roadway and involved a bicyclist who was riding on the correct side of the street. In all cases, the bicyclist passed in front of one or more stopped vehicles before colliding with the accident vehicle.

Standing motor vehicle(s) obstructed the motorist's view of the bicyclist in 53% of the cases. In these cases, there was no chance for the motorist to initiate successful

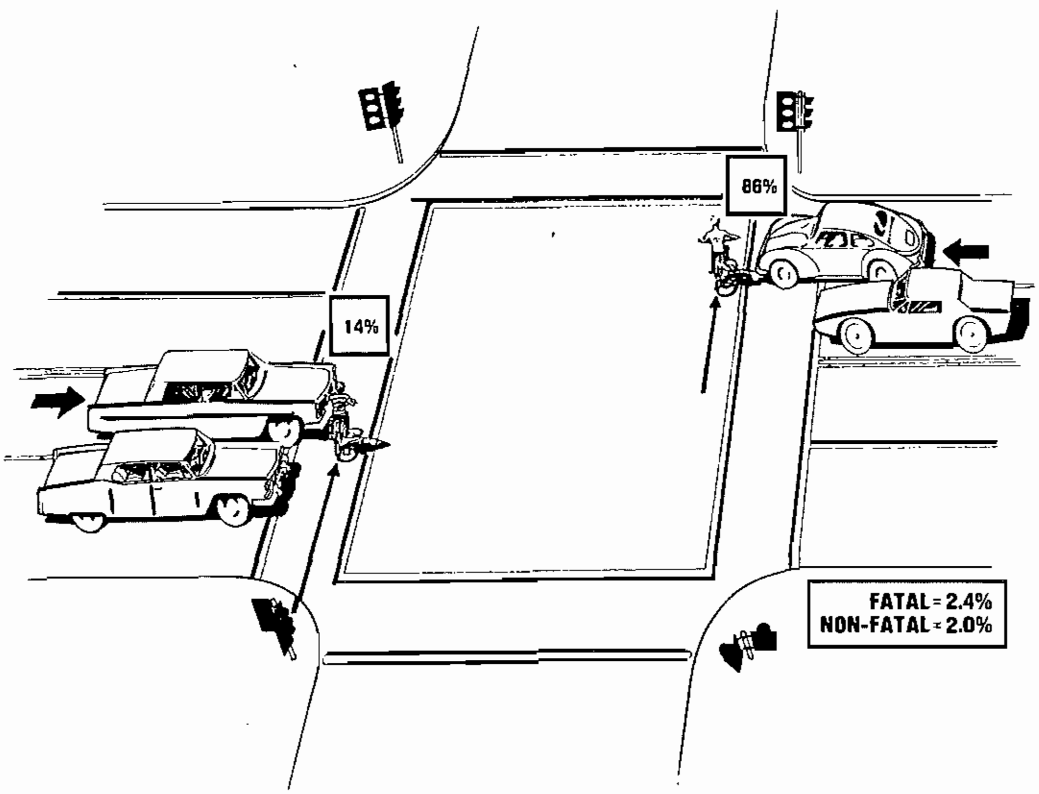


Figure 14. Illustration of Problem Type 7, ***Bicycle Rideout: Intersection Controlled by Signal, Multiple Threat.***

evasive action once the bicyclist emerged from behind the stopped vehicles. In 40% of the cases, it was judged that the motorist could have observed the approaching bicyclist, but he failed to search in the bicyclist's direction. In about seven percent of the cases, the motorist searched in the bicyclist's direction but failed to detect the bicyclist because of darkness, inadequate bicycle lighting, or both.

The standing motor vehicle(s) obstructed the bicyclist's view of the approaching motor vehicle in nearly 27% of the cases. Given the speed the bicyclist was traveling prior to the collision, it was judged that there was insufficient time to have avoided the accident once the bicyclist first could have observed the motor vehicle. In 40% of the cases, it was judged that the bicyclist could have observed the approaching motor vehicle early enough to have avoided the accident but failed to search in the direction of the motor vehicle until an accident was imminent. In about one-third of the cases, the motor vehicle was stopped at the intersection and was observed by the bicyclist long before the accident; the bicyclist proceeded with the assumption that the stopped vehicle would remain stationary until he had passed.

Unlike Problem Type 6, it was found that only 20% of the bicyclists underestimated the length of the amber phase. Most bicyclists were perfectly aware that the amber phase was about to terminate but assumed that all motor-vehicle traffic would remain stationary or yield to them.

The bicyclists age distribution for Problem Type 7 was similar to that for Problem Type 6. The median age of the bicyclists was 15.2 years; about 25% were 16 years of age or older. Only five percent of the bicyclists were younger than 12 years or older than 33 years of age.

Other Class B (1.2% Fatal; 1.7% Non-Fatal)

The sample contained a small number of cases in which the bicyclist entered a signalized intersection well after the onset of the red-signal phase. Because of the small number of such cases and because of the lack of commonality in the accident-generation process, it was not possible to define one or more clear-cut problem types for these cases. Therefore, the cases were classified into "Other Class B."

If the data base for bicycle/motor-vehicle accidents is expanded in the future, it is probable that at least three additional Class B problem types would be revealed. One type would include cases in which a bicycle failure or a skill deficiency prevented the bicyclist from stopping for the red signal. A second type would include cases in which the bicyclist was suffering from a physical or mental impairment (particularly alcohol) and therefore failed to monitor the signal carefully. A third type would include cases in which the bicyclist knowingly failed to stop at the intersection because he assumed he could successfully dodge or otherwise evade approaching motor vehicles. Examples of each of these types of accidents were found among the cases classified into "Other Class B." However, the findings of the present study indicate that such problem types would occur infrequently. The present data, and other samples of accident reports that have been examined by the author, indicate that few bicycle/motor-vehicle accidents occur when bicyclists enter an intersection when the signal is clearly red. Although most readers know that failing to stop for a red signal is not at all uncommon for bicyclists, the bicyclists who engage in this hazardous activity apparently exercise a good deal of caution when doing so.

EDUCATIONAL COUNTERMEASURES FOR CLASS B PROBLEM TYPES

The evidence is clear that Type 5 accidents seldom occur when the bicyclist stops or slows his speed significantly before entering an intersection controlled by a stop or yield sign. Although it is necessary for bicyclists to search for and evaluate the closing velocity of approaching motor vehicles, bicyclists usually perform the search and evaluation functions in an adequate manner when they consider it necessary to slow or stop at an intersection. Thus, a primary goal of countermeasures for Problem Type 5 is to induce bicyclists to slow their speed considerably or, preferably, come to a complete stop before entering a signed intersection. The other objective of countermeasures for Problem Type 5 is to teach bicyclists to avoid multiple-threat accidents at signed intersections.

The objective of countermeasures for Problem Types 6 and 7 is to prevent bicyclists from entering a signalized intersection when it is not possible for them to clear the intersection before the termination of the amber phase. An additional objective for Problem Type 7 is to teach bicyclists and motorists to avoid multiple-threat accidents at signalized intersections. The objective of countermeasures for Other Class B accidents is to prevent bicyclists from entering a signalized intersection against a red signal.

Bicyclists

A careful study of the accident-generation process for Problem Types 5, 6, and 7 shows that these accidents were seldom due to the bicyclist's willingness to accept an uncommonly high degree of risk, and were never due to the bicyclist's misunderstanding of the laws governing behavior at controlled intersections. Rather, the bicyclist's critical actions were primarily due to misjudgment of the risk associated with the critical action, misjudgment of the length of the amber phase, failure to recognize a "multiple-threat" situation, competing needs, and momentary distractions. Therefore, an educational program for bicyclists must be developed to accomplish the following objectives:

- Modify bicyclists' assessment of the risk associated with entering a signed intersection without slowing or stopping.
- Modify bicyclists' assessment of the risk associated with entering a signalized intersection during the amber phase.
- Teach bicyclists to search for and recognize all types of visual obstructions and the exact behavioral sequence to follow when obstructing objects are present.
- Teach bicyclists to recognize and cope with a "multiple-threat" situation at both signed and signalized intersections.
- Teach bicyclists the proper behavioral sequence when entering a controlled intersection when visual obstructions are *not* present.
- Teach bicyclists the importance of momentary distractions and how to cope with them.

If the education is to be received before a significant number of accidents already have occurred, education to curtail Type 5 accidents must be introduced during the second or third grade (7- or 8-year-old bicyclists). Education to curtail Types 6 and 7 accidents may be delayed until the fifth or sixth grade (10- or 11-year-old bicyclists) without sustaining significant losses.

Motorists

An education program that would serve to increase motorists' awareness of multiple-threat situations may prove beneficial in reducing multiple-threat accidents, particularly at signed intersections. Certainly, motorists in standing vehicles should be taught to always check for other approaching motor vehicles before motioning bicyclists to cross in front of them. It may be possible to develop a standardized hand signal or horn signal that motorists can use to inform bicyclists that it is *not* safe to pass. Also, some benefit may result from educating motorists that slow-moving bicyclists may not have enough time to clear the intersection during the amber phase.

CLASS C PROBLEM TYPES: MOTORIST TURN-MERGE/DRIVE THROUGH/DRIVEOUT

Problem Class C consists of five problem types that together accounted for 2.4% of the fatal cases and 18.7% of the non-fatal cases. The Class C problem types are listed in Table 16 along with the proportions of fatal and non-fatal cases classified into each problem type. All Class C accidents occurred as the motorist entered an uncontrolled roadway from a driveway, alley, or from a controlled leg of an intersection. Except for Problem Type 12, all the motorists stopped or slowed significantly at the junction before proceeding into the intersecting roadway. In nearly every case, the motorist entered the intersection without having observed the bicyclist who was approaching the junction. The motorist's failure to observe the bicyclist was often the result of the bicyclist's unexpected location--on the sidewalk or on the wrong side of the roadway. Many of the bicyclists involved in Class C accidents observed the motor vehicle soon enough to have avoided

TABLE 16

PROBLEM CLASS C--MOTORIST TURN-MERGE/DRIVE THROUGH/DRIVEOUT

	FATAL (N=166)	NON-FATAL (N=753)
TYPE 8 MOTORIST TURN-MERGE: COMMERCIAL DRIVEWAY/ ALLEY	---	5.3%
TYPE 9 MOTORIST TURN-MERGE/DRIVE THROUGH: INTERSECTION CONTROLLED BY SIGN	1.2%	10.2%
TYPE 10 MOTORIST TURN-MERGE: INTERSECTION CONTROLLED BY SIGNAL	---	1.9%
TYPE 11 MOTORIST BACKING FROM RESIDENTIAL DRIVEWAY	---	.8%
TYPE 12 MOTORIST DRIVEOUT: CONTROLLED INTERSECTION	1.2%	.5%
TOTAL CLASS (N: FATAL = 4; NON-FATAL = 141)	2.4%	18.7%

the accident, but failed to initiate evasive action because of the erroneous assumption that they had been or would be observed by the motorist.

The vast majority of collisions occurred shortly after the motorist accelerated from a stopped position. This fact accounts for the low incidence of fatalities for Class C accidents. When the motor vehicle struck the bicycle, the impact velocity was low and the bicyclist usually careened off the front of the motor vehicle. When the bicyclist struck the motor vehicle, the impact velocity was solely a function of the bicyclist's speed. Apparently, the bicycle speed was not often great enough to produce fatal injuries. Because of the low incidence of fatal accidents, Class C accidents must be considered less important than other types of accidents that account for fewer accidents but more fatal injuries.

PROBLEM-TYPE DESCRIPTIONS

Problem Type 8 (5.3% Non-Fatal; No Fatal)

All of the cases classified into Problem Type 8 occurred as the motorist was entering a roadway from a driveway that served one or more commercial establishments. In a slight majority of cases, the motorist was entering a street with four or more lanes (55%); most of the remaining cases occurred as the motorist was entering a two-lane street (40%). Only five percent of the cases occurred on a rural roadway. Ninety-three percent of the accidents occurred during the daytime; 88% occurred between 11:00 AM and 7:00 PM.

It was found that 82% of the motorists came to a complete stop at the roadway junction. Eighteen percent of the motorists slowed to a low speed when approaching the junction but failed to bring their vehicle to a complete halt before proceeding into the roadway. In every case of this type, the motorist failed to observe the approaching bicyclist even though it was judged that the search function was performed in a manner that would be considered normal for motorists in this situation. As is explained below, the reason for the motorist's failure to observe the bicyclist was found to differ somewhat for each of the subtypes illustrated in Figure 15.

- Bicyclist on sidewalk approaching from the right (32.5%)--It was found that the motorist's view of the bicyclist was obstructed in over half of these cases. In the remaining cases, the motorist failed to search far enough along the driveway to observe the approaching bicyclist. Apparently, the motorists searched in a manner that they considered adequate to detect aprpoaching pedestrians. That is, they judged that a pedestrian located more than a few feet from the driveway junction could not possibly arrive at the junction before they had passed, so considered it unnecessary to scan the sidewalk more than a few feet from the junction. Because of the search pattern of motorists in this situation, it is probable that the removal of visual obstructions would have little effect on the incidence of accidents of this type.

- Bicyclist on roadway approaching from the right (30%)--It was found that the motorist's view of the approaching bicyclist was obstructed in about 25% of the cases. In the remaining cases, the motorist failed to search in the bicyclist's direction because he did not expect a hazard to be approaching from that direction. This pattern was found to be particularly prevalent when the motorist was intending to make a right-hand turn. Again, it is unlikely that the removal of visual obstructions would effect a reduction in accidents such as these.

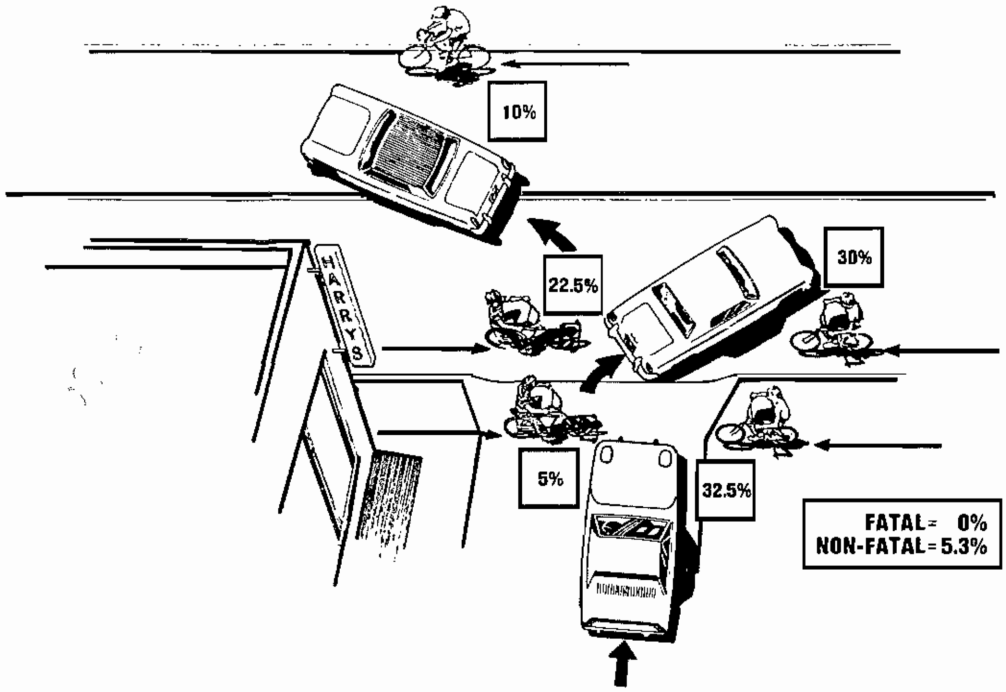


Figure 15. Illustration of Problem Type 8, *Motorist Turn-Merge: Commercial Driveway/Alley.*

(NOTE: The building was drawn in the above illustration to indicate that this type of accident occurs at the junction of a *commercial* rather than a residential driveway/alley. Although a building sometimes obstructed the operator's view in accidents of this type, buildings were not the most frequent type of obstructing object.)

- Bicyclist on sidewalk approaching from the left (5%)--This variation of Problem Type 8 occurred so infrequently that it is not possible to draw valid inferences about the reasons for the motorist's failure to observe the approaching bicyclist. However, it is probable that the reasons are the same as for the cases in the next paragraph.

- Bicyclist on street approaching from the left (22.5%)--In slightly over half of these cases, the motorist searched in the bicyclist's direction but failed to observe the bicyclist even though he was clearly visible and the lighting conditions were good. Apparently, the bicyclist's image appeared in the motorist's field of view (on motorist's retina) one or more times but was not consciously perceived. This phenomenon is sometimes referred to as "selective perception." In about one-fifth of the cases, the motorist's failure to detect the bicyclist was because of darkness, inadequate bicycle lighting, or both. In the remaining cases, the motorist failed to search in the bicyclist's direction. Surprisingly, not a single case was found in which the motorist's view of the bicyclist was obstructed.

- Bicyclist in far lane approaching from the right (10%)--This variation of Problem Type 8 occurred infrequently. However, in every case of this type, it was found that the motorist searched in the bicyclist's direction but failed to observe him. Only one-fourth of the cases of this type occurred at night and involved inadequate bicycle lighting. Judging from the characteristics of the traffic context in which accidents of this type occurred, it seems reasonable to assume that information overload and/or attentional conflict would be contributing factors in a substantial number of cases. Information overload is particularly likely in cases in which the motorist was attempting to turn left across a busy multiple-lane roadway.

The finding that fewer sidewalk accidents occurred when the bicyclist was approaching from the motorist's left is a significant finding. There is no reason to expect that bicyclists ride on the sidewalk in one direction more frequently than another, so it seems reasonable to conclude that accident likelihood is less when the bicyclist is traveling in the same direction as traffic in the adjacent traffic lane. The apparent reason for this finding is that motorists must search almost 90 degrees to their left in order to check for traffic that may be approaching in the near traffic lane. Since the bicyclist is often only a few feet from the traffic lane, he is likely to be detected, even though the motorist is mainly concerned with checking for approaching motor vehicles.

The bicyclist's preview time was critically limited by a visual obstruction in about 15% of the cases. In all but one of these cases, the bicyclist was riding on the sidewalk. In 25% of the cases, the bicyclist failed to search in the direction of the motorist until an accident was imminent. In 60% of the cases, the bicyclist observed the motor vehicle early enough to have easily avoided the accident but proceeded with the assumption that the motor vehicle would not enter the roadway until he had passed. Many of the bicyclists reported that they temporarily slowed their speed until they observed the motorist scanning in their direction. The eye contact with the motorist led the bicyclist to assume that he had been detected by the motorist when, in fact, he had not.

The data revealed that the bicyclist's decision to ride facing traffic was based upon convenience rather than ignorance of the law. Every bicyclist was questioned about this matter, and every bicyclist reported that he knew--before the accident occurred--that it is unlawful to ride facing traffic.

Problem Type 8 involved bicyclists whose ages varied widely. The median age of the bicyclists was 15.4 years. Only five percent were seven years of age or younger, and five percent were 49 years of age or older. About 50% of the bicyclists were between 13 and 17 years of age.

Problem Type 9 (1.2% Fatal; 10.2% Non-Fatal)

Problem Type 9 was one of the two most frequently occurring problem types, but only 1.2% of the fatal accidents were classified into this problem type. The reason for this large difference, as was explained earlier, is the generally low motor-vehicle speeds and resultant impact velocities for accidents that occur in this manner. The nature of the accident-generation process for Problem Type 9 is highly similar to that defined above for Problem Type 8. The main difference is that all the cases in Problem Type 9 occurred at a signed intersection rather than at the junction of a roadway and a commercial driveway. For Problem Type 9, the bicyclist approached the junction on an uncontrolled leg of the intersection, and the motorist approached the junction on an orthogonal leg that was controlled by a stop sign (97%) or a yield sign (3%). Accidents of this type occurred in both urban and rural areas and occurred on a variety of roadway types. The characteristics of the uncontrolled roadways are as follows: (a) a two-lane urban street (46%), (b) an urban street with more than two lanes (43%), (c) a two-lane rural roadway (8%), and (d) a rural roadway with more than two lanes (3%). This type of accident typically occurred during the daytime, but a significant number (17%) occurred during darkness. Ten percent of the accidents occurred between 7:00 AM and 9:00 AM, and another 66% occurred between 12:00 PM and 8:00 PM.

Ninety-four percent of the motorists came to a complete stop before entering the intersection, and 95% of the motorists entered the intersection without having observed the approaching bicyclist. When the motorist observed the bicyclist before entering the intersection, the accident occurred because the motorist misjudged the bicyclist's intended path. Usually, the motorist incorrectly assumed that the bicyclist was going to turn before intersecting the intended path of the motorist. The reasons for the motorist's failure to observe the bicyclist before entering the intersection are described below, within the context of the four subtypes illustrated in Figure 16.

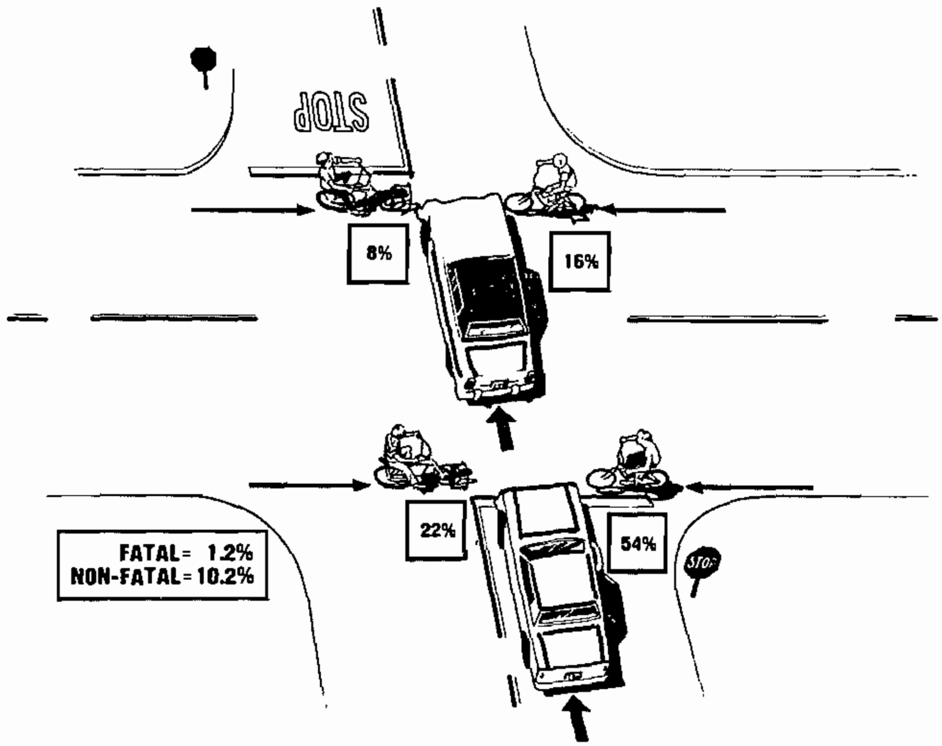


Figure 16. Illustration of Problem Type 9, ***Motorist Turn-Merge/Drive Through: Intersection Controlled by Sign.***

- Bicyclist in near lane(s), approaching from the right (54%)--Although not illustrated in Figure 16, about one-fifth of these cases involved a bicyclist who was riding on the sidewalk before entering the roadway. In the remaining cases, the bicyclist was in the roadway riding facing traffic. However, the reason the motorist failed to observe the bicyclist was the same for all of these cases; namely, the motorist failed to scan in the direction of the bicyclist because he did not expect a hazard to be approaching from that direction. In this context, the typical motorist searches to his right for traffic approaching in the far lanes and to his left for traffic approaching in the near lanes; motorists seldom search 90 degrees to their right because they have seldom, if ever, encountered a threat approaching from that direction.

- Bicyclist in near lane(s), approaching from the left (22%)--When the motorist failed to observe the bicyclist approaching from the left in the near lane, it was most often due to inadequate search or selective perception. However, about one-third of these cases occurred during darkness and involved a bicyclist with inadequate bicycle lighting.

- Bicyclist in far lane(s), approaching from the right (16%)--In these cases, the motorist's failure to observe the bicyclist was usually due to inadequate search, but about one-fourth of the cases occurred during darkness and involved a bicyclist with inadequate lighting.

- Bicyclist in far lane(s), approaching from the left (8%)--More than half of the accidents of this type occurred during darkness and involved a bicyclist with inadequate lighting. In the remaining cases, the motorist failed to search in the bicyclist's direction because he did not expect a hazard to be approaching from that direction.

In 13% of the cases, the bicyclist failed to search in the motorist's direction until it was too late to avoid the accident. The bicyclist proceeded through the intersection without searching because he knew he had the right of way and assumed vehicles on intersecting roadways would yield to him. However, in 83% of the cases, the bicyclist observed the motor vehicle soon enough to have easily avoided the accident. The bicyclist's failure to initiate evasive action was due to his faulty assumption that he had been or would be detected by the motorist, and that the motorist would remain stationary until he had passed through the intersection. Surprisingly, nearly all the bicyclists who were riding facing traffic observed the motor vehicle long before the collision. All of these bicyclists were aware that riding facing traffic was unlawful, but still assumed that they would be observed by the motorist. The faulty assumption that they would be detected by the motorist was also prevalent among bicyclists who were riding during darkness.

Problem Type 9 involved an older group of bicyclists than any problem type discussed previously. The median age of the bicyclists involved in this type of accident was 16.3 years, and few of the bicyclists were very young. For instance, it was found that less than five percent of the bicyclists were younger than ten years of age; slightly over 50% of the bicyclists were between 13 and 20 years of age.

Problem Type 10 (1.9% Non-Fatal; No Fatal)

Problem Type 10 occurred infrequently and is simple and straightforward to explain. In all cases of this type, the motorist came to a complete stop at a signalized intersection, searched for traffic approaching from the left in the near traffic lanes, and proceeded to make a right-turn-on-red. In every case, the motorist failed to observe the bicyclist before entering the intersection. Figure 17 illustrates that 85% of the Type 10 accidents involved a bicyclist who was riding facing traffic. The motorist failed to observe the bicyclist because he did not search in the bicyclist's direction. In 86% of the cases, the bicyclist observed the motor vehicle but proceeded through the intersection with the faulty assumption that he had been or would be detected by the motorist.

Although the sample size was too small to provide an accurate indication of the age distribution of bicyclists involved in Type 10 accidents, it was found that the small number of bicyclists who were involved in this type of accident varied in age from ten years

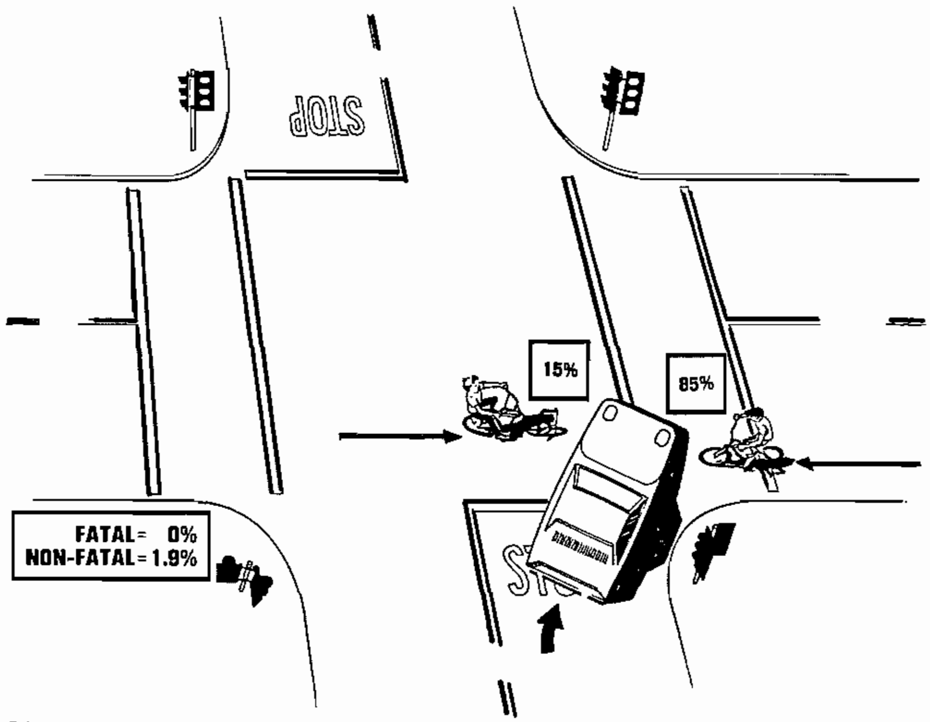


Figure 17. Illustration of Problem Type 10, *Motorist Turn-Merge: Intersection Controlled by Signal.*

to over 70 years of age. Very young bicyclists are probably involved in this type of accident only infrequently because they seldom ride in the types of locations in which such accidents occur.

Problem Type 11 (.8% Non-Fatal; No Fatal)

Accidents classified into Problem Type 11 occurred when a motorist backed from a residential driveway into the path of an approaching bicyclist (see Figure 18). All of the bicyclists were riding in the street, and only one bicyclist was riding facing traffic prior to the collision. The motorist's view of the bicyclist was degraded in every case. One-third of the accidents occurred during darkness; the motorist's view of the bicyclist was obstructed by vegetation or parked motor vehicles in all of the remaining cases.

One of the main reasons for including this problem type is to show the infrequency with which it occurs. Since bicyclists must encounter motor vehicles backing from residential driveways very often and since the motorist's view in this situation is often obstructed by external objects or parts of the motor vehicle's structure, one would expect that Type 11 accidents would occur quite frequently. However, the research findings showed that this type of accident occurs far less often than accidents in which motorists are exiting a driveway in a forward direction (Problem Type 8). Although the reason for this large difference is not known for certain, it seems reasonable to assume that bicyclists perceive backing vehicles as potential threats and seldom make the erroneous assumption that they have been detected by the driver of a backing vehicle. It is also possible that

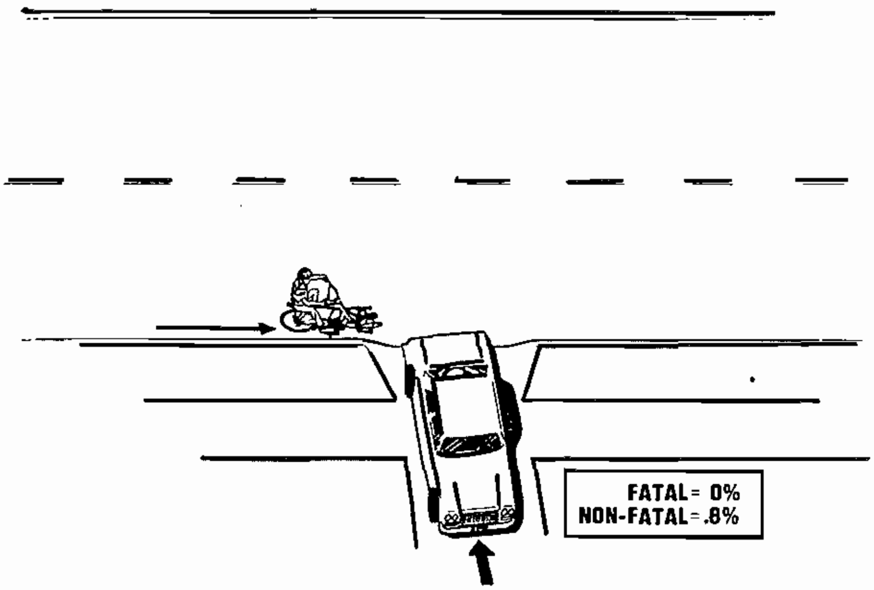


Figure 18. Illustration of Problem Type 11, *Motorist Backing from Residential Driveway.*

motorists recognize the hazardousness of this situation and exercise more caution when backing from a driveway than when exiting a driveway in a forward direction.

The age range of the bicyclists who were involved in Type 11 accidents varied from five to 25 years of age.

Problem Type 12 (1.2% Fatal; .5% Non-Fatal)

As is illustrated in Figure 19, Problem Type 12 occurred when the motorist passed through a stop sign without making any attempt to stop or slow. This type of accident occurred infrequently, but is likely to result in fatal injuries to the bicyclist when it does occur. No inferences can be made about the nature of the accident-generation process for this type of accident because of the small sample size. However, it is interesting to note that three out of four motorists in the non-fatal sample failed to observe the stop sign; the remaining motorist in the non-fatal sample was unable to stop because of faulty brakes. All of the fatal cases involved an intoxicated motorist.

EDUCATIONAL COUNTERMEASURES FOR CLASS C PROBLEM TYPES

Bicyclists

It was found that 52% of all Class C accidents involved a bicyclist who was riding on the wrong side of the roadway (riding facing traffic). Nearly all bicyclists are aware that riding facing traffic is unlawful, so there is no need to educate bicyclists about the law. Some persons have suggested that bicyclists should be taught the techniques that are required to ride facing traffic in a safe manner. However, it is unlikely that it would be possible to teach bicyclists techniques that would be as safe as riding on the

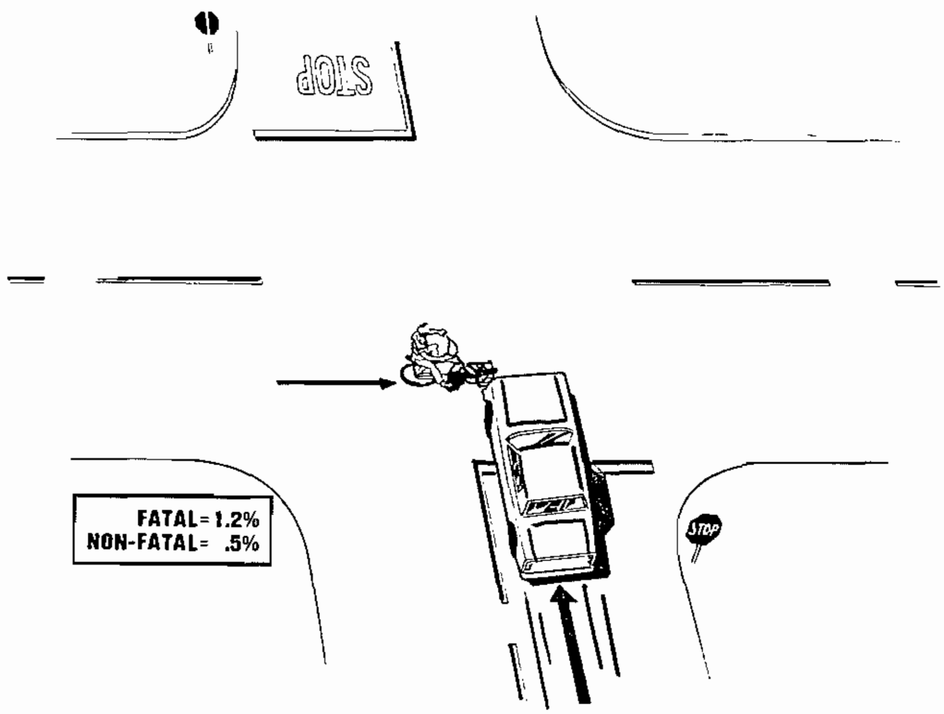


Figure 19. Illustration of Problem Type 12, *Motorist Driveout: Controlled Intersection.*

correct side of the roadway. Furthermore, it is probable that such training would serve to promote wrong-way riding and thereby increase the number of wrong-way riding accidents, even though the training reduced accident *rate* for this type of accident. For these reasons, it seems that the most effective alternative is to design a training program to curtail wrong-way riding. To be effective, the program must convince the bicyclists (and their parents) that riding facing traffic is a hazardous thing to do and that accident likelihood is increased greatly when a bicyclist chooses to ride on the wrong side of the roadway. At the same time, the bicyclists and their parents must be informed that riding on the correct side of the roadway will not lead to increased numbers of accidents if the bicyclist exercises reasonable caution in selecting where and when he will ride.

For every problem type in Class C, it was found that a large proportion of the bicyclists observed the motor vehicle early enough to have easily avoided the accident. This finding was the same regardless of the bicyclist's location and direction of travel. The relatively small number of cases in which the bicyclist failed to search in the motorist's direction were due mainly to the bicyclist's fundamental assumption that all intersecting traffic would yield to him. One means of preventing such accidents is to modify bicyclists' views about the infallibility of motorists. A safety-education program developed for bicyclists should teach them the typical search patterns of motorists in this type of traffic context, the limitations of the human visual system, and the types of accidents that occur because a motorist fails to observe a bicyclist that may be clearly visible. This information must be presented in a manner that will serve to modify bicyclists' assumptions that they have been or will be detected by motorists who are preparing to enter an uncontrolled roadway from a driveway or from a controlled leg of an intersection.

Many existing educational materials instruct both bicyclists and pedestrians to establish eye contact with a motorist before proceeding across a stopped motor-vehicle's path. This education is probably counterproductive; it suggests that the bicyclist or pedestrian can safely assume that he has been detected by the motorist if he has established eye contact. This is a clearly invalid assumption that led to a substantial proportion of Class C accidents.

Many bicycling experts advocate riding in the center of the traffic lane rather than along the right-hand edge of the roadway. They claim that riding in the center of the traffic lane increases the chances of being observed by motorists who are preparing to enter the roadway from intersecting streets or driveways. Also, they argue that riding in the center of the lane provides a greater buffer zone between the bicycle's path and the position at which motor vehicles stop before entering the roadway. Thus, riding in the center of the traffic lane provides additional time for the bicyclist to initiate evasive action once it becomes apparent that a motor vehicle is going to enter the roadway. It is believed that the following important questions must be answered before it is possible to recommend that bicyclists be taught to ride in the center of the traffic lane.

- Would riding in the center of the traffic lane increase the likelihood of detection by a margin that has practical significance?
- Would riding in the center of the traffic lane increase the bicyclist's preview time by a margin that has practical significance?
- How would traffic efficiency be affected if riding in the center of the traffic lane became a common practice?
- Should riding in the center of the traffic lane be prohibited on some types of roadways and/or during certain time periods? If so, what types of roadways and what time periods?
- Should young bicyclists and/or slow-moving bicycles be permitted to ride in the center of the traffic lane? If not, what is the cutoff age/speed?
- Would riding in the center of the traffic lane increase the incidence of other types of bicycle/motor-vehicle accidents or the incidence of accidents involving two motor vehicles?

Motorists

An education and training program for motorists has the potential for reducing the incidence of most problem types within Class C. The main objective of an education program would be to increase the effectiveness with which motorists search when entering uncontrolled roadways from driveways or from a controlled leg of an intersection. It is particularly important to modify the typical search patterns of motorists such that they make a concerted effort to scan for wrong-way bicyclists and for bicyclists riding on the sidewalk. When designing a training program for motorists, care must be taken to avoid promoting wrong-way riding. For instance, motorist-training materials developed for presentation on public television--and therefore observed by both motorists and bicyclists--should always include a message that stresses the danger and illegality of wrong-way riding.

CLASS D PROBLEM TYPES: MOTORIST OVERTAKING/OVERTAKING-THREAT

Class D includes five problem types that occurred when (a) a vehicle overtook and collided with a bicyclist traveling in the same direction, or (b) the threat of an overtaking motor vehicle caused the bicyclist to collide with an object that obstructed the path he would have taken if the obstruction had not been present. Class D does *not* include cases in which the bicyclist turned or swerved into the path of an overtaking motor vehicle.

Table 17 lists the problem types and subtypes for Class D and shows the proportion of fatal and non-fatal cases that were classified into each problem type and subtype. It can be seen in Table 17 that Class D accounted for nearly 38% of all fatal cases and that nearly one-fourth of all fatal accidents were classified into Problem Type 13. Since Class D accounted for only 10.5% of the non-fatal cases, it is clear that the likelihood of suffering fatal injuries is far higher for Class D accidents than for any other accident class. The high incidence of fatal injuries is mainly the result of the high speed of the motor vehicle on impact. About 45% of both the fatal and non-fatal accidents in Class D occurred in a rural area. It also was found that 56% of all rural accidents in the fatal sample and 31% of the rural accidents in the non-fatal sample were classified into Class D.

TABLE 17

PROBLEM CLASS D--MOTORIST OVERTAKING/OVERTAKING-THREAT

		SUBTYPE		TYPE	
		FATAL	NON-FATAL	FATAL (N=166)	NON-FATAL (N=753)
TYPE 13	MOTORIST OVERTAKING: BICYCLIST NOT OBSERVED			24.6%	4.0%
	■ RURAL NIGHTTIME	9.0%	1.3%		
	■ RURAL DAYTIME	5.4%	.4%		
	■ URBAN NIGHTTIME	8.4%	1.3%		
	■ URBAN DAYTIME	1.8%	1.0%		
TYPE 14	MOTORIST OVERTAKING: MOTOR VEHICLE OUT OF CONTROL			4.2%	.7%
TYPE 15	MOTORIST OVERTAKING: COUNTERACTIVE EVASIVE ACTION			2.4%	1.7%
TYPE 16	MOTORIST OVERTAKING: MOTORIST MISJUDGED SPACE REQUIRED TO PASS			1.8%	2.0%
TYPE 17	MOTORIST OVERTAKING: BICYCLIST'S PATH OBSTRUCTED			.6%	2.0%
	■ BICYCLIST COLLIDED WITH OVERTAKING MOTOR VEHICLE	.6%	.8%		
	■ BICYCLIST COLLIDED WITH OBSTRUCTING OBJECT	---	.4%		
	■ BICYCLIST COLLIDED WITH OPENING MOTOR-VEHICLE DOOR	---	.8%		
TYPE UNKNOWN	MOTORIST OVERTAKING: TYPE UNKNOWN			4.2%	.1%
TOTAL CLASS (N: FATAL = 63; NON-FATAL = 79)		25.2%	6.0%	37.8%	10.5%

PROBLEM-TYPE DESCRIPTIONS

Problem Type 13 (24.6% Fatal; 4.0% Non-Fatal)

Although seven other problem types occurred more frequently than Problem Type 13, this problem type must be considered one of the most important because it accounted for nearly one-fourth of all fatal accidents in the sample--three times as many as any other problem type. The distinguishing characteristic of Problem Type 13 is that the operator of the overtaking motor vehicle failed to observe the bicyclist until the vehicles were in such close proximity that successful evasive action was impossible. Fifty percent of the non-fatal accidents and 59% of the fatal accidents of this type occurred in a rural area. About three-fifths of the rural accidents and about one-half of the urban accidents occurred on a narrow, two-lane roadway with no ridable shoulder. Thus, about 60% of the Type 13 accidents occurred on a narrow, "rural-type" roadway with two traffic lanes and no ridable shoulder or sidewalk. This type of roadway context is depicted in the illustration of Problem Type 13 (see Figure 20).

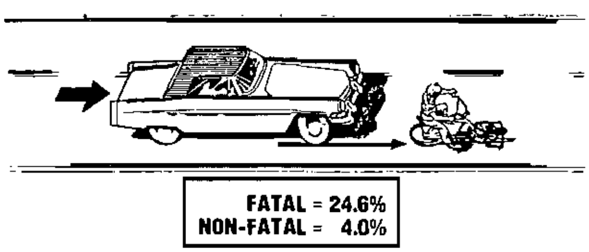


Figure 20. Illustration of Problem Type 13, *Motorist Overtaking: Bicyclist Not Observed.*

Problem Type 13 is the only problem type for which nighttime accidents were more frequent than daytime accidents. It was found that 63% of the non-fatal accidents and 71% of the fatal accidents occurred during darkness.

The exact position of the bicyclist and motorist at impact was difficult to determine with sufficient precision to know whether the bicyclist was traveling too far to the left or the motorist was traveling too far to the right. In about 20% of the cases, it was clearly established that the motorist was traveling farther to the right than he should have been. In the remaining cases, neither the motorist's position nor the bicyclist's position was judged to be clearly abnormal; it is probable that both operators were slightly out of position when the collision occurred.

The interviews revealed that bicyclists tend to ride farther from the right-hand edge of the roadway during darkness than during the daytime. Because of the combined effects of darkness and inefficiency of the bicycle headlight (if any), bicyclists are unable to detect and dodge road-surface defects and debris that often are present along the extreme edge of the roadway. To avoid such hazards, bicyclists ride farther to the left where the roadway is usually swept clean by the draft of motor-vehicle traffic. Because of this practice, it is probable that most of the bicyclists involved in nighttime accidents on narrow roads were riding farther to the left than is safe on such roadways.

Since Problem Type 13 includes only the overtaking accidents in which the motorist failed to observe the bicyclist until too late to avoid the accident, the main question about this problem type concerns the reasons for the motorist's failure to observe the bicyclist. In nearly every case, the motorist's failure to observe the bicyclist was the result of one or more of the following factors: darkness, inadequate bicycle lighting, alcohol use by the motorist, and operator distractions. Since vehicle speeds are usually considerably faster on rural than on urban roadways, the type of location can also be considered a contributing factor for this problem type. The reasons for the motorist's failure to search can be most meaningfully described by subdividing Problem Type 13 into the following subtypes:

- Rural nighttime (9% fatal; 1.3% non-fatal). For this subtype, the motorist's failure to observe the bicyclist must be explained in terms of the relatively high speed of the motor vehicle, darkness, inadequate bicycle lighting, and alcohol use by the motorist. It is interesting to note that one-third of the fatal accidents of this type involved a motorist who had been drinking; none of the non-fatal accidents involved an intoxicated motorist.

- Rural daytime (5.4% fatal; .4% non-fatal). The motorist's failure to observe the bicyclist must be explained in terms of high motor-vehicle speeds, alcohol use by the motorist, and search failures by the motorist due to momentary distractions. Again, it is of interest to note that one-third of the fatal cases, but none of the non-fatal cases, involved an intoxicated motorist.

- Urban nighttime (8.4% fatal; 1.3% non-fatal). The factors contributing to the motorist's failure to search in this situation are essentially the same as for rural nighttime accidents, except that high motor-vehicle speed is not a factor. Like rural nighttime accidents, urban nighttime accidents often involved alcohol use by the motorist. An intoxicated motorist was involved in 43% of the fatal cases and eight percent of the non-fatal cases.

- Urban daytime (1.8% fatal; 1.0% non-fatal). This subtype occurred so infrequently that it is not possible to draw valid inferences about the motorist's failure to search. However, it is almost certain that the motorist's attention was temporarily distracted from the roadway ahead shortly before the collision.

The above findings can be summarized by saying that it is dangerous to ride in rural areas at any time and it is dangerous to ride during darkness at any location, but accident likelihood is increased even more when riding in a rural area during darkness.

It is interesting to note that about 60% of the bicyclists who were involved in nighttime accidents had lawful taillights on their bicycles when the accident occurred. This finding suggests that the standards that have been established for bicycle rear reflectors are inadequate under some circumstances. In establishing standards for taillights, the question is not how far away a motorist can observe the rear reflectors under optimal conditions, but what is required to attract a motorist's attention under non-optimal conditions. For instance, what type of taillight would be required to attract the attention of a fatigued drunk driver who is traveling at a relatively high speed on a rural roadway where he does not expect to encounter a bicyclist? It is probable that this type of accident will continue to occur until a device is developed that will increase the nighttime conspicuity of the bicycle to such an extent that the previously described motorist will detect and identify the bicyclist most of the time.

Few young bicyclists were involved in Type 13 accidents. For example, it was found that the age of the 5th centile bicyclist in the fatal and non-fatal samples was 12.9 years and 11.2 years, respectively. Apparently, bicyclists younger than 11 or 12 years of age are not permitted to ride during darkness and in the types of areas where Type 13 accidents occur. The median age was 18.3 years for the bicyclists in the non-fatal sample and 20.5 years for bicyclists in the fatal sample.

Problem Type 14 (4.2% Fatal; .7% Non-Fatal)

Problem Type 14 includes overtaking accidents that occurred because the motorist was unable to maintain control of his vehicle. The illustration of Problem Type 14, shown in Figure 21, is somewhat misleading in its suggestion that the motor vehicle was in an uncontrolled slide or spin prior to the collision. Although the motor vehicle was totally out of control in some cases, more often the motor vehicle veered too far to the right due to the motorist's inability to maintain precise control of the vehicle.

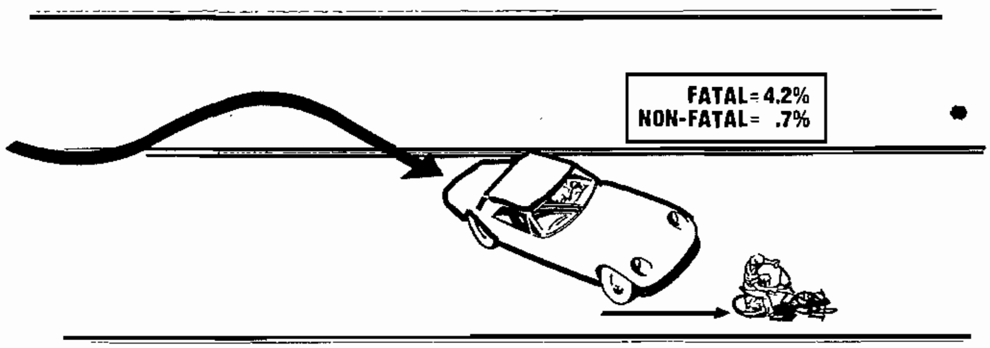


Figure 21. Illustration of Problem Type 14, *Motorist Overtaking: Motor Vehicle Out of Control.*

Alcohol use by the motorist was the main contributing factor in 71% of the fatal cases and 40% of the non-fatal cases. In these cases, it was judged that the motorist's capability was impaired to such an extent that he was unable to steer the vehicle along his intended path. These accidents would have occurred whether or not the bicyclist had been observed by the motorist. In the remaining cases, loss of control was due to vehicle failure, snow and ice on the roadway, or a prior collision with another motor vehicle. It might be expected that accidents of this type would occur most often on narrow roadways where the space is marginally adequate for both motor vehicles and bicycles. However, it was found that 86% of the fatal cases and all of the non-fatal cases occurred on an urban street with more than two traffic lanes. Although the preponderance of accidents on wide roadways may be an artifact due to the small number of Type 14 accidents in the sample, it seems safe to conclude that limited roadway width is not an important contributing factor for Problem Type 14. Twenty-nine percent of the fatal accidents and 40% of the non-fatal accidents occurred during darkness, but degraded visibility was not judged to be a contributing factor. The higher incidence of Type 14 accidents during darkness is simply because the number of intoxicated motorists on the roadway is greater at night than during the daytime.

The number of cases classified into Problem Type 14 was too small to define a bicyclist target group, but it seems reasonable to conclude that involvement in this type of accident would be totally independent of the age of the bicyclist. The small number of bicyclists involved in this type of accident varied in age from six to 17 years.

Problem Type 15 (2.4% Fatal; 1.7% Non-Fatal)

Problem Type 15 includes overtaking accidents that resulted from both operators misjudging the direction of the other operator's evasive action. In the typical case, the motorist observes the bicyclist ahead, riding close to the center of the traffic lane. As the motorist approaches the bicyclist from the rear, he honks his horn and swerves left to pass the bicyclist. Upon hearing the horn (or the sound of the overtaking motor vehicle in some cases), the bicyclist evades to the left with the assumption that the motor vehicle is going to pass on the right. In short, the bicyclist's evasive action counteracts the evasive action taken by the motorist. Although Figure 22 shows both operators evading to the left, there were some accidents of this type that occurred when both operators evaded to the right.

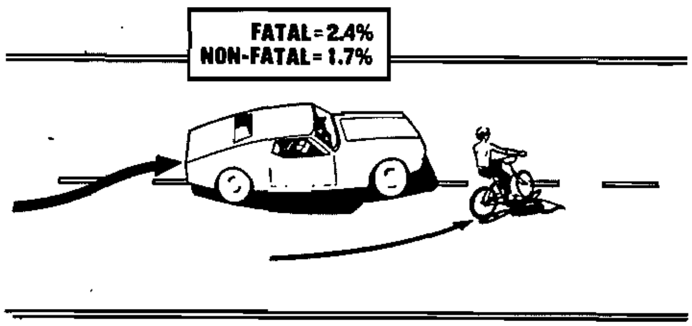


Figure 22: Illustration of Problem Type 15, *Motorist Overtaking: Counteractive Evasive Action.*

More than three-fourths of the accidents of this type occurred in a rural area on a two-lane roadway (52%) or on a roadway with more than two lanes (25%). The remaining 23% of the accidents occurred on a two-lane urban street. All accidents classified into Problem Type 15 occurred during the daytime between noon and 8:00 PM.

This type of accident usually involved a juvenile bicyclist. The median age of the bicyclists was 12.3 years, and fewer than five percent were older than 16 years of age. Slightly over five percent of the bicyclists were younger than six years of age.

Problem Type 16 (1.8% Fatal; 2.0% Non-Fatal)

An overtaking accident was classified into Problem Type 16 only when there was clear evidence that the accident resulted from the motorist's misjudgment of the space required to overtake and pass the bicyclist. As is shown in Figure 23, the bicyclist usually was struck by the extreme right-front portion of the motor vehicle. In 13% of the cases, the motorist misjudged the space and time required to scan behind and change lanes before closing on the bicyclist riding ahead. These accidents could easily have been avoided if the motorist had slowed his speed before scanning behind to determine if it was safe to change lanes. In the remaining cases, the motorist observed the bicyclist ahead and incorrectly concluded that there was sufficient space to overtake and pass the bicyclist without changing lanes. In some cases, the motorist was temporarily prevented from changing lanes; in other cases, the motorist could have changed lanes but did not deem it necessary to do so.

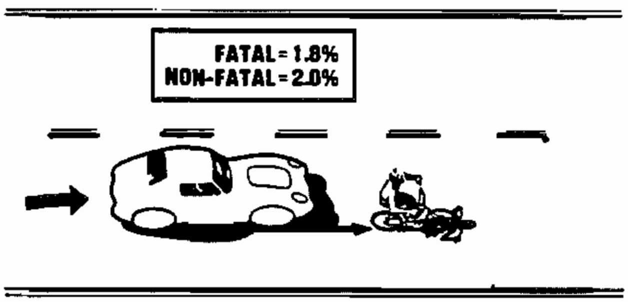


Figure 23. Illustration of Problem Type 16, ***Motorist Overtaking: Motorist Misjudged Space Required to Pass.***

Type 16 accidents occurred on a variety of roadways, including: an urban two-lane street (29%), an urban street with more than two lanes (29%), a rural two-lane roadway (29%), and a rural roadway with more than two lanes (13%). All Type 16 accidents occurred during the daytime.

The age of the bicyclists involved in Type 16 accidents varied widely. The median age of the bicyclists for this problem type was 15 years; about five percent were younger than nine years of age and five percent were older than 42 years of age. Older motorists are clearly overrepresented in this problem type. It was found that 25% of the motorists were older than 66 years of age and five percent were older than 86 years of age.

Problem Type 17 (.6% Fatal; 2.0% Non-Fatal)

The distinguishing characteristic of Problem Type 17 is that the bicyclist was confronted simultaneously with the threat of an overtaking motor vehicle and an object that obstructed the path that he otherwise would have followed. Reference to Figure 24 shows that the bicyclist in this situation sometimes collided with the overtaking motor vehicle and sometimes collided with the obstructing object. In 40% of the cases, the bicyclist collided with the overtaking motor vehicle while swerving around an obstruction in his path (parked motor vehicle, roadway defect, pole, etc.). The motorist in these accidents observed the bicyclist but misjudged the magnitude of the bicyclist's turn to the left. In 20% of the cases, the bicyclist collided with the rear of a parked motor vehicle that obstructed his path. Many accidents involving a parked motor vehicle probably go unreported.

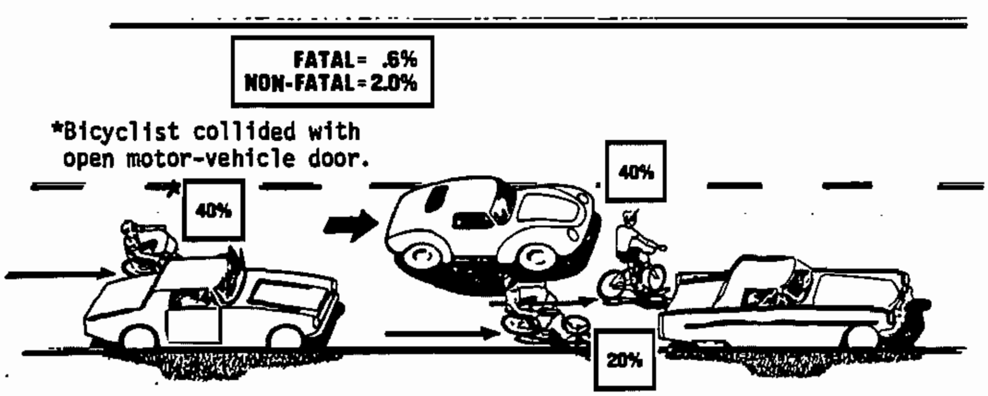


Figure 24. Illustration of Problem Type 17, ***Motorist Overtaking: Bicyclist's Path Obstructed.***

Forty percent of the Type 17 accidents occurred when the occupant of a parallel-parked motor vehicle opened the left-hand door into the bicyclist's path. Although some motorists reported that they searched to the rear for traffic, none observed the bicyclist prior to the collision. Similarly, the bicyclist failed to observe that the parked motor vehicle was occupied. The relative frequency with which bicycles collide with an opening motor-vehicle door may be higher in some areas than was found in this study. In an unreported study by the author, 931 traffic accident report forms from areas within five different states were studied. It was found that car-door-opening accidents accounted for 2.6% of all reported bicycle/motor-vehicle accidents. However, the frequency with which this type of accident occurs was found to vary widely from one area to another. For instance, in a sample of 220 reports from Washington, D. C., it was found that 6.4% of all reported bicycle/motor-vehicle accidents were car-door-opening accidents. Conversely, not a single car-door-opening accident was found among a sample of 184 bicycle/motor-vehicle accidents that occurred in Fairfax County--an area located only a few miles from Washington, D. C. Based upon the information presently available, it is estimated that car-door-opening accidents account for between two and four percent of the accidents that occur in urban areas. The percentage would probably be highest in the central business districts where the number and turnover of parallel-parked motor vehicles is high.

Most Type 17 accidents occur in urban areas; 57% occur on an urban two-lane street and 29% on an urban street with more than two lanes. Only 14% occurred on a rural roadway. All accidents of this type occurred during the daytime.

Surprisingly, few very young bicyclists were involved in this type of accident. The median age of the bicyclists was 16.3 years; only five percent were younger than nine years of age. The interquartile range for Problem Type 17 accidents was 12.9 years to 23.2 years.

Motorist Overtaking, Type Unknown (4.2% Fatal; .1% Non-Fatal)

In 4.2% of the fatal cases and .1% of the non-fatal cases, the information on the traffic accident report form was sufficient to establish that the accident was an overtaking accident but was not sufficient to determine the motorist's function failure and, therefore, the specific problem type into which the case should be classified. About half of the accidents occurred at night and about half occurred in rural areas. From the information that was available for these accidents, it is probable that most of them would have been classified into Problem Type 13. If this assumption is correct, the proportion shown in Table 17 for fatal accidents represents an underestimate of the frequency with which Type 13 fatal accidents occur.

EDUCATIONAL COUNTERMEASURES FOR CLASS D PROBLEM TYPES

Bicyclists

With only a few exceptions, there is little that a bicyclist can be taught that would help him avoid Class D accidents once he has decided to ride where and when such accidents are most likely to occur. As a consequence, the primary objective of an education and training program for bicyclists should center on modifying the bicyclist's choice of where and when he will ride. Until more effective rear-lighting systems are available, bicyclists should be taught to minimize the amount of night riding they do on any type of roadway, but particularly night riding on rural roadways. Bicyclists must also be taught to be highly selective in choosing the type of rural roadways they will ride on, regardless of the lighting conditions that prevail at the time of their trip. Specifically, bicyclists should be taught to avoid riding on any type of rural roadway unless operating speeds are low and a ridable shoulder is present.

Ideally, bicyclists could be taught to monitor overtaking motor vehicles using a rear-vision device and to always evade to the shoulder when overtaking motor vehicles are observed. Although most overtaking accidents in rural areas would be avoided if bicyclists could be induced to follow this procedure, it is unrealistic to expect them to do so as a common practice. Such a procedure would become so tiresome that all the pleasure would be lost from bicycle touring.

Bicyclists must be taught to recognize situations in which the space is so limited that a motorist's misjudgment of the width of his vehicle might result in an overtaking accident. In some instances, the bicyclist can slow his speed enough that the motor vehicle and bicycle do not arrive at a bottleneck at the same moment. When traffic is heavy and the lateral space is limited for some distance, little can be done other than to avoid riding in such areas. Similarly, bicyclists should receive special instructions on how to behave when they must ride to the left of objects that obstruct the path along the right-hand edge of the roadway. When the street is narrow and there are many parked cars along its length, bicyclists should be taught to search the parked cars for occupants who may open the left-hand door of the parked motor vehicle.

In some instances, it may be safer to ride in the center of the traffic lane than to attempt to anticipate an opening motor-vehicle door. However, as was stated earlier, considerable study is required before it can be recommended that bicyclists be taught to ride in the center of the traffic lane.

Bicyclist's Parents

The objective of parental education would be to induce parents to prohibit their children from riding their bicycles in rural areas at any time, during darkness in any location, and on any type of roadway for which operating speeds are high and space is limited. Essentially, the parents should receive the same type of education as the bicyclists.

Motorists

It is unlikely that any type of training would increase the likelihood that motorists will observe bicyclists under the circumstances in which Type 13 accidents occur. However, it is possible that motorist training would serve to decrease the incidence of accidents that result from a motorist's misjudgment of the space required to overtake and pass a bicyclist and accidents that occur when a motorist opens the left-hand door of his motor vehicle into the path of a bicyclist.

CLASS E PROBLEM TYPES: BICYCLIST UNEXPECTED TURN/SWERVE

All the accident cases classified into Problem Class E occurred when a bicyclist--suddenly and without warning--turned or swerved into the path of an overtaking motor vehicle or a motor vehicle approaching from directly ahead of the bicyclist. The cases within Class E were classified into four problem types that together accounted for 16.2% of the fatal cases and 14.2% of the non-fatal cases. Table 18 lists the descriptive titles for the Class E problem types and shows the proportion of fatal and non-fatal cases classified into each problem type.

TABLE 18

PROBLEM CLASS E--BICYCLIST UNEXPECTED TURN/SWERVE

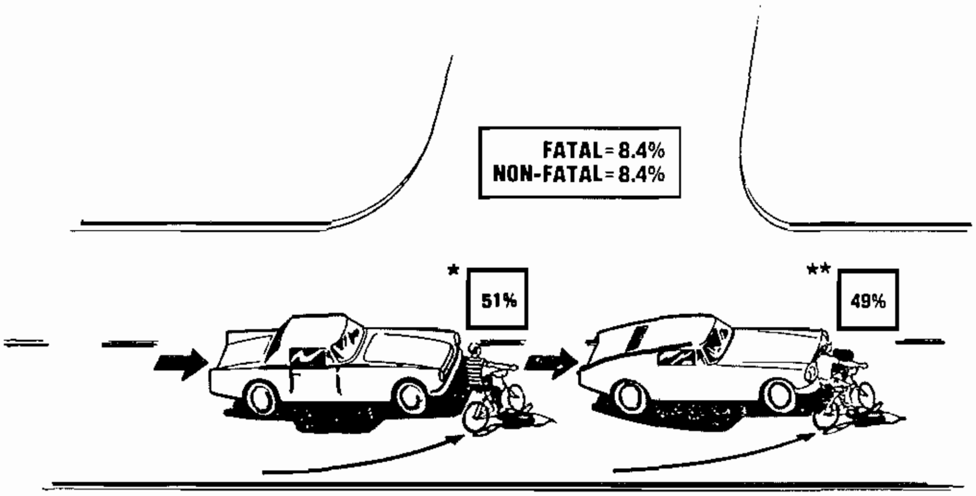
		FATAL (N=166)	NON-FATAL (N=753)
TYPE 18	BICYCLIST UNEXPECTED LEFT TURN: PARALLEL PATHS, SAME DIRECTION	8.4%	8.4%
TYPE 19	BICYCLIST UNEXPECTED LEFT TURN: PARALLEL PATHS, FACING APPROACH	3.0%	3.2%
TYPE 20	BICYCLIST UNEXPECTED SWERVE LEFT: PARALLEL PATHS, SAME DIRECTION (UNOBSTRUCTED PATH)	3.6%	1.5%
TYPE 21	WRONG-WAY BICYCLIST TURNS RIGHT: PARALLEL PATHS	1.2%	1.1%
TOTAL CLASS (N: FATAL = 27; NON-FATAL = 107)		16.2%	14.2%

PROBLEM-TYPE DESCRIPTIONS

Problem Type 18 (8.4% Fatal; 8.4% Non-Fatal)

Problem Type 18 is one of the most important problem types, both in terms of frequency of occurrence and injury severity. Every Type 18 accident occurred when a bicyclist suddenly turned left into the path of an overtaking motor vehicle. About one-half of the bicyclists turned left at the junction of a roadway or driveway, and the remaining bicyclists initiated their turn at a point that was *not* in close proximity to any type of junction. (This finding is illustrated by the two sets of vehicles shown in Figure 25.) Problem Type 18 does not include cases in which the bicyclist lost control of his bicycle and inadvertently swerved left.

About one-half of the accidents occurred on a two-lane urban street and about 30% occurred on a two-lane rural roadway. The remaining 20% occurred with about equal frequency on urban and rural roadways with more than two lanes. Only seven percent of the fatal and two percent of the non-fatal accidents occurred during darkness, so degraded visibility is seldom a factor in accidents of this type. The apparent reason for the low



*Bicyclist turned at junction.

**No junction nearby.

Figure 25. Illustration of Problem Type 18, *Bicyclist Unexpected Left Turn: Parallel Paths, Same Direction.*

incidence of nighttime accidents is that bicyclists can detect the headlights of overtaking motor vehicles without searching to the rear.

In 92% of the cases, it was judged that the motorist observed the bicyclist far enough in advance to have easily avoided the accident. The motorist failed to initiate any type of evasive action because he had no idea that the bicyclist intended to turn. A search failure by the motorist was found in slightly less than five percent of the cases. Conversely, a search failure by the bicyclist was evident in 94% of the cases. In the remaining six percent of the cases, the bicyclist was aware of the overtaking motor vehicle but incorrectly assumed there was sufficient time to cross the roadway before the approaching motor vehicle arrived.

It was known from pilot studies that accidents of this type occur frequently, so the Field Investigators were instructed to make a special attempt to determine *why* bicyclists fail to search behind before initiating a left turn. Although the interviews revealed a variety of different factors that may have contributed to the bicyclist's failure to search, it is believed that the most important contributing factors simply were not revealed by the interviews. Knowledge of the locations at which Type 18 accidents typically occur and informal discussions with many different bicyclists have led the author to the tentative conclusion that bicyclists often fail to search behind because they assume an overtaking motor vehicle can be heard if it is near enough to pose a threat. Some accidents may occur because the sound of the overtaking motor vehicle is masked by other auditory stimuli. Wind noise, conversations with riding companions, and the noise generated by motor vehicles approaching in the opposing lane are examples of common noises that may serve to mask the sound of an overtaking motor vehicle. The interview data indicated that other accidents may occur when a bicyclist hears an overtaking motor vehicle but misjudges its proximity or its approach velocity. However, whether the sound of the overtaking motor vehicle is masked or misinterpreted, the fundamental error is a total reliance on auditory cues.

A probable secondary factor contributing to the bicyclist's failure to search concerns the degree of skill and effort required to search 180 degrees to the rear while maintaining lateral control of the bicycle. Searching to the rear without losing control of the bicycle is difficult under the best of circumstances, but is even more difficult when the bicyclist must simultaneously rotate the head and tilt it forward as is required when riding a bicycle with dropped handlebars. When riding a bicycle with dropped handlebars, many bicyclists look *under* their left arm when searching to the rear. This action requires the head to be tilted down about 90 degrees from vertical and rotated about 45 degrees to the left. Consequently, when searching to the rear, the vestibular mechanism is placed in a highly unusual position, and the signals from the vestibular system are equally unusual. Pilots of high-performance aircraft know that placing the head in an unusual position (tilting and/or rotating) while undergoing even moderate "g" forces creates unusual vestibular signals that, in turn, cause instant vertigo. It is hypothesized that bicyclists experience the same type of problems as aircraft pilots, only less severe.

In summary, it is believed that bicyclists are reluctant to search behind because it is difficult to do so. The reluctance to search behind has led bicyclists to rely on auditory cues to detect overtaking motor vehicles whenever possible. When bicyclists are traveling a roadway with heavy and continuous traffic, they recognize the necessity to search behind before turning left. However, when traveling a roadway with light and/or sporadic traffic, they believe that auditory cues are adequate to detect overtaking motor vehicles and consider it safe to turn left when they fail to hear the sound of a nearby motor vehicle. Although auditory cues are reliable in most situations, there are some circumstances in which the sound of the overtaking motor vehicle is masked or distorted. It is in these situations that bicyclists turn left into the path of an overtaking motor vehicle.

In about six percent of the Type 18 accidents, the bicyclist did search to the rear before turning but failed to observe the overtaking motor vehicle or misjudged its speed. In several cases, the motor vehicle that collided with the bicyclist was masked from view by another motor vehicle. The bicyclist searched behind and observed the lead vehicle, searched in a forward direction until it had passed, and turned into the path of the second (trailing) motor vehicle.

At least three percent of the Type 18 accidents resulted from one bicyclist "blindly" following another. The lead bicyclist searched to the rear and correctly judged that he had enough time to turn left and clear the roadway before an overtaking motor vehicle arrived. Without searching to the rear, the trailing bicyclist followed the lead bicyclist--assuming that it was safe to turn. Although the trailing bicyclist turned shortly after the lead bicyclist initiated his turn, the lag time was great enough to place the trailing bicyclist on a collision course with the overtaking motor vehicle. Because bicyclists may be reluctant to admit that they were blindly following a lead bicyclist, it is probable that this behavior was a factor in more Type 18 accidents than was revealed by the interview data.

Most of the bicyclists who were involved in Type 18 accidents were juveniles. The median age of the bicyclists was 12.7 years; five percent of the bicyclists were younger than seven years of age and 75% were 14 years of age or younger.

Problem Type 19 (3.0% Fatal; 3.2% Non-Fatal)

Like Problem Type 18, Problem Type 19 includes cases in which the bicyclist suddenly turned left into the path of the motorist. However, Problem Type 19 includes only the cases in which the bicyclist turned into the path of a motor vehicle approaching from straight ahead. Functionally, the most important differences between Problem Types 18 and 19 are the ease with which bicyclists can perform a search for the approaching motor vehicle (straight ahead vs. straight behind) and the amount of time the motorist has to respond once the bicyclist initiates his left-hand turn.

Although it might be assumed that Type 19 accidents would occur most often on busy multiple-lane roadways, it was found that only 17% of the cases occurred on a roadway with more than two lanes. The remaining cases occurred on either a two-lane urban roadway (58%) or a two-lane rural roadway (25%). It was found that 96% of the accidents classified into Problem Type 19 occurred during the daytime.

Figure 26 shows that only three-fourths of the bicyclists initiated their left-hand turn at a point that was in close proximity to a roadway or driveway junction. In the remaining cases, there was no junction of any kind near the point at which the bicyclist initiated his turn. The bicyclists in Figure 26 are shown turning from a point close to the right-hand edge of the roadway. Although such turns were most typical, the data show that about 29% of the bicyclists initiated their turn from a point close to the center of the roadway. Contrary to expectations, the bicyclists who were riding close to the center of the roadway prior to initiating their turn were *not* on a multiple-lane roadway.

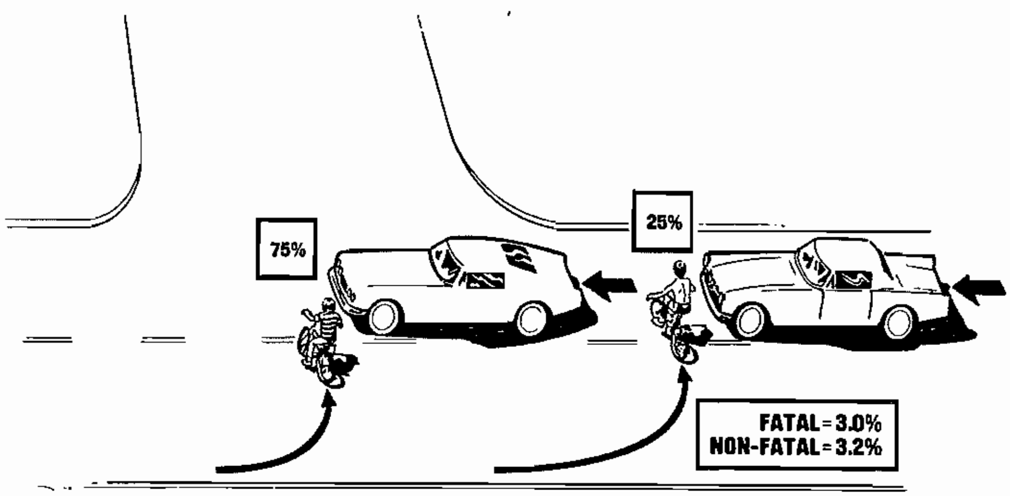


Figure 26. Illustration of Problem Type 19, *Bicyclist Unexpected Left Turn: Parallel Paths, Facing Approach.*

(NOTE: Most, but not all, bicyclists initiated their left-hand turn at a point close to the right-hand edge of the roadway.)

Despite the fact that the motor vehicle was approaching from directly ahead and was clearly visible to the bicyclist, it was found that at least 75% of the bicyclists failed to search in the direction of the motor vehicle until an accident was imminent. The proportion of search failures would probably have been higher, but the bicyclist's function failure could not be confidently established in 12% of the cases. Surprisingly, not a single case was found in which the bicyclist observed the motor vehicle but misjudged its approach velocity. The bicyclist's search failure was most often due to operator distractions. The types of distractions that most often contributed to the bicyclist's search failure include: Interacting with riding companion (41%), vehicles/pedestrians considered an accident threat (24%), and game playing (12%). In another 12% of the cases, it was found that the bicyclist's failure to search was due to his faulty assumption that a riding companion would search for hazards and select a safe course.

About 70% of the motorists observed the bicyclist before he initiated his turn. Because of the narrowness of the roadway and the bicyclist's high-angle turn, it was judged that only about 10% of the motorists who were searching in the bicyclist's direction had sufficient time for evasive action once the bicyclist initiated his turn. These motorists failed to initiate evasive action because they assumed the bicyclist would slow or stop before entering the motor vehicle's path. Twelve percent of the motorists failed to search in the direction of the bicyclist. In eight percent of the cases, the motorist's view of the bicyclist was temporarily obstructed by a moving vehicle.

Knowledge of the bicyclist's behavior in this situation would suggest that Type 19 accidents would most often involve very young bicyclists. Although young bicyclists were most frequently involved, half the bicyclists were older than 13 years of age and 25% were older than 18 years of age. The median age of the bicyclists was 13.8 years and five percent were younger than seven years of age.

Problem Type 20 (3.6% Fatal; 1.5% Non-Fatal)

Problem Type 20 includes accidents in which the bicyclist inadvertently swerved left and collided with an overtaking motor vehicle. Figure 27 shows the bicyclist swerving into the path of an overtaking motor vehicle, but some bicyclists swerved into the side of the motor vehicle. Accidents of this type occurred on urban two-lane streets (46%), urban streets with more than two lanes (27%), and on rural two-lane roadways (27%). Every case classified into Problem Type 20 occurred during the daytime.

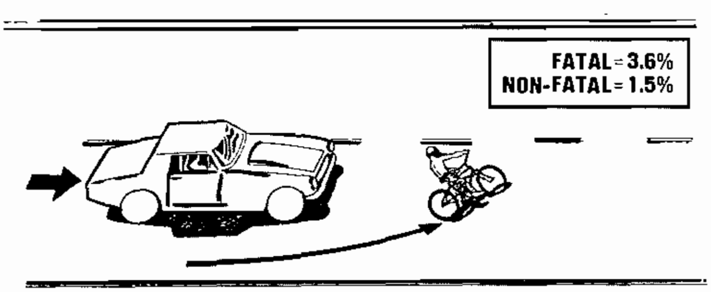


Figure 27. Illustration of Problem Type 20, *Bicyclist Unexpected Swerve Left: Parallel Paths, Same Direction (Unobstructed Path).*

The most frequent reason for the bicyclist's inadvertent swerve was a prior collision with a curb (25%) or another bicycle (17%). Vehicle failures, operator skill deficiencies, and roadway-surface defects were each found to be a contributing factor in about 17% of the cases. In nearly every case, the motorist observed the bicyclist well in advance but had insufficient time to avoid the accident once the bicyclist swerved.

Accidents of this type seldom involved adult bicyclists. The median age of the bicyclists for Problem Type 20 was 11.5 years. Only five percent of the bicyclists were older than 17 years of age; 75% of the bicyclists were between 8.5 and 15.1 years of age.

Problem Type 21 (1.2% Fatal; 1.1% Non-Fatal)

Problem Type 21 includes accidents in which a bicyclist who had been riding facing traffic suddenly initiated a right-hand turn into the path of an approaching motor vehicle. Figure 28 shows the bicyclist turning into the path of a motor vehicle approaching from the opposite direction. Although most accidents occurred in this way, Problem Type 21 also includes accidents in which the bicyclist crossed the first half of the roadway and collided with an overtaking motor vehicle in the second half. However, only one case was found that occurred in this manner. Seventy-five percent of the accidents occurred on a two-lane urban street, and all Type 21 accidents occurred during the daytime.

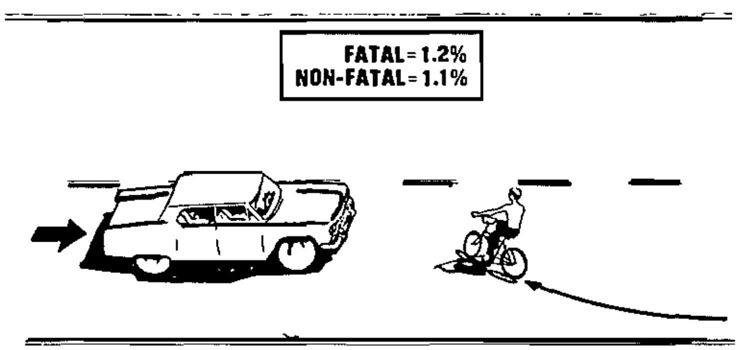


Figure 28. Illustration of Problem Type 21, *Wrong-Way Bicyclist Turns Right: Parallel Paths.*

In one case, it was found that the bicyclist's view of the oncoming motor vehicle was obstructed by a parked vehicle. In the remaining cases, the bicyclist failed to search in the motorist's direction because of a momentary distraction. In most cases, the bicyclist was distracted by another person with whom he was riding (57%). Other distractors contributing to the bicyclist's search failure include abnormal functioning of the bicycle (14%), riding an unfamiliar bicycle (14%), and riding a bicycle that was too large for the bicyclist (14%).

Except for the one case in which the bicyclist emerged suddenly from behind a parked motor vehicle, the motorist observed the bicyclist soon enough to have avoided the accident if he had been able to anticipate the bicyclist's intention to turn.

The bicyclists involved in Problem Type 21 varied in age from seven to 13 years. The sample was too small to obtain a reliable estimate of the centiles.

EDUCATIONAL COUNTERMEASURES FOR CLASS E PROBLEM TYPES

Bicyclists

A study of Class E accidents suggests two types of education and training for bicyclists. First, education and training is needed to increase the bicyclist's propensity to search--both ahead and to the rear--and to signal prior to turning across the roadway. An important part of this training involves convincing bicyclists that auditory cues alone are not sufficient to signal the presence of an overtaking motor vehicle. Specifically, bicyclists should be taught that they should be alert to auditory cues but not to assume the absence of a motor vehicle because one cannot be heard. Because distractions often contributed to the bicyclist's search failure, bicyclists should be taught the importance of momentary distractors and how to overcome them.

It is possible that the bicyclist's reluctance to scan to the rear can be overcome by training. Expert bicyclists claim that, through proper training, bicyclists can become quite proficient at scanning to the rear without veering. However, before such training is introduced on a large-scale basis, it would be necessary to conduct research to determine the type of training that is best and the extent to which proficiency at this task can be increased through training the target population for Class E accidents.

Finally, when effective rear-vision devices become available, bicyclists should be taught how and when to use such devices.

Motorists

It is possible that some benefit would be derived from an education and training program designed to inform motorists of the frequency with which Class E accidents occur and to modify motorists' assumptions that a bicyclist will search and signal before initiating his turn. Certainly, motorists should be taught to give the bicyclist as wide a berth as possible when overtaking and passing. However, because of the suddenness of the bicyclist's turn, it is unlikely that such training would result in a substantial decrease in accidents of this type.

CLASS F PROBLEM TYPES: MOTORIST UNEXPECTED TURN

Problem Class F includes accidents that occurred when a motorist turned into the path of a bicyclist approaching from the motorist's front or rear. In nearly every case, the motorist failed to observe the bicyclist before initiating his turn--usually because the bicyclist was riding in an unexpected location. In some cases, the bicyclist failed to observe the turning motor vehicle until the accident was imminent. In most cases, however, the bicyclist observed the motor vehicle and either failed to anticipate the motorist's turn or incorrectly assumed that the motorist would delay his turn until the intersection was clear. As is shown in Table 19, Problem Class F accounted for 2.4% of the fatal cases and 14.5% of the non-fatal cases. The three problem types within Class F differ in terms of the motorist's direction of turn and the bicyclist's position and direction of travel relative to that of the motorist.

TABLE 19

PROBLEM CLASS F--MOTORIST UNEXPECTED TURN

	FATAL (N=166)	NON-FATAL (N=753)
TYPE 22 MOTORIST UNEXPECTED LEFT TURN: PARALLEL PATHS, SAME DIRECTION	.6%	1.3%
TYPE 23 MOTORIST UNEXPECTED LEFT TURN: PARALLEL PATHS, FACING APPROACH	---	7.6%
TYPE 24 MOTORIST UNEXPECTED RIGHT TURN: PARALLEL PATHS	1.8%	5.6%
TOTAL CLASS (N: FATAL = 4; NON-FATAL = 109)	2.4%	14.5%

PROBLEM-TYPE DESCRIPTIONS

Problem Type 22 (.6% Fatal; 1.3% Non-Fatal)

Problem Type 22 includes accidents in which the motorist turned left into the path of a bicyclist approaching from the left-rear of the motor vehicle. Figure 29 shows that accidents of this type occurred in two distinctly different ways. In 60% of the cases, the bicyclist was traveling in the same direction and in the same lane as the motor vehicle. As the motor vehicle slowed in preparation for a left-hand turn, the bicyclist overtook and collided with the turning motor vehicle. In the remaining cases, the

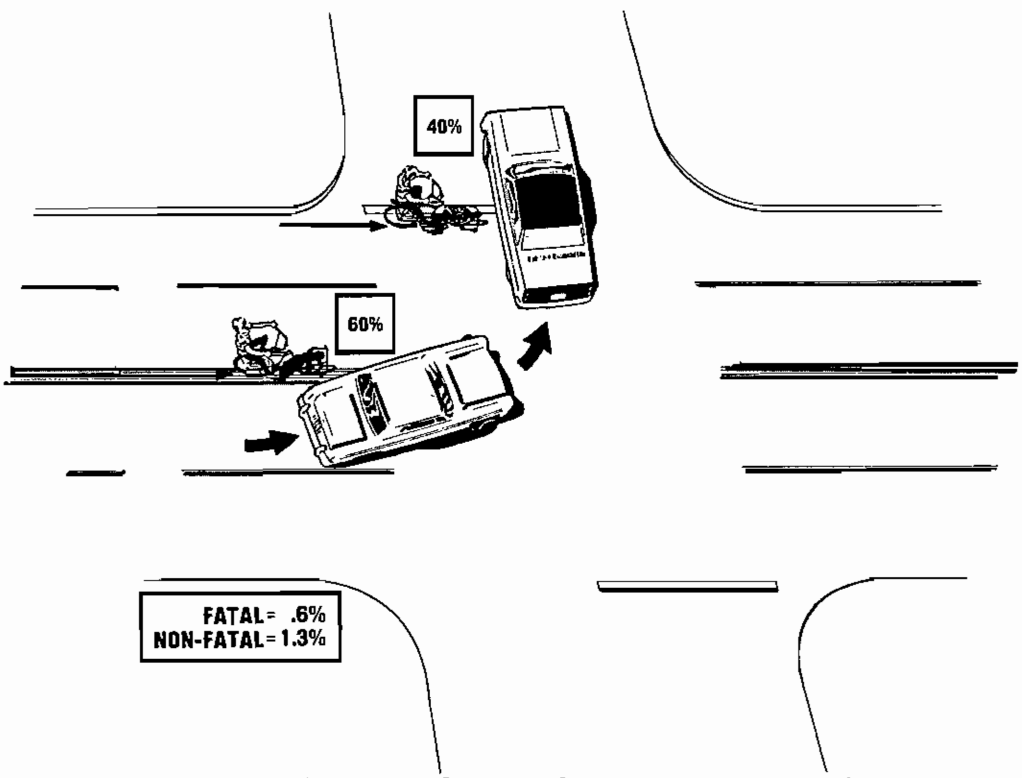


Figure 29. Illustration of Problem Type 22, *Motorist Unexpected Left Turn: Parallel Paths, Same Direction.*

bicyclist was riding facing traffic along the left-hand edge of the roadway prior to the collision.

Twenty percent of the accidents of this type occurred on a two-lane rural roadway. The accidents that occurred in an urban area occurred with equal frequency on a two-lane street and on a street with more than two lanes. Although 30% of the accidents occurred during darkness, darkness was judged to be a contributing factor in only one case. In all other cases, the bicyclists were riding in a location that was not searched by the motorist. That is, it was judged that the accident would have occurred even if the lighting conditions had been optimal.

In 90% of the cases, the motorist failed to search in the bicyclist's direction before initiating his turn because he simply did not expect a threat to be approaching from that direction. Thirty percent of the bicyclists also failed to search and consequently failed to observe the motor vehicle until it was too late to avoid the accident. All the search failures were committed by the wrong-way-riding bicyclists. In the remaining cases, the bicyclist observed the motorist early enough to have avoided the accident. The bicyclist's failure to initiate evasive action upon observing the motor vehicle was due to his failure to anticipate the turn or his assumption that he had been detected by the motorist and that the motorist would yield to him.

The median age of the bicyclists involved in Type 22 accidents was 15.9 years; fewer than five percent were younger than 12 years of age. Conversely, 25% of the bicyclists were older than 23.5 years of age.

Problem Type 23 (7.6% Non-Fatal; No Fatal)

Problem Type 23 includes cases in which the motorist turned left into the path of a bicyclist approaching from the opposite direction. Specific subtypes of Problem Type 23 are as follows:

- Intersection, bicyclist in street (68%),
- Intersection, bicyclist rode off sidewalk (7%),
- Driveway/alley junction, bicyclist in street (16%), and
- Driveway/alley junction, bicyclist on sidewalk (9%).

Only three problem types accounted for more non-fatal cases than Problem Type 23; yet, not a single Type 23 accident was found among the fatal sample. Figure 30 shows that 86% of the bicyclists were riding legally in the roadway prior to the accident; the remaining bicyclists had been riding on the sidewalk before entering the junction where the collision occurred.

Sixty percent of the accidents classified into Problem Type 23 occurred on an urban street with four or more lanes; 39% occurred on a two-lane urban street. Only four percent of the accidents occurred in a rural area. Accidents of this type occurred at a significant rate throughout the period between 6:00 AM and 11:00 PM; 13% of the accidents occurred during darkness.

The operator's view was obstructed by vegetation (bicyclist on sidewalk) or moving motor vehicles in only six percent of the cases, so visual obstructions clearly are not an

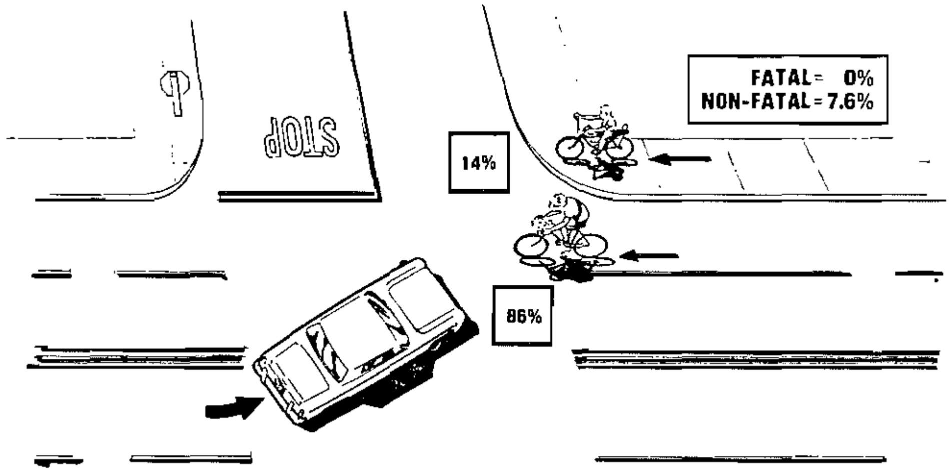


Figure 30. Illustration of Problem Type 23, *Motorist Unexpected Left Turn: Parallel Paths, Facing Approach.*

important factor for this problem type. In nearly one-fifth of the cases, the motorist failed to observe the bicyclist because of degraded visibility conditions. In these cases, the motorist's visibility was degraded by one of the following: darkness (14%), sun glare (6%), or glare from artificial lights (2%). Of the bicyclists who went undetected by the motorist at night, one-half were equipped with an operational headlamp.

In 68% of the cases, the bicyclist was not observed by the motorist even though the motorist's view was unobstructed and the visibility conditions were good. Thirty-eight percent of the motorists reported that they scanned in the bicyclist's direction several times before turning but still failed to observe the bicyclist until the vehicles collided, or a moment before. It is probable that all the motorists who committed a search failure did, in fact, scan in the general direction of the bicyclist at least once. Thirty-six percent of the motorists reported that their search failure was at least partly due to distractions by vehicles or pedestrians that were considered an accident threat.

An examination of the traffic context in which Type 23 accidents occurred would lead one to expect that information overload may have often contributed to the motorist's search failure. Although the information was seldom sufficient to clearly establish the presence of information overload, an evaluation of the traffic context indicates that this may have been a factor in at least half the cases in which a search failure was identified.

Thirty percent of the bicyclists failed to search in the direction of the motor vehicle until it was too late to avoid the accident. The remaining bicyclists observed the motor vehicle but did not, or could not, initiate evasive action until the accident was imminent. Typical patterns of failures by the bicyclist are as follows:

- The bicyclist failed to search in the motorist's direction because he falsely assumed that all turning traffic would yield to him (30%).

- The bicyclist observed the motorist, correctly concluded that the motor vehicle was going to turn, but falsely assumed that he had been detected and that the motorist would yield (29%).

- The bicyclist observed the motor vehicle stopped in the center of the roadway waiting for an opportunity to turn. The bicyclist continued because he assumed that the motor vehicle would remain stopped until he had cleared the junction (24%).

- The bicyclist correctly concluded that the vehicles were on a collision course but was unable to avoid the collision because of a vehicle failure (wet or defective brakes) or a skill deficiency (9%).

It was found that the bicyclists involved in this type of accident were older than for any other problem type. The median age of the bicyclists was 20.1 years. Only 25% of the bicyclists were younger than 16 years of age and only five percent were younger than 11 years of age.

Problem Type 24 (1.8% Fatal; 5.6% Non-Fatal)

The distinguishing characteristic of Problem Type 24 is that a motorist collided with an approaching bicyclist while in the process of making a right-hand turn. Figure 31 shows that 74% of the accidents involved a bicyclist who was approaching from the motorist's right rear. This subtype typifies the classical right-turn accident that has been so widely publicized. In the remaining cases, the motorist turned into the path of a bicyclist approaching from straight ahead--riding facing traffic.

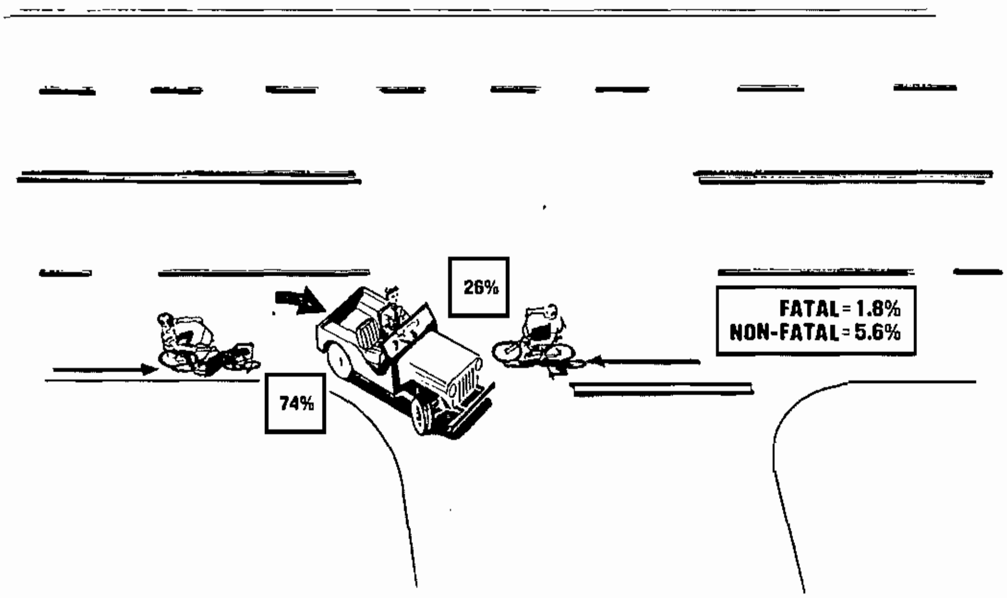


Figure 31. Illustration of Problem Type 24, ***Motorist Unexpected Right Turn: Parallel Paths.***

Every accident of this type occurred in an urban area. In 59% of the cases, the motorist was traveling on a two-lane urban street prior to the collision. In the remaining cases, the motorist was traveling on a street with more than two lanes. Most accidents occurred at either the junction of two roadways (64%) or the junction of a street and driveway (29%), but Problem Type 24 also includes a small number of cases (7%) in which the motorist turned right to enter an on-street parking space. In most cases, the bicyclist was traveling on the same roadway as the motorist. However, in eight percent of the cases, the bicyclist entered the junction from a sidewalk. Ninety-five percent of the accidents occurred during the daytime; 83% occurred during the period between 11:00 AM and 6:00 PM.

More than 97% of the motorists reported that they failed to observe the approaching bicyclist at the time they initiated their right-hand turn. In about five percent of the cases, the motorist's view of the bicyclist approaching from the rear was obstructed. In about 93% of the cases, however, the bicyclist was clearly visible to the motorist but went undetected because the motorist failed to scan carefully in the bicyclist's direction. The most common reasons given for the motorist's failure to search in the bicyclist's direction include:

- Bicyclist in unusual/unexpected location (40%),
- Assumed bicyclist overtaken before turn was far behind and posed no threat (37%),
- Expected all traffic to yield or evade (13%),
- Motorist was momentarily distracted (13%), and
- Motorist misjudged the speed of the approaching bicyclist (3%).

About 12% of the bicyclists failed to search in the motorist's direction--usually because of momentary distractions. The remaining bicyclists observed the motorist far in advance but failed to correctly evaluate the motorist's intentions. In 24% of the cases, the motor vehicle was stopped in a queue of motor vehicles when first observed by the bicyclist. As the bicyclist approached the junction at which the accident occurred, the queue of motor vehicles began moving, which enabled the motorist to move to the junction where he intended to turn right. The bicyclist either failed to anticipate the motorist's turn or assumed he could clear the junction before the motorist turned. Only one case of this type involved a wrong-way-riding bicyclist.

In about 64% of the cases, the bicyclist did not expect the motorist to turn, even though he observed the motor vehicle slow at the approach to the junction. In some cases the motorist failed to signal before turning; in other cases the motorist signaled but the bicyclist did not, or could not, see the signal. Because of conflicting testimony by the operators, it was impossible to estimate the number of cases in which the motorist failed to signal, the bicyclist failed to observe a clearly visible signal, or the bicyclist was riding alongside the motor vehicle and could not see the motor-vehicle's turn-signal light. However, it is estimated that these three situations occurred with about equal frequency.

It was found that the bicyclists involved in accidents of this type varied widely in age. The median age was 16.8 years; about five percent of the bicyclists were 12 years of age or younger and 25% were older than 22 years of age.

EDUCATIONAL COUNTERMEASURES FOR CLASS F PROBLEM TYPES

Bicyclists

About one-third of all Class F accidents were the direct or indirect result of bicyclists riding in an unexpected location (excluding bicyclists approaching from the right-rear of the motorist). Thus, bicyclist education and training programs should be designed to curtail the following behavior:

- Wrong-way riding (14% of Class F),
- Entering a junction from a sidewalk (10% of Class F), and
- Overtaking and passing on the left of a motor vehicle at a junction (5% of Class F).

Whether or not bicyclists are riding in an expected location, they should be taught to search for motor vehicles that are in a position to turn (right or left) into their path. Although bicyclists should be taught to search for turn-signal lights and hand signals, they should also be taught that the lack of a signal does not necessarily mean that the motorist does not intend to turn. Bicyclists must be informed of the low conspicuity of the bicycle/bicyclist unit and taught to never assume that they have been observed by the motorist--even when the visibility conditions are good and the motorist scans in the bicyclist's direction. Finally, bicyclists must be informed of the dangers of overtaking and passing slow-moving or standing motor vehicles at junctions. Greatest emphasis should be placed on training to curtail passing on the right-hand side of slow-moving or standing motor vehicles.

Some bicycling experts believe that many Class F accidents would not occur if bicyclists were taught to ride in the center of the traffic lane rather than along the right-hand curb. They claim that riding in the center of the traffic lane would increase the likelihood that the bicyclist will be detected by the motorist and would eliminate the right-of-way conflicts with right-turning accidents. As was discussed earlier, a number of critical questions must be answered before recommending that bicyclists be taught to ride in the center of the traffic lane (see discussion of countermeasures for Class E accidents).

Motorists

The main objective of a motorist education and training program is to modify motorists' search patterns in the traffic contexts where Class F accidents occur. An effective training and education program must increase motorists' expectations of encountering bicyclists and must teach them precisely where to search when preparing to make a left-hand or right-hand turn.

CLASS G PROBLEM TYPES: OTHER

Class G includes the problem types that could not meaningfully be classified into any of the previously described classes (see Table 20). With the exception of Problem Types 25 and 26, the problem types within Class G occurred so infrequently that it was not possible to draw valid inferences about the nature of the accident-generation process. For this reason, Problem Types 27 through 36 are described in only enough detail to provide a general notion of how the accident occurred.

TABLE 20

PROBLEM CLASS G--OTHER

		FATAL (N=166)	NON-FATAL (N=753)
TYPE 25	VEHICLES COLLIDE AT UNCONTROLLED INTERSECTION: ORTHOGONAL PATHS	.6%	2.8%
TYPE 26	VEHICLES COLLIDE HEAD-ON, WRONG-WAY BICYCLIST	2.4%	3.6%
TYPE 27	BICYCLIST OVERTAKING	.6%	.9%
TYPE 28	HEAD-ON, WRONG-WAY MOTORIST	1.8%	.8%
TYPE 29	PARKING LOT, OTHER OPEN AREA: ORTHOGONAL PATHS	.6%	.8%
TYPE 30	HEAD-ON, COUNTERACTIVE EVASIVE ACTION	---	.1%
TYPE 31	BICYCLIST CUTS CORNER WHEN TURNING LEFT: ORTHOGONAL PATHS	.6%	---
TYPE 32	BICYCLIST SWINGS WIDE WHEN TURNING RIGHT: ORTHOGONAL PATHS	---	.3%
TYPE 33	MOTORIST CUTS CORNER WHEN TURNING LEFT: ORTHOGONAL PATHS	---	.4%
TYPE 34	MOTORIST SWINGS WIDE WHEN TURNING RIGHT: ORTHOGONAL PATHS	---	.1%
TYPE 35	MOTORIST DRIVEOUT FROM ON-STREET PARKING	---	.3%
TYPE 36	WEIRD	---	1.1%
---	INSUFFICIENT INFORMATION TO CLASSIFY	7.2%	---
TOTAL CLASS (N: FATAL = 23; NON-FATAL = 84)		13.8%	11.2%

PROBLEM-TYPE DESCRIPTIONS

Problem Type 25 (.6% Fatal; 2.8% Non-Fatal)

Problem Type 25 includes cases in which (a) the collision occurred within an uncontrolled intersection and (b) the two vehicles approached on orthogonal legs of the intersection. Every case classified into Problem Type 25 occurred at the junction of a pair of two-lane roadways; 86% occurred in an urban area and 14% occurred in a rural area. Figure 32 shows that a slight majority of the accidents of this type occurred in the second half of the roadway (57%). Although not illustrated in Figure 32, about 25% of the bicyclists were riding on the wrong side of the roadway prior to the collision. Ninety percent of the accidents occurred during the daytime when visibility conditions were near optimal.

Visual obstructions located close to the junction served to limit the motorist's preview time in 38% of the cases. Vegetation and parked motor vehicles were the most common type of obstructing objects. Darkness and inadequate bicycle lighting prevented the motorist from detecting the bicyclist in about ten percent of the cases. The remaining cases involved either a search failure or an evaluation failure by the motorist. In about 24% of the cases, the motorist failed to search in the direction of the bicyclist--usually because the bicyclist was traveling in an unexpected location (wrong-way riding).

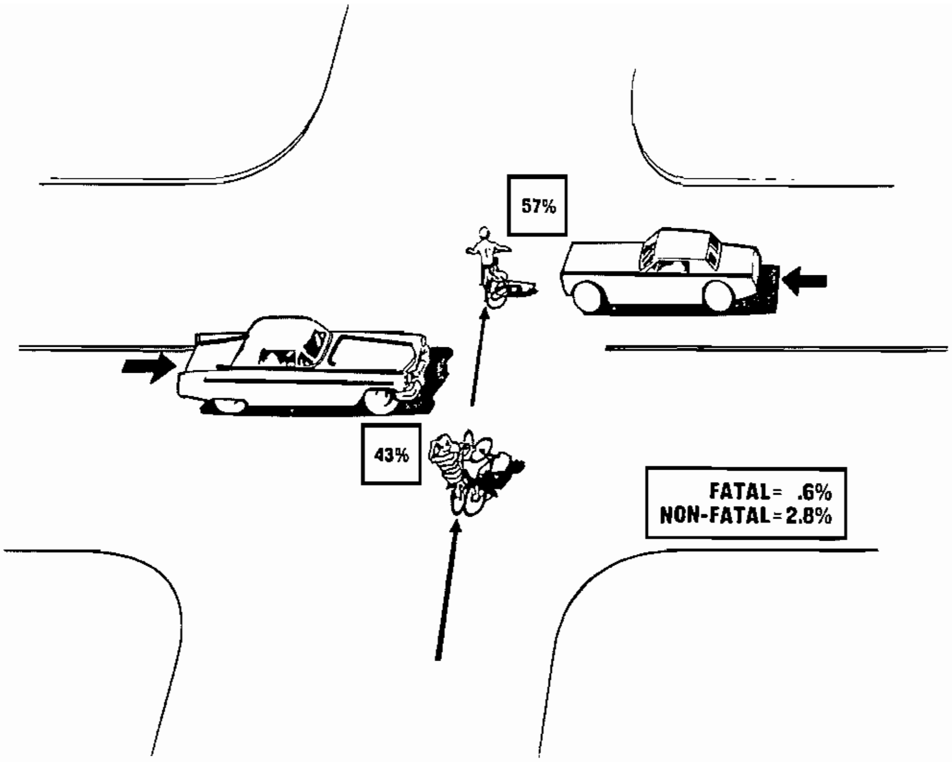


Figure 32. Illustration of Problem Type 25, *Vehicles Collide at Uncontrolled Intersection: Orthogonal Paths.*

The motorist observed the bicyclist early enough to have avoided the accident in 19% of the cases. The motorist's failure to initiate evasive action was usually due to his faulty assumption that the bicyclist would slow or turn before entering the junction.

More than half the bicyclists failed to search effectively on their approach to the junction. Usually, the bicyclist's failure to search was due, in part, to distractions from game playing and interacting with a passenger or another bicyclist. About 19% of the bicyclists observed the motor vehicle early enough to have avoided the accident but incorrectly assumed the motorist would turn or slow before reaching the bicyclist's intended path. About ten percent of the cases were due to an action failure--usually due to faulty brakes or a skill deficiency in operating caliper brakes.

A substantial number of the bicyclists who were involved in accidents of this type were very young. The median age of the bicyclists was 12.4 years. Five percent were six years of age or younger and only 25% were 14 years of age or older.

Problem Type 26 (2.4% Fatal; 3.6% Non-Fatal)

The accident cases classified into Problem Type 26 are highly similar to those classified into Class D (Motorist Overtaking/Overtaking Threat). The main difference is that all Type 26 accidents involved a wrong-way-riding bicyclist and, therefore, a head-on collision. Ninety-six percent of all Type 26 accidents occurred on a relatively narrow two-lane roadway; 55% of the accidents occurred in an urban area and 41% occurred in a rural area. Seventy-eight percent of the accidents occurred during the daytime.

Problem Type 26 contains five distinctly different subtypes; these subtypes are described briefly below. It should be noted that several of the subtypes of Problem Type 26 correspond closely to problem types within Class D.

- Bicyclist detected by motorist--The bicyclist was riding facing traffic and was located in or near the center of the traffic lane. The motorist observed the bicyclist approaching and slowed or stopped his vehicle. Because the bicyclist was scanning elsewhere, he rode into the front of the slow-moving or stopped motor vehicle. This subtype accounted for 18% of the Type 26 accidents.

- Bicyclist not detected by motorist--The bicyclist was riding facing traffic but was located close to the edge of the roadway. The motorist failed to observe the bicyclist because of a search failure (three cases), degraded visibility conditions at night (five cases), or because an object obstructed his view (six cases). The motorist's view was obstructed by a parked or moving motor vehicle in three cases; an embankment along a curve obstructed the motorist's view in the remaining three cases. Fifty-two percent of the Type 26 accidents were classified into this subtype.

- Counteractive evasive action--When on a head-on approach, both operators evaded in the same direction. This subtype accounted for 11% of the Type 26 accidents.

- Motor vehicle control failure--The operator permitted the motor vehicle to drift too far to the right on a curve (4% of Type 26).

- Bicycle control failure--The bicycle drifted/swerved too far to the right (15% of Type 26).

Most of the bicyclists involved in Type 26 accidents were juveniles. The median age of the bicyclists was 12.9 years; about 70% of the bicyclists were between six and 15 years of age.

Problem Type 27 (.6% Fatal; .9% Non-Fatal)

Problem Type 27 includes cases in which the bicyclist collided with the rear of a stopped or slow-moving motor vehicle. About 43% of the accidents were the result of a search failure by the bicyclist, and an equal number were due to the bicyclist's failure to anticipate a sudden reduction in the motor vehicle's speed. In 14% of the cases, the bicyclist was unable to stop because of a skill deficiency in manipulating the caliper brakes.

Problem Type 28 (1.8% Fatal; .8% Non-Fatal)

All Type 28 collisions were head-on and involved a motor vehicle that was traveling on the wrong side of the roadway. Two cases involved a motor vehicle that was out of control. The other cases occurred as follows:

- A truck offloading cement inched forward as a bicyclist approaching from straight ahead was preparing to swerve around the front of the truck.

- The motorist was leaving an unpaved area adjacent to the roadway and drove a short distance on the wrong side of the roadway.

- The motorist veered into the left lane when preparing to make a sharp right-hand turn.

Problem Type 29 (.6% Fatal; .8% Non-Fatal)

All Type 29 accidents occurred in a parking lot or another large open area (83% occurred in a commercial parking lot); the vehicles were traveling orthogonal paths in every case. Visual obstructions were a factor in about one-third of the cases. Otherwise, the accidents resulted from a search failure by one or both operators.

Problem Type 30 (.1% Non-Fatal; No Fatal)

Problem Type 30 includes accidents in which the vehicles collided head-on because both operators evaded in the same direction. Type 30 includes only the accidents that occurred on a roadway so narrow that neither vehicle can be said to have been traveling on the wrong side of the roadway.

Problem Type 31 (.6% Fatal; No Non-Fatal)

Problem Type 31 accidents (one case) occurred when a bicyclist cut a corner when turning left and collided with a motor vehicle approaching on an orthogonal leg of the intersection.

Problem Type 32 (.3% Non-Fatal; No Fatal)

Problem Type 32 includes cases in which the bicyclist swung too far to the left when making a high-speed right-hand turn. The bicyclist collided with a parked motor vehicle, a standing motor vehicle, or a moving motor vehicle located on the roadway onto which the bicyclist turned.

Problem Type 33 (.4% Non-Fatal; No Fatal)

Problem Type 33 is similar to Problem Type 31 except that Type 33 accidents resulted from the *motorist* (rather than the bicyclist) cutting a corner when making a left-hand turn.

Problem Type 34 (.1% Non-Fatal; No Fatal)

Problem Type 34 includes accidents in which the motorist swung wide when making a right-hand turn and collided with a bicyclist approaching an intersection in the roadway onto which the motorist turned. Problem Type 34 is the counterpart of Problem Type 32.

Problem Type 35 (.3% Non-Fatal; No Fatal)

Problem Type 35 includes accidents that occurred when a motorist drove into the path of an approaching bicyclist when exiting an on-street parking space (one case parallel-parking space and one case diagonal-parking space).

Problem Type 36 (1.1% Non-Fatal; No Fatal)

Problem Type 36 includes a variety of accidents termed "weird" because of the unusual circumstances that led to their occurrence. Examples include:

- Bicyclist fell while being towed by a motorcycle.
- Bicycle struck by object that fell from a truck.
- Bicyclist was pushed into motor vehicle's path by pedestrian.
- Motorist deliberately collided with bicyclist (hostile act).
- Motor vehicle was struck in the rear by another motor vehicle and pushed into the bicyclist's path.
- Bicyclist stopped in the center of a traffic lane to retrieve dropped object and was struck by a motor vehicle.

EDUCATIONAL COUNTERMEASURES FOR CLASS G PROBLEM TYPES

The educational countermeasures required to counter Type 25 accidents (vehicles collided at uncontrolled intersection) are similar to those suggested for the bicyclist driveout and motorist turn-merge/drive through accidents. Among the most important educational countermeasures for Problem Type 25 are:

- Teach bicyclists to search for, recognize, and cope with all types of visual obstructions.
- Teach both bicyclists and motorists to search more effectively at uncontrolled intersections.
- Modify both bicyclists' and motorists' assessments of of the risk associated with uncontrolled intersections.

The educational countermeasures for the remaining Class G accidents are similar to the countermeasures suggested for other problem types. Because of the great differences among Class G problem types, no attempt will be made to list the educational countermeasures for each of them.

DESCRIPTION OF QUICK-REFERENCE TABLE

The persons who reviewed the material presented in this section of the report expressed a need for a single table that presents selected information about the composite set of problem types. Table 21 was prepared in response to that need. The first two columns of Table 21 show the designator for each problem type; the next column shows the generic description of each problem type. Columns four and five show the proportion of the fatal and non-fatal samples accounted for by each problem type. The remaining five columns show the 5th, 25th, 50th, 75th, and 95th centile age of the bicyclists who were involved in the associated problem type. A dashed line in these columns indicate that the sample was too small to provide a reliable estimate of the bicyclist age distribution for that problem type. Because of the small number of cases in the fatal sample, the centiles are based solely on the age of the bicyclists in the non-fatal sample.

TABLE 21

QUICK-REFERENCE TABLE SHOWING RELATIVE FREQUENCY OF OCCURRENCE AND BICYCLIST AGE DISTRIBUTION FOR EACH PROBLEM TYPE

CLASS/TYPE DESIGNATOR		PROBLEM-TYPE DESCRIPTION	RELATIVE FREQUENCY OF OCCURRENCE		BICYCLIST AGE (CENTILES)				
CLASS	TYPE		FATAL	NON-FATAL	5TH	25TH	50TH	75TH	95TH
A	1	BICYCLE RIDEOUT: RESIDENTIAL DRIVEWAY/ALLEY, PRE-CRASH PATH PERPENDICULAR TO ROADWAY	6.7%	5.7%	5.2	7.4	9.8	12.3	15.9
A	2	BICYCLE RIDEOUT: COMMERCIAL DRIVEWAY/ALLEY, PRE-CRASH PATH PERPENDICULAR TO ROADWAY	2.4%	3.2%	7.6	9.4	13.8	14.9	24.9
A	3	BICYCLE RIDEOUT: DRIVEWAY/ALLEY APRON, PRE-CRASH PATH PARALLEL TO ROADWAY	2.4%	2.5%	5.9	9.6	11.5	13.1	16.0
A	4	BICYCLE RIDEOUT: ENTRY OVER SHOULDER/CURB	3.6%	2.5%	6.9	9.5	11.5	14.5	15.0
B	5	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGN	7.8%	10.2%	6.8	9.1	11.8	14.3	19.4
B	6	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, SIGNAL PHASE CHANGE	.6%	3.1%	10.1	13.3	16.1	17.8	32.8
B	7	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, MULTIPLE THREAT	2.4%	2.0%	11.8	12.9	15.2	15.9	33.2
B	-	BICYCLE RIDEOUT: INTERSECTION CONTROLLED BY SIGNAL, OTHER	1.2%	1.7%	9.6	13.9	16.9	23.9	34.4
C	8	MOTORIST TURN-MERGE: COMMERCIAL DRIVEWAY/ALLEY	---	5.3%	7.9	13.3	15.4	17.5	49.9
C	9	MOTORIST TURN-MERGE/DRIVE THROUGH: INTERSECTION CONTROLLED BY SIGN	1.2%	10.2%	10.4	13.8	16.3	20.5	35.6
C	10	MOTORIST TURN-MERGE: INTERSECTION CONTROLLED BY SIGNAL	---	1.9%	10.6	12.1	13.3	24.4	72.4
C	11	MOTORIST BACKING FROM RESIDENTIAL DRIVEWAY	---	.8%	-	-	-	-	-
C	12	MOTORIST DRIVEOUT: CONTROLLED INTERSECTION	1.2%	.5%	-	-	-	-	-
D	13	MOTORIST OVERTAKING: BICYCLIST NOT OBSERVED	24.6%	4.0%	11.2	15.4	18.1	23.2	59.6
D	14	MOTORIST OVERTAKING: MOTOR VEHICLE OUT OF CONTROL	4.2%	.7%	-	-	-	-	-
D	15	MOTORIST OVERTAKING: COUNTER-ACTIVE EVASIVE ACTION	2.4%	1.7%	5.7	9.2	12.3	14.4	15.7
D	16	MOTORIST OVERTAKING: MOTORIST MISJUDGED SPACE REQUIRED TO PASS	1.8%	2.0%	8.7	13.5	15.0	25.2	41.3
D	17	MOTORIST OVERTAKING: BICYCLIST'S PATH OBSTRUCTED	.6%	2.0%	9.1	12.9	16.3	23.2	32.2
D	-	MOTORIST OVERTAKING: TYPE UNKNOWN	4.2%	.1%	-	-	-	-	-

TABLE 21 (CONTINUED)

CLASS/TYPE DESIGNATOR		PROBLEM TYPE DESCRIPTION	RELATIVE FREQUENCY OF OCCURRENCE		BICYCLIST AGE (CENTILES)				
CLASS	TYPE		FATAL	NON-FATAL	5TH	25TH	50TH	75TH	95TH
E	18	BICYCLIST UNEXPECTED LEFT TURN: PARALLEL PATHS, SAME DIRECTION	8.4%	8.4%	7.2	10.6	12.7	14.5	20.9
E	19	BICYCLIST UNEXPECTED LEFT TURN: PARALLEL PATHS, FACING APPROACH	3.0%	3.2%	6.2	11.7	13.8	18.5	35.8
E	20	BICYCLIST UNEXPECTED SWERVE LEFT: PARALLEL PATHS, SAME DIRECTION (UNOBSTRUCTED PATH)	3.6%	1.5%	8.5	10.2	11.5	15.1	16.4
E	21	WRONG-WAY BICYCLIST TURNS RIGHT: PARALLEL PATHS	1.2%	1.1%	-	-	-	-	-
F	22	MOTORIST UNEXPECTED LEFT TURN: PARALLEL PATHS, SAME DIRECTION	.6%	1.3%	11.5	13.5	15.9	23.5	37.5
F	23	MOTORIST UNEXPECTED LEFT TURN: PARALLEL PATHS, FACING APPROACH	---	7.6%	10.8	15.7	20.1	26.6	46.2
F	24	MOTORIST UNEXPECTED RIGHT TURN: PARALLEL PATHS	1.8%	5.6%	12.1	14.6	16.8	22.9	33.9
G	25	VEHICLES COLLIDE AT UNCONTROLLED INTERSECTION: ORTHOGONAL PATHS	.6%	2.8%	6.0	9.3	12.4	13.9	19.9
G	26	VEHICLES COLLIDE HEAD-ON, WRONG-WAY BICYCLIST	2.4%	3.6%	6.5	10.9	12.9	15.3	20.5
G	27	BICYCLIST OVERTAKING	.6%	.9%	-	-	-	-	-
G	28	HEAD-ON, WRONG-WAY MOTORIST	1.8%	.8%	-	-	-	-	-
G	29	PARKING LOT, OTHER OPEN AREA: ORTHOGONAL PATHS	.6%	.8%	-	-	-	-	-
G	30	HEAD-ON, COUNTERACTIVE EVASIVE ACTION	---	.1%	-	-	-	-	-
G	31	BICYCLIST CUTS CORNER WHEN TURNING LEFT: ORTHOGONAL PATHS	.6%	---	-	-	-	-	-
G	32	BICYCLIST SWINGS WIDE WHEN TURNING RIGHT: ORTHOGONAL PATHS	---	.3%	-	-	-	-	-
G	33	MOTORIST CUTS CORNER WHEN TURNING LEFT: ORTHOGONAL PATHS	---	.4%	-	-	-	-	-
G	34	MOTORIST SWINGS WIDE WHEN TURNING RIGHT: ORTHOGONAL PATHS	---	.1%	-	-	-	-	-
G	35	MOTORIST DRIVEOUT FROM ON-STREET PARKING	---	.3%	-	-	-	-	-
G	36	WEIRD	---	1.1%	-	-	-	-	-
G	37	INSUFFICIENT INFORMATION TO CLASSIFY	7.2%	---	-	-	-	-	-

SECTION VI
DISCUSSION OF EDUCATION AND TRAINING OBJECTIVES

The establishment of a set of concise educational[5] objectives is among the most important and most difficult tasks to be accomplished in developing an educational program, so it seems appropriate to devote a separate section to the discussion of bicycle-safety education objectives. This section begins with a discussion of what are considered the most important sources of the controversy associated with bicycle-safety education objectives. Then, educational objectives for bicyclists, motorists, bicyclists' parents, law enforcement officers, and bicycle designers are discussed in turn. Bicyclist education is discussed far more extensively than the education of the other groups. Bicyclist education has been stressed for two reasons. First, it is believed that the education of bicyclists has more accident reduction potential than the education of other groups. Secondly, the education of bicyclists is inherently more difficult than the education of other groups because bicyclists must be educated at a younger age.

Education objectives for traffic and transportation engineers are not discussed because of the raging controversy surrounding the safety benefits to be derived from modifying the traffic system to better accommodate bicycles. Similarly, this section contains no discussion of educational objectives for legislators, officials of governmental agencies, traffic-safety researchers, school administrators, classroom instructors, or the many other persons who may benefit from education about the incidence, consequences, and causes of bicycle accidents. The discussion of educational objectives for these persons must be left for another time and another report.

The reader should keep in mind that the educational objectives discussed in the following pages are based almost entirely on a consideration of the behavioral causes of bicycle/motor-vehicle accidents. Hopefully, the type of education that will effect a reduction in bicycle/motor-vehicle accidents will also serve to reduce NMV accidents. However, it is almost certain that the set of educational objectives presented here will have to be expanded once detailed data on the causes of NMV accidents become available.

SOURCES OF CONTROVERSY ABOUT EDUCATIONAL OBJECTIVES

A careful review of bicycle-safety education programs developed in the recent past reveals a great many differences in the objectives that the programs were designed to

[5]Throughout this section, the term "education" will be used in two different ways. When referring to general education and training programs or general education and training objectives, only the term "education" will be used; the term "training" will be dropped to avoid repeating "education and training" again and again. When referring to specific education and training activities, the term "education" will be used to refer to activities that impart knowledge; the term "training" will be used to refer to activities that enhance specific perceptual or motor skills.

accomplish[6]. Many of the differences are the direct result of the lack of valid information about the specific knowledge and skill deficiencies that lead to bicycle accidents. Other reasons for the differences are discussed below.

MOTIVES OTHER THAN PROMOTING SAFETY

It is apparent from an examination of existing educational materials that the promotion of safety was not always the sole motive in operation when the materials were developed. Other apparent motives include: promoting greater bicycle usage, increasing bicyclists' ability to ride efficiently, modifying patterns of bicycle usage, and modifying attitudes toward the bicycle and bicycle users. There are few who believe that the inclusion of such topics in an education program will serve to reduce accidents. Rather, they are included because of the belief that (a) greater and more efficient use of the bicycle will result in societal benefits that are at least as great as reducing accidents, and (b) a bicycle-safety education program provides a convenient vehicle for promoting bicycling and teaching bicyclists to ride more efficiently. Those who oppose the inclusion of such topics argue that the time and resources available for safety education are so limited that a safety-education program should be limited to the topics and activities that are known to reduce accidents.

FAILURE TO DEFINE UNDERLYING RATIONALE

It is believed that much of the controversy about educational objectives stems from the failure to define the rationale that led to the selection of a specific educational objective. This is particularly true when the objective is to enhance rudimentary knowledge or skills that a student must possess before he can be taught more complex and more directly relevant concepts or skills. For example, on first examination, it may be difficult to see why a bicycle-safety education program would include material about the functioning of the human visual system. However, the usefulness of this information quickly becomes apparent when it is explained that some knowledge of the functioning of the visual system is required to teach students why bicyclists sometimes fail to observe clearly visible cues to hazard, why motorists sometimes fail to observe clearly visible bicyclists, and so on. It is believed that much of the controversy about educational objectives would vanish if each educational objective was accompanied by a brief description of the rationale that led to the establishment of that objective. To be effective, the description should be complete enough to enable readers to easily perceive the link(s) between an educational objective and the accident-producing behavior to be modified.

ASSUMPTIONS ABOUT THE TARGET GROUP

There appears to be almost universal agreement that bicyclists in general and juvenile bicyclists in particular constitute the primary target group for bicycle-safety

[6]Readers who have not had the opportunity to review a sample of bicycle-safety education programs and materials are encouraged to review the inventory of educational objectives presented in Appendix B. This inventory was compiled from a study of ten recent bicycle-safety education programs.

education. However, there is no universal agreement about the specific age at which bicycle-safety education must be introduced. Some persons believe that bicycle-safety education should commence in kindergarten and continue in every grade through high school. Others believe that it is futile to attempt to educate very young children, so have developed programs only for older children. Obviously, the specific objectives of a program are going to vary greatly as a function of the age at which bicycle-safety education is to be introduced.

To complicate matters even more, the objectives of programs developed for the same young age group often differ because of differences in opinion about what young children can and cannot be taught. Child development experts agree that certain concepts simply cannot be learned by children before they reach a certain maturational level, no matter how much effort is expended in trying to teach the child the concepts. However, child development is not well enough understood to enable even the most knowledgeable experts to define exactly how old the average child must be before he can be taught a given safety-related concept. Estimates about the earliest age at which a child can be taught a given concept may vary over a range of several years. Concepts that fall in this range of uncertainty may be included or excluded from an educational program designed for a specific age group, depending on the opinion and biases of the program developer. Controversies of this type can be resolved only through research.

ASSUMPTIONS ABOUT RESOURCES AND CONSTRAINTS

Perhaps the most important source of controversy about educational objectives is the assumptions that are made about the resources that can be devoted to bicycle-safety education or, conversely, the constraints within which a program must operate. Examples of assumptions that may have an important impact on educational objectives include:

- The agency who is responsible for developing and implementing the program (schools, police departments, bicycling organizations, civic groups, etc.).
- The amount of time students will be available for education and training.
- The funds and other resources available for developing educational materials and activities.
- The educational media and method (the distribution of reading materials, public-service radio or television spot announcements, one-shot rodeos, classroom training, on-the-road training, training in driving simulators, or some combination of these).
- The knowledge and sophistication of the instructional personnel.

Until now, there has been a strong tendency to tailor educational programs to the capabilities and limitations of the organization that will be responsible for administering the program. Since organizations differ greatly in their capabilities and limitations, it is not surprising to find important differences in the specific educational objectives they have adopted for their programs. Tailoring educational objectives to the capabilities and limitations of an organization is a dangerous practice that can lead to programs which are so incomplete and superficial that they have little or no impact on accidents. A better approach is to define the objectives of an ideal program and then identify the organizations who are most capable of administering that program. The same is true for educational methods and media. That is, the educational methods and media to be employed should be dictated by the educational objectives rather than attempting to tailor educational objectives to a specific method or media.

MULTIPLE EDUCATIONAL STRATEGIES

For most types of accidents, there are several educational strategies that may prove effective in reducing accident likelihood. One strategy might focus on education that would induce bicyclists to avoid riding in high-hazard areas; another strategy might focus on education that would induce bicyclists to modify their speed and path at high-hazard locations; a third strategy might focus on training that would increase the bicyclists' ability to make emergency stops and turns. Differences in educational strategy account for some of the differences in the objectives of contemporary bicycle-safety education programs. The controversy about such differences would be greatly reduced if (a) the various education strategies were defined more explicitly, and (b) the rationale for selecting one strategy over another was explained by educational program developers.

OBJECTIVES OF BICYCLIST EDUCATION

Because an accident is the end product of a sequential chain of events, it is possible that the causal chain may be broken and the accident avoided by modifying any one of the events in the causal chain. The implication of this assertion is that there may be several different educational solutions for the same type of accident. When discussing educational objectives, it is important that the full range of potential educational solutions be considered, and it is important that they be considered in an organized fashion. To provide an organizational framework for discussing the full range of educational objectives, the bicycle-riding task has been divided into three sets of functions. The first set of functions--the Preparatory-Phase functions--are those ordinarily accomplished before the bicyclist departs on a trip. The second set of functions--the Anticipatory-Phase functions--are those required to select a safe course (both path and speed) through an area. The third set of functions--the Reactive-Phase functions--are those required to respond to a specific threat in the environment.

For each of the three sets of functions, educational objectives are discussed at two levels of specificity. At the most general level (Level I), the objectives are defined in broad behavioral terms. Level II objectives are defined in terms of the knowledge and skills that must be enhanced and the values that must be modified in order to achieve the behavioral changes specified by the Level I objectives. If the educational objectives defined here prove valid and meaningful, it will be necessary to define objectives at a third level of specificity. Objectives at Level III would define the specific methods and techniques required to accomplish the Level II objectives. An effort is presently underway to conduct the research, development, and evaluation needed to define objectives at the third level of specificity. The effort is being funded by the National Highway Traffic Safety Administration (NHTSA) and should be completed by late 1979 or early 1980. Readers who have ideas about specific methods and techniques for accomplishing the Level II objectives defined below are encouraged to convey their ideas to NHTSA directly or to convey them indirectly through the AAA Foundation for Traffic Safety.

The discussion of educational objectives follows a brief discussion of the target groups for bicyclist education.

COMMENTS ABOUT THE TARGET GROUPS FOR BICYCLIST EDUCATION

Decisions about the target groups for bicyclist education must be based on a joint consideration of two factors: (a) the age distribution of the accident population of bicyclists, and (b) the relationship between educational costs and the age of the bicyclists being educated. On one hand, there is a need to introduce education at an early enough age so that substantial numbers of accidents will not have occurred before bicyclists receive the education. On the other hand, there is a desire to delay education for as long as possible because the ease and efficiency of accomplishing the educational objectives tends to increase as a function of the age of the student. That is, within limits, it is easier to teach complex concepts and skills to older children than to younger children. The following paragraphs address this dilemma.

Consider first the age distribution of the bicycling population. The curves in Figure 33 show the proportion of fatal and non-fatal bicycle/motor-vehicle accidents that occur *after* each age from four to 18 years. The proportion of accidents occurring after a specified age provides an indication of the maximum payoff that could be realized from education introduced at that age. For instance, Figure 33 shows that only 36% of the fatal accidents and 21% of the non-fatal accidents involve a bicyclist who is older than 18 years of age. Thus, the maximum benefit that could be realized from education introduced at this age level is a 36% reduction in fatal and a 21% reduction in non-fatal accidents.

The finding that accident rate is highest for bicyclists between 11 and 13 years of age has led some persons to conclude that education should be focused on bicyclists within this age group. Examination of Figure 33 shows that the potential payoff would be considerably reduced if education was delayed until bicyclists had reached the age of 11, 12, or 13 years. For instance, if education was delayed until the age of 13, the potential payoff would be reduced to 64% for fatal and 52% for non-fatal accidents. The potential payoff would be higher if the education was introduced at age 11; but, even so, it would be only 75% and 70% for fatal and non-fatal accidents, respectively.

The data in Figure 33 make it clear that a major educational effort must be introduced at the elementary school level if bicycle-safety education is to have a significant impact on accidents. However, this conclusion gives rise to several important questions that are difficult to answer with the data presently available.

- What is the earliest age at which children can be taught the necessary concepts, principles, and skills?
- How long can children of different ages be expected to retain the concepts, principles, and skills they are taught?

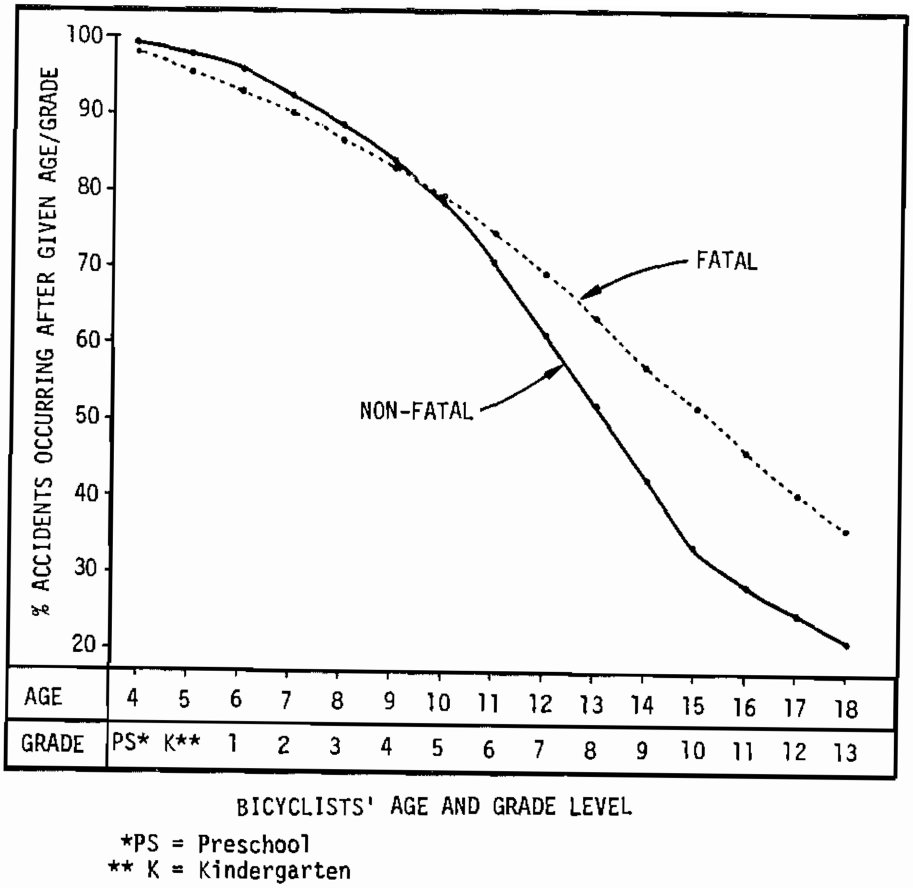


Figure 33. Maximum payoff in accident reduction as a function of age/grade at which education is introduced.

- If retention is a problem, what are the requirements for education to refresh students' recollection of key concepts and principles in the years after they have completed a comprehensive education program?
- What is to be done to educate bicyclists who are older than the educational target group at the time a bicycle-safety education program is first introduced?

A final answer to the above questions must await the development and evaluation of prototype educational methods and materials. And yet, even prototype methods and materials cannot be developed without making initial assumptions about the age of the educational target group. What must be done to answer these questions is: make best guesses about the educational target group; develop methods and materials to educate that target group; conduct a formal evaluation of the effectiveness of the education; and use the research findings to better define the optimal target group, refine the methods and techniques, or both. So, at this stage of development, the task at hand is to make "best guesses" about the educational target group. These "best guesses" will form the basis for developing prototype methods and materials which will subsequently be evaluated. The author's "best guesses" are described below along with the supporting rationale.

The ease and efficiency of almost any type of education is importantly determined by the language skills of the student, particularly the student's ability to read and write. According to experts in elementary education with whom the author has discussed this problem, the language skills of a typical student represent a serious barrier to efficient education until the student has completed the third grade (about nine years of age). For this reason, most elementary education experts identified the fourth grade as the earliest age at which bicycle-safety education could be accomplished with reasonable efficiency. Some experts believed that education should not be introduced until the fifth grade, but few expressed the view that it would be effective to introduce a truly comprehensive education program earlier than the fourth grade.

The data show that the potential payoff of a comprehensive educational program introduced at the fourth-grade level would be about 87%. But, what about the 13% of the accidents that will have already occurred before the education is introduced? When attempting to formulate an answer to this question, the data were examined to determine the type of accidents that involve bicyclists who have not yet reached the fourth grade (bicyclists younger than about nine years of age). It was found that bicyclists younger than nine years of age are involved in a relatively small number of different types of accidents. About 60% of the accidents are "bicyclist-rideout" accidents that occur at the junction of a street and driveway/alley, at an intersection controlled by a stop sign, or at an uncontrolled intersection. Another 15% of the accidents occur when a bicyclist makes an unexpected left-hand turn into the path of an overtaking motor vehicle. This finding suggests the possibility of a limited educational program that would focus solely on the behavioral errors that contribute to "bicycle-rideout" and "unexpected-left-turn" accidents. Such a program would have maximum potential payoff if it was introduced at the kindergarten level; but because of the difficulty of educating kindergarteners, it is believed that the program would be most effective if introduced at the first-grade level.

A limited educational program introduced at the first grade and a comprehensive educational program introduced at the fourth grade would have a combined potential payoff in excess of 90%. The actual payoff would be a function of the program's effectiveness in achieving the desired behavioral changes and the extent to which the educational material is retained by the students. Even if a program proved highly effective in achieving the desired behavioral changes, it is unlikely that the effects would be long lasting without subsequent education to refresh bicyclists' recollection of key concepts and principles. If a comprehensive program is introduced at the fourth-grade level, it is believed that "refresher" education should be introduced at least every other year thereafter, through the tenth grade. It must be emphasized, however, that the recommendation about the grade levels for administering refresher education is based upon precious little empirical information. Once a comprehensive program has been developed, this issue can be resolved empirically by retesting students each year for several years after they have received the education. With such test data in hand, it would be a relatively simple matter to judge when retention has degraded enough to warrant refresher education.

In summary, the author's "best guesses" about the target groups for bicyclist education are as follows:

- First graders (six-year olds)--limited program aimed at "bicyclist-rideout" and "unexpected-left-turn" accidents.
- Fourth graders (nine-year olds)--comprehensive education program aimed at all types of accidents, including NMV accidents.
- Sixth graders (11-year olds)--reinforcement education aimed at all types of accidents.
- Eighth graders (13-year olds)--reinforcement education aimed at all types of accidents.
- Tenth graders (15-year olds)--reinforcement education with emphasis on Problem Types 6, 8, 9, 10, 13, 16, 17, 19, 22, 23, and 24.

Assuming that it is possible to introduce a program to educate the target groups defined above, it is then appropriate to ask, What is to be done to educate bicyclists who are older than the primary target group (fourth graders) at the time the program is first introduced? The answer to this question depends almost entirely on the funding available. Ideally, it would be possible to commence a long-term educational program by educating the entire population of bicyclists during the first year and educating only the primary target group in each subsequent year. However, a one-shot program to educate the entire population of bicyclists in a single year would involve monumental costs and countless logistics problems. In all likelihood, it would be impossible to obtain the funds needed to accomplish such an ambitious task. This means that educating the population must be accomplished over a number of years.

In the author's view, the education of each year's crop of first and fourth graders should be considered first priority. If additional funds can be obtained, they should be spent providing *comprehensive* education to as large a group of older bicyclists as is possible with the funds available, rather than providing *limited* education to every bicyclist older than the primary target group. A decision to exclude some bicyclists from a safety-education program may seem callous, but it would be far worse to decide upon expending the limited educational resources on a program that would provide only superficial education to large numbers of bicyclists.

EDUCATION TO ENHANCE PREPARATORY-PHASE FUNCTIONS

By definition, the Preparatory Phase of a bicycling trip commences when the operator makes a decision to execute a trip and terminates at the point at which the operator begins the task of selecting a course through a particular area. During the Preparatory Phase, a bicyclist must evaluate his own capability and that of his vehicle to complete the anticipated trip under the environmental conditions that will be encountered during the trip. In addition, the bicyclist must evaluate alternate routes to his destination and select the one that best suits his momentary needs. Education aimed at the Preparatory-Phase functions is based upon the assumption that bicycle accidents can be prevented by education that would increase bicyclists' ability and inclination to perform the Preparatory-Phase functions. The Level I and Level II educational objectives for enhancing the performance of Preparatory-Phase functions are listed in Table 22 and discussed below. The discussion includes objectives that are clearly important as well as some whose importance is marginal or has yet to be determined.

TABLE 22

EDUCATIONAL OBJECTIVES FOR ENHANCING PERFORMANCE OF PREPARATORY-PHASE FUNCTIONS

LEVEL I OBJECTIVES	LEVEL II OBJECTIVES
Increase bicyclists' ability and inclination to perform a safety check of bicycle before departing on a trip.	Increase knowledge of parts of bicycle and their functions. Increase knowledge of procedures and criteria for evaluating the bicycle's state of repair. Increase knowledge of procedures and criteria for evaluating the adequacy of safety equipment for the contemplated trip. Increase knowledge of procedures and criteria for determining whether the bicycle fits the rider. Increase knowledge of risk associated with riding a bicycle that has mechanical defects, is ill-fitting, and/or is not equipped with needed accessories.
Increase bicyclists' ability and inclination to repair bicycle and perform necessary maintenance and adjustments before departing.	Increase knowledge of maintenance, adjustment, and repair procedures/techniques. Increase knowledge of maintenance, adjustments, and repairs that should be accomplished by a parent or professional bicycle mechanic.
Increase bicyclists' ability and inclination to evaluate the impact of weather and lighting conditions that will be encountered during trip.	Increase knowledge of the effect of inclement weather on accident likelihood. Increase knowledge of the effect of darkness on accident likelihood. Increase knowledge of the necessity for lighting equipment when night riding cannot be avoided.
Increase bicyclists' ability and inclination to consider alternate routes to destination and to select the safest route.	(Level II objectives cannot be defined until additional research is conducted to determine the type and weighting of criteria to be used for evaluating the relative safety of alternate routes.)
Increase bicyclists' ability and inclination to consider their own capabilities for completing the contemplated trip safely.	Increase knowledge of the effect of specific mental and physical impairments on accident likelihood. Increase awareness of the effect of specific knowledge and skill deficiencies on accident likelihood. Increase awareness of the knowledge and skills required to complete various types of trips with reasonable safety.

Perform Safety Check of Bicycle

Mechanical condition. Nearly every bicycle-safety program in existence stresses the importance of performing a safety check of the bicycle before departing on a trip. Some programs merely attempt to induce the bicyclist to perform the safety check, whereas others are designed to teach bicyclists how the safety check is to be accomplished. If education is to be introduced at the fourth-grade level, it seems certain that many bicyclists will not possess the knowledge required to perform a safety check. Thus, if young bicyclists are to be taught to perform an effective safety check, it will be necessary to increase their knowledge of:

- The parts of a bicycle and their functions.
- The procedures and criteria for evaluating the state of repair of each bicycle part.
- The procedures and criteria for evaluating the adequacy of safety equipment for the contemplated trip.
- The procedures and criteria for determining whether the bicycle fits the rider.

Assuming a bicyclist can be taught how to perform the safety check, education also will be required to induce him to do so on a regular basis. This will require education to increase bicyclists' knowledge of the risk associated with riding a bicycle that has mechanical defects, is ill fitting, is not equipped with the necessary safety equipment, or a combination of these. In short, the bicyclist must be educated about the extent to which accident likelihood is increased when they fail to perform a safety check before departing on their trip.

Although there is evidence that a substantial proportion of bicycles have defects which are potentially accident producing (see Figure 6 in Section IV), it was found that a bicycle defect contributed to less than three percent of all bicycle/motor-vehicle accidents. The main contributor was defective brakes, which was a factor in about one percent of the bicycle/motor-vehicle accidents. The role of bicycle defects in NMV accidents is not known for certain, but many experts feel strongly that mechanical defects contribute to a substantial portion of NMV accidents. In summary, teaching bicyclists to check the mechanical condition of their bicycle could have a small, but significant, impact on bicycle/motor-vehicle accidents and possibly a far greater impact on NMV accidents.

Bicycle size/fit. The literature contains a great deal of instructional material that has been designed to teach bicyclists how to select the proper size bicycle and how to adjust the bicycle handlebars and seat to fit the rider. This fact reflects the common belief that many bicyclists ride ill-fitting bicycles, that a bicyclist's ability to maintain proper control is seriously degraded when riding an ill-fitting bicycle, and that accidents frequently result from bicyclists riding ill-fitting bicycles. These views are so logically appealing that it is difficult to argue with them; yet, there is little recent empirical data to support them. The author knows of no systematic research that has been conducted to determine the number of bicyclists who ride ill-fitting bicycles or to assess the extent to which control is degraded when bicycle fit is non-optimal. In Section V, it was mentioned that riding an oversized bicycle was a contributing factor in about one percent of all bicycle/motor-vehicle accidents. Although it seems probable that non-optimal fit would contribute to an even larger proportion of NMV accidents, no data have been located to support or refute this assumption. In addition to fit, as measured by the operator's ability to reach the pedals and handlebars, a small number of accidents were noted in which the bicyclist's hands were too small to grasp caliper-brake handles. Although only one or two bicycle/motor-vehicle accidents of this kind were noted, it is possible that this aspect of bicycle fit accounts for an important number of NMV accidents.

After reading the above paragraph, the reader may be surprised that teaching bicyclists to check the size and fit of their bicycle has been included as an educational objective. Although such education appears to have the potential for eliminating only a small number of bicycle/motor-vehicle accidents, it is the type of education that can be accomplished quickly and in a straightforward manner. The low cost of teaching bicyclists to check bicycle size and fit, combined with the possibility that such education would serve to reduce NMV accidents, seems sufficient justification for the inclusion of this educational objective.

Safety equipment. Education to induce bicyclists to check the type and condition of safety equipment on their bicycle appears to have considerable potential for reducing accidents. The main emphasis should be placed on lighting equipment. It will be recalled from Table 13 (Section III) that a large proportion of bicyclists involved in night accidents were riding a bicycle with inadequate lighting equipment. For instance, only 13% of the bicycles were equipped with an operational headlight, about 40% were equipped with side reflectors, about 40% were equipped with a front reflector, about 63% were equipped with reflectorized pedals, and 67% were equipped with a rear reflector. Although there is a clear need for the development of more effective bicycle-lighting equipment, it seems reasonable to assume that a substantial proportion of night accidents would be avoided if bicycles were equipped with the best lighting equipment that is presently on the market.

There is virtually no question that a safety-education program should place heavy emphasis on checking the adequacy of a bicycle's lighting equipment before departing on a trip that will involve night riding. Indeed, it is appalling to find that only 13% of the bicycles involved in night accidents were equipped with an operational headlight. Riding at night without a headlight reduces the bicycle's visibility to motorists and also may increase the likelihood of NMV accidents. Standard headlights provide sufficient illumination for the bicyclists to observe *major* street-surface defects and other large hazards. Headlights with greater than standard power will be required to provide the illumination needed to observe less visually prominent hazards, such as speed bumps, small debris in the roadway, cables across driveway entrances, and so on.

Other types of safety equipment that may decrease accident likelihood include safety flags, baskets and racks, chain guards, handlebar grips or tape, rear-vision mirrors, and auditory warning devices (horn or bell). Unfortunately, there are no data to use in estimating the number of accidents that would be eliminated if bicycles were equipped with such devices. It is known that lack of daytime conspicuity is a contributing factor in many bicycle/motor-vehicle accidents, and it is highly probable that daytime conspicuity would be increased by safety flags. However, the potential benefit of educating bicyclists to equip their bicycles with safety flags cannot be estimated until research is conducted to evaluate their effectiveness. Additional research is also needed to evaluate the benefit of education to equip bicycles with the other safety-equipment items listed above.

In summary, it is highly probable that considerable benefit would derive from educating bicyclists about the need for effective lighting equipment. Educating them about the benefit of other safety-equipment items remains uncertain at this time, but providing such education would certainly not be harmful if it could be accomplished without reducing the time available to educate bicyclists about more important matters.

Bicycle maintenance, adjustments, and repairs. As was stated above, about three percent of all bicycle/motor-vehicle accidents are the direct or indirect result of bicycle defects. Some experts believe that a substantial number of NMV accidents result from bicycle malfunctions, but no data are available to estimate this number accurately. Unless the number of NMV accidents resulting from bicycle defects proves to be large, the accident reduction potential of education about bicycle repair and adjustment must be considered marginal at best. In light of these facts, education about bicycle repair and adjustment would not be cost-effective unless methods can be developed to accomplish this educational objective with only a small expenditure of time and resources.

It is unlikely that cost-effective methods could be developed to teach young bicyclists the full range of skills required to fully maintain their bicycles and repair any malfunction that could arise. However, it is possible that it would be cost-effective to (a) teach bicyclists to perform the most simple maintenance, adjustment, and repair tasks, and (b) teach bicyclists the specific tasks that should be performed by a parent or professional bicycle mechanic. For instance, it should be a relatively simple matter to teach young bicyclists to adjust their seat and handlebars, tighten loose nuts and bolts, replace dead batteries in headlights, clean reflectors, adjust the chain, and perhaps other simple maintenance and repair tasks as well.

As of now, the advisability of educating bicyclists to maintain, adjust, and repair their bicycles remains uncertain. Whether or not teaching such skills should be established as an educational objective will depend on the level of skill that must be acquired, the efficiency of the methods that are developed to teach the skill, and the time and resources needed to accomplish more important educational objectives. In any event, teaching such skills cannot be considered a *primary* educational objective.

Evaluation of Weather and Lighting Conditions

Decisions about whether or not to make a trip and decisions about an optimal route to a destination should be based upon a careful consideration of the weather and lighting conditions that will be encountered during the trip. Judicious decisions can be made only if bicyclists have a clear knowledge of the effect of inclement weather on accident likelihood, the effect of darkness on accident likelihood, and the necessity for effective lighting equipment when riding at night. According to the evidence presently available, the incidence of bicycle riding is reduced drastically at night and during periods of inclement weather. Even so, night accidents account for about one-third of all fatalities and ten percent of all injuries resulting from bicycle/motor-vehicle accidents. About three percent of the bicycle/motor-vehicle accidents in the Cross and Fisher study (1977) sample were found to occur during inclement weather, but the number of inclement-weather accidents may be considerably higher in some geographical areas. Moreover, it is probable that inclement weather contributes to a substantial number of NMV accidents.

For the above reasons, educating bicyclists to carefully evaluate weather and lighting conditions is considered a worthwhile objective for a bicycle-safety education program. The education should induce bicyclists to either refrain from riding at night and during periods of inclement weather or, at least, select routes that are safest when lighting and/or weather conditions are suboptimal. Education about route selection is discussed in detail below.

Route Selection

Teaching bicyclists to select the "safest" route is among the most common objectives of existing educational programs. However, programs differ greatly in what bicyclists are taught about route selection. Some programs accomplish little more than making an emotional appeal to always select the safest route. These programs make no reference whatsoever to the criteria to be used in evaluating the relative safety of alternate routes. Some safety-education programs developed for school-age children provide explicit instruction on safe routes to school. The safe routes to school are usually defined by an employee of the local traffic engineering department. Although the criteria used to select safe routes to school are seldom defined explicitly, it appears that heavy weighting is placed on: roadway width, traffic volume, traffic speed, parking density, number of intersecting roadways (including driveways and alleys), number of traffic signs and signals, complexity of intersection configuration, roadway-surface condition, and number of left-hand turns required to travel the route. No program has been found that identifies both the types and relative importance of route selection criteria.

There are three problems that must be addressed before it will be possible to increase bicyclists' ability and inclination to select the safest route to their destination. First, it will be necessary to conduct research to clearly establish the relationship between accident likelihood and various route characteristics. A careful search of the literature has revealed no such data, so it must be concluded that existing materials on route selection criteria are based upon logical considerations rather than on empirical data. Although it is probable that accident likelihood is far greater on some types of roadways than on others, it is also probable that the most dangerous routes are not the ones that would be judged most dangerous by a panel of experts. As a whole, bicyclists and motorists are capable of recognizing dangerous situations and countering the hazard by exercising more caution than normal. Because of this fact, accident likelihood may very well be inversely related to the *apparent* hazardousness of the situation.

If route selection criteria can be established empirically, the next problem that must be dealt with is that of developing techniques that will enable young bicyclists to evaluate alternate routes in terms of these criteria. Unless all criteria are of equal importance, a comparison of alternate routes will require a bicyclist to formulate a composite safety index for each route based upon different combinations of differently weighted variables. Such a task would be difficult for adults and quite impossible for children if the number of criteria is large and their weights highly variable.

A third problem is that of inducing bicyclists to select the safest route when an alternate route is faster, shorter, flatter, or otherwise more desirable to the bicyclist. Bicyclists are notorious for their reluctance to: deviate significantly from the most direct route, climb long or steep hills when they can be avoided, ride on rough roads when a smoother route is available, and ride on a roadway with many stop signs/signals when a more continuous route is available. Therefore, it will be difficult to develop educational methods that will modify bicyclists' values to such an extent that safety considerations will always have priority over riding ease, efficiency, and enjoyment.

As is shown in Table 22, the uncertainties about educating bicyclists to select safe routes are so great that it is not presently possible to define Level II objectives; the above discussion shows that the possibility and desirability of accomplishing this educational objective remains in serious doubt. However, one fact seems certain: it would be extremely difficult to teach young children the complex computational skills needed to make an objective assessment of the safety of alternate routes. This suggests that it may be necessary for an expert to make an objective assessment of all or most roadways in a community and to use the results to develop a special map that classifies each roadway in terms of its safety for bicycle travel. Such a map would be a valuable training aid for young bicyclists and a valuable route-selection aid for bicyclists of all ages.

Bicyclists' Evaluation of Their Own Physical/Mental Capabilities

It would be highly desirable if bicyclists could be taught to make a rational assessment of their own capability to complete a trip safely--given the bicycle they intend to ride, the conditions under which they intend to ride, and the characteristics of the route they plan to take to the destination. In order to provide such education, it is first necessary to define, in some reasonably exacting terms, the types of bicyclists that are incapable of safely completing certain types of trips. In principle, a bicyclist may be incapable of completing a certain type of trip safely because of specific knowledge deficiencies, physical impairments, sensory impairments, or mental impairments. The impairments may be temporary or permanent. In practice, it is very difficult to establish a firm relationship between accident likelihood and any of the types of deficiencies or impairments that may contribute to accidents. Furthermore, it would be necessary to measure the capabilities of individual riders before it would be possible to instruct them about their ability to complete a trip with reasonable safety. For these reasons, it is necessary to identify specific groups with easily measurable characteristics that are known to be related to accidents.

Since there is a high correlation between age on the one hand and knowledge and skill level on the other, it seems safe to assume that age can be used to identify bicyclists who are incapable of making certain types of trips with reasonable safety. A second group of bicyclists who are incapable of bicycling with reasonable safety are those who are temporarily impaired by alcohol or drugs. The study of bicycle/motor-vehicle accidents showed that about two percent of the accidents involved a bicyclist who was under the influence of alcohol or drugs. A third high-risk group is bicyclists who are retarded. Surprisingly, it was found that about one percent of the bicycle/motor-vehicle accidents involved a retarded bicyclist, and it is altogether possible that the actual proportion is somewhat greater. Clearly, even moderately retarded bicyclists must be considered incapable of bicycling safely. A fourth high-risk group includes bicyclists with sensory or motor impairments. Impaired vision and impaired limbs, together, were found to contribute to about one percent of all bicycle/motor-vehicle accidents.

Is it reasonable to believe that education would be effective in inducing young bicyclists, permanently impaired bicyclists, or temporarily impaired bicyclists to refrain from riding? With one exception, it is believed that this question must be answered negatively. It is believed that education has some potential for inducing young bicyclists to refrain from taking trips[7] that are clearly beyond their capability to complete with a reasonable degree of safety. It is believed that this education would be particularly effective if combined with a program to educate parents about the types of trips that young children should not be permitted to take unless accompanied by an adult. Some additional research will be required to identify the types of trips that are excessively hazardous for bicyclists in various age groups.

A program to induce retarded bicyclists to refrain from riding would be difficult to develop and costly to administer. It would be equally difficult to develop education that would induce bicyclists to avoid riding a bicycle when they are under the influence of alcohol or drugs. Historically, education has not proved highly effective in reducing the number of motor-vehicle operators who drive while under the influence of alcohol or drugs, and there is no reason to expect that such education would be more effective for bicyclists than for motorists. In short, education to increase retarded and impaired bicyclists' ability and inclination to consider their own capabilities for completing the contemplated trip safely must be considered of secondary importance.

EDUCATION TO ENHANCE ANTICIPATORY-PHASE FUNCTIONS

Once a bicyclist has decided to travel a given segment of roadway, he must decide upon the specific path he will follow and the speed he will travel as he traverses that segment of roadway. The term *course selection* refers to the selection of a path and a speed to be traveled along a roadway segment and should not be confused with the term *route selection*. By definition, the Anticipatory-Phase functions are those that a bicyclist must perform to select the safest course through an area. The safest course through an area is the lawful and reasonable course for which accident likelihood is smallest. A course is not considered reasonable if it is so inconvenient or uncomfortable that even a skilled, safety-conscious bicyclist would never select that course. All courses other than the safest one are referred to here as "suboptimal" courses; only the safest course is referred to as "optimal." As is discussed later, it is often difficult to define the single course that is optimal in some traffic contexts.

It was found that about 75% of all bicycle/motor-vehicle accidents were either the direct or indirect result of the bicyclist's selection of a suboptimal course. In about 15% of the cases, the bicyclist's suboptimal course led directly and immediately to the crash. That is, because of the bicyclist's suboptimal course, neither operator had

[7]The term trip is used here in the broadest sense of the word. It includes both travel to a specific destination and recreational riding with no specific destination.

sufficient time to initiate successful evasive action once the other vehicle could first be seen. These accidents became inevitable at the moment the bicyclist decided on the suboptimal course. In another 60% of the cases, it was judged that the bicyclist's suboptimal course was not the most immediate cause of the accident, but contributed to the accident by (a) decreasing the time and space available for evasive action and/or (b) increasing the level of skill required for successful evasive action. That is, while there was sufficient time and space for successful evasive action once the other vehicle first became observable, successful evasive action required far more skill or a higher level of alertness than would have been required if the bicyclist had not selected a suboptimal course.

The contribution of bicyclists' suboptimal pre-crash courses to bicycle/motor-vehicle accidents has important implications for bicycle-safety education. These findings emphasize the fact that there are some accidents that simply cannot be avoided by educating bicyclists to respond to potentially threatening motor vehicles in the environment. Rather, the education must concentrate on decisions that are made before a potentially threatening motor vehicle can be observed. This is not to suggest that educating vehicle operators about course selection is new. Indeed, many of the laws, ordinances, and safety rules that have been developed for both motor-vehicle and bicycle operators have been designed to induce vehicle operators to select the safest possible path and speed through an area.

The educational objectives for enhancing the performance of the Anticipatory-Phase functions are listed in Table 23 and are discussed below. Level I and Level II objectives are discussed in turn.

Education on Course Selection--Level I Objective

It is unlikely that there would be sufficient time in even the most extensive education program to teach bicyclists the optimal course to follow in every traffic context they might encounter. And yet, with only a few exceptions, it is impossible to formulate general rules about course selection that are valid for all traffic contexts and effective in prescribing the *exact* course that minimizes accident likelihood. It is therefore necessary to focus on the course-selection behavior that has the greatest accident reduction potential. The course-selection behavior that is most critical for bicycle/motor-vehicle accidents can be defined from a study of the accident illustrations presented in Section V. Other important course-selection behavior undoubtedly would be revealed by the study of NMV accidents.

The general objectives of education to enhance the performance of Anticipatory-Phase functions is to increase the bicyclists' ability and inclination to select the optimal course through an area. The specific behavior the education must induce is outlined in the left-hand column of Table 23 and is discussed in more detail below. It is important that the reader keep in mind that the objectives included here do not include teaching bicyclists the evasive actions that are required when a potentially threatening motor vehicle is observed. Evasive action is one of the Reactive-Phase functions discussed later.

TABLE 23

EDUCATIONAL OBJECTIVES FOR ENHANCING PERFORMANCE OF ANTICIPATORY-PHASE FUNCTIONS

LEVEL I OBJECTIVE	LEVEL II OBJECTIVES
Increase bicyclists' ability and inclination to select the optimal course through an area: ■ Always ride with traffic. ■ Select optimal course when entering the roadway. ■ Stop at signed intersections. ■ Avoid entering signalized intersections after the onset of the amber phase. ■ Select optimal course at uncontrolled intersections. ■ Select optimal course when making left-hand turns. ■ Select optimal course when visual obstructions are encountered. ■ Ride an optimal distance from right-hand edge of roadway. ■ Select optimal speed when riding downhill, when riding during darkness, and when riding on wet or debris-covered roadway.	Increase ability to identify optimal course for high-hazard locations, maneuvers, and conditions. Increase the validity of bicyclists' assessment of the relative degree of risk associated with optimal and suboptimal courses. Increase knowledge of needs that are in competition with the need for safety, and decrease the perceived need satisfaction associated with suboptimal courses. Increase ability and inclination to search for, recognize, and cope with visual obstructions. Increase validity of expectations that may influence course selection. Increase knowledge of the time and space required to respond to a threat (as a function of bicycle handling skill and bicycle speed). Increase knowledge of amber-signal phase.

Ride with traffic. One of the most important educational objectives is to teach bicyclists to always ride with traffic. This is one of the few rules about course selection that is explicit and generalizable to nearly every traffic context. The only case in which the rule does not apply is the roadway with a two-way bike lane along it. However, two-way bike lanes do not represent a serious problem because there are so few of them; it is unlikely that additional two-way bike lanes will be built since they are universally disapproved in the contemporary literature dealing with bicycle-facilities design.

Entering roadway. About 15% of all fatal and 14% of all non-fatal bicycle/motor-vehicle accidents occurred as a bicyclist was entering the roadway at a mid-block location; the bicyclist's course was judged suboptimal in nearly every case. It is tempting to propose that bicyclists be educated to always stop and walk their bicycle into the roadway. However, it is unlikely that education could ever induce bicyclists to adopt such an inconvenient behavior pattern, especially when there are no laws and ordinances to motivate them to do so. It seems more reasonable to develop educational methods to accomplish the following objectives:

- Teach bicyclists to never enter a roadway by riding over a curb or any other discontinuity at the roadway edge that is so large/rough that they must scan downward at the curb/discontinuity rather than searching for approaching traffic.
- Teach bicyclists to slow their roadway-entry speed to the extent needed to provide sufficient time to search for approaching traffic and to initiate successful evasive action.
- Teach bicyclists to select an entry path that minimizes the time they are exposed to traffic.

These educational objectives cannot be accomplished by requiring bicyclists to learn a few general rules, because the optimal course for entering the roadway varies greatly with the physical characteristics of the traffic context and the intended direction of travel by the bicyclist. Rather, bicyclists must be taught the exact course to follow in a wide range of specific traffic contexts, including those in which visual obstructions are present. For each traffic context, the bicyclist must be taught the best course to follow when turning right, turning left, and proceeding straight across the roadway.

Signed intersections. The importance of education that will induce bicyclists to select an optimal course at signed intersections cannot be emphasized enough; a suboptimal course at signed intersections was a prime contributor to about eight percent of all fatal and 10% of all non-fatal bicycle/motor-vehicle accidents. There is no question that young bicyclists should be taught to come to a *complete* stop at *all* signed intersections. Whether older bicyclists should be taught to come to a complete stop or to merely slow to a very low speed remains open to question.

One fact is certain: this educational objective will not be accomplished by teaching bicyclists the law. Bicyclists know full well that the law requires bicycles to stop at signed intersections, even very young bicyclists. To be effective, education must convince bicyclists of the necessity for stopping (or at least slowing significantly) at all signed intersections, including those that carry light traffic and are not perceived as hazardous by the bicyclist.

Signalized intersections. Inducing bicyclists to avoid running red lights probably should be included among the objectives of an education program, but few accidents occur because bicyclists blatantly ride through a red light. Instead, the accidents usually occur because a bicyclist enters the intersection after or shortly before the onset of the amber phase. The problem is sometimes compounded by a multiple-threat situation in which the bicyclist is struck after passing in front of one or more lanes of standing motor vehicles whose operators have observed the bicyclist and are waiting for him to pass. Accordingly, two important objectives are:

- Teach bicyclists to avoid entering a signalized intersection after the onset of the amber phase.
- When bicyclists see they cannot clear the intersection before the onset of the red light, teach them to stop at a central island or, if none is available, continue at a slow speed and search the traffic lanes beyond any motor vehicles that are stopped--apparently waiting for the bicyclist to clear the intersection--before proceeding.

Uncontrolled intersections. Less than three percent of all bicycle/motor-vehicle accidents occur at uncontrolled intersections. Even so, education on course selection must be considered an important objective. Except for the different traffic context, these accidents occur in much the same way as those occurring when bicyclists enter the roadway from a mid-block location. Speed control is of primary importance but path selection may be important when visual obstructions are present.

Left-hand turns. Most accidents that occur when a bicyclist turns left into the path of a motor vehicle are the direct result of the bicyclist's failure to search.

However, it is possible that the bicyclist's inclination to search may be influenced by the specific course he adopts for making the left-hand turn. Analytical considerations and casual observations have led the author to conclude that the course many bicyclists select for left turns imposes excessive demands on their information-processing system. For instance, a sharp left-hand turn from the right-hand curb requires the bicyclist to search simultaneously both the overtaking and the opposing lanes of traffic. The difficulty of this task is a direct function of the number of traffic lanes in each direction and the volume of motor-vehicle traffic at the time. The information-processing load on the bicyclist would be less if he executed a two-phase turn. He would first scan behind for overtaking traffic and proceed to the center of the roadway when it was safe to do so. He would then ride along the center of the roadway until he had scanned ahead and determined that it was safe to turn left across the opposing traffic lane(s).

Education on left turns requires that bicyclists be taught to evaluate the traffic context in terms of its general complexity and select a course that does not place excessive demands on the bicyclist's information-processing system. The greatest benefit would result from explicit demonstrations of the optimal course for a left-hand turn in a wide variety of traffic contexts, including those that clearly overload the bicyclist's information-processing system.

Visual obstructions. The importance of visual obstructions for course selection has been mentioned in the above discussion of course selection when entering the roadway at a mid-block location and when entering signed, signalized, and uncontrolled intersections. Visual obstructions are also important when riding on sidewalks that intersect alleys and driveways and when riding on uncontrolled roadways that intersect controlled streets and controlled or uncontrolled driveways/alleys. It is in these situations that motorists inadvertently drive into the path of the bicyclist because the bicyclist is obscured from view. Since visual obstructions are a contributor to such a large number of different types of accidents, it seems worthwhile to establish as a separate objective the education of bicyclists to recognize and cope with visual obstructions. Obviously, there is a great deal of overlap between this objective and those discussed earlier in this section.

Proximity to right-hand edge of roadway. Most communities have a law or ordinance stating that "bicyclists must ride as close to the right-hand edge of the roadway as is practicable." Such a law is difficult to enforce because what is "practicable" depends on such a wide variety of factors. Simple rules about how close to the edge of the roadway bicyclists should ride are more likely to be counterproductive than productive. What is needed is highly specific instruction on the best path to follow (relative to the edge of the roadway) on each of a wide variety of traffic contexts and for bicyclists with various skill levels.

Unfortunately, there is considerable disagreement, even among bicycling experts, about how close to the edge of the roadway bicyclists should travel in order to minimize accident likelihood. The problem stems from the fact that riding too far to the right increases the likelihood of some types of accidents and riding too far to the left increases the likelihood of other types of accidents. For instance, when riding along a row of parallel-parked motor vehicles, riding too far to the right increases the chances of colliding with an opening car door, and riding too far to the left increases the chances of being struck by an overtaking motor vehicle. The path that is optimal in this situation depends on such factors as: the width of the roadway, the volume and speed of overtaking motor vehicles, the bicyclist's ability to see whether the parked vehicles are occupied, the bicyclist's ability to maintain accurate lateral control, and perhaps others as well. The bicyclist is faced with a similar dilemma when there are other obstacles or roadway-surface debris in the area where he would ordinarily choose to ride.

The author is not yet prepared to make specific recommendations about how close to the right bicyclists should be taught to ride in various traffic contexts. It is believed that analytical study by a group of experts and perhaps additional field research will be required to formulate specific recommendations about where bicyclists should be taught to ride in various traffic contexts.

Other course control. In the above paragraphs, the educational requirements for course selection were defined in terms of hazardous traffic contexts, hazardous maneuvering, or both. There are additional educational requirements for course selection that must be defined in terms of general conditions or situations rather than specific traffic contexts. All of the important requirements of this type are for speed control, including:

- Speed control when riding downhill.
- Speed control when riding on a wet roadway.
- Speed control when riding with wet caliper brakes.
- Speed control when riding on a roadway covered by sand, gravel, or other debris.
- Speed control during darkness.

There was no one of the above conditions in which suboptimal speed control contributed to large numbers of accidents; but together they easily constitute a significant enough problem to warrant attention in a safety-education program. What must be accomplished is to teach bicyclists the fastest speed that is safe under each of these conditions.

Education on Course Selection--Level II Objectives

At Level II, educational objectives are defined in terms of the knowledge that must be imparted, the skills that must be developed, and the values that must be modified in order to achieve the behavioral changes specified by the Level I objectives. Accordingly, the Level II objectives described below were formulated through a study of the reasons why bicyclists in the accident sample selected a suboptimal course. The Level II objectives for enhancing the performance of the Anticipatory-Phase functions are listed in the right-hand column of Table 23 and are discussed below.

Increase ability to identify optimal course. Although bicyclists often select a course they know is less safe than another, there are many cases in which bicyclists lack the knowledge and skill needed to differentiate the optimal course from the many suboptimal courses that are available. Thus, a primary educational objective is to teach bicyclists to identify the optimal course for a wide variety of traffic contexts, maneuvers, and conditions. First priority should be given to the high-hazard traffic contexts, maneuvers, and conditions that were identified in the discussion of Level I objectives.

Education to increase bicyclists' ability to identify optimal courses must commence with instruction that will (a) increase bicyclists' inclination to search their immediate surroundings and (b) increase their ability to recognize the physical and operational attributes of the traffic context that influences the relative safety of alternate courses through that area. The acquisition of this skill involves discrimination learning. The bicyclist must learn to scan a highly complex visual field and discriminate the relatively small number of stimuli that are relevant for course selection. Although the acquisition of this skill sounds difficult, humans can often acquire such a skill in less time than it takes to describe it.

The second task is to teach bicyclists to recognize the high-hazard locations, maneuvers, and conditions. This education must establish a powerful association between specific sets of cues and a bicyclist's expectation that a hazardous situation will arise. If the associations are powerful enough, it would be difficult for bicyclists to avoid becoming more alert and attentive when such cues are encountered in the traffic environment. The sole purpose of this type of training--often referred to as hazard-recognition training--is to increase a vehicle operator's level of alertness and attentiveness under selected circumstances. In some instances, hazard-recognition training is all that is required. That is, once an operator is alerted to the fact that he is in a potentially hazardous situation, he has both the motivation and capability to cope with the situation.

A third task is to eliminate any uncertainties and misconceptions about the exact path that is safest. As was suggested earlier, this task cannot be accomplished by teaching bicyclists a few generalized rules. Rather, it will be necessary to demonstrate the exact course that is optimal for a large and representative sample of high-hazard traffic contexts, maneuvers, and conditions. Specifying the optimal course is simple and straightforward for some situations; in other cases, it may be difficult or impossible with the information presently available. Although there is still a considerable amount of controversy about the course that is optimal in some situations, this fact in no way changes the need to provide *highly explicit* instructions on course selection.

The final task is to reinforce the education described above through exercises in course selection. Such exercises would expose bicyclists to a variety of situations and require them to identify the optimal course for each situation. The exercises must cover the full range of traffic contexts, maneuvers, and conditions. An essential part of such exercises is immediate feedback on the correctness of the bicyclist's choice and reiteration of the reasons why one course is safer than others.

Risk assessment. There are countless cases in which bicyclists select a course that they know is less safe than another they could have chosen. Riding through a stop sign is a good example; even very young bicyclists know it is safer to stop than to proceed without stopping. Such acts, when committed knowingly, are often assumed to reflect an abnormally high willingness to take risks; persons who commit such acts are often called "risk takers." However, there is no evidence that more than a minute fraction of the so-called risk takers are any more willing to accept risk than the bicycling population at large. That is, the thought of an accident, with its attendant pain and suffering, is no less repulsive to the so-called "risk taker" than to persons who ride more safely. The results of the bicycle/motor-vehicle accident study showed that most bicyclists who knowingly select a suboptimal course do so because of the fallacious belief that the added risk associated with the suboptimal course is inconsequential. In short, the problem is that of risk *assessment* rather than risk *acceptance*.

Conventionally, bicyclists acquire their notions about the relative risk of alternate courses through long-term observation of near accidents or through analytical considerations. This is an inefficient and often unreliable way to acquire knowledge about how much more risky one course is than another. Young children are at a particular disadvantage because both their experience and their analytical skills are more limited than an adult's. Consequently, an important objective of a safety-education program is to increase the validity of bicyclists' assessment of the relative degree of risk associated with optimal and non-optimal courses that may be chosen. It is presumed that this education would be administered at the same time bicyclists are taught to identify the optimal course for the various high-hazard situations.

It is unlikely that it would be possible to obtain the data needed to develop an objective, numerical index of risk for each course that could be selected in the many traffic contexts that bicyclists encounter. However, it is believed that sufficient information is available (research data, analytical findings, and expert opinion) to convince bicyclists that (a) the optimal course is *significantly* safer than any other and (b) the absolute risk associated with suboptimal courses is great enough to justify avoiding them.

Competing needs. Bicyclists sometimes have momentary needs that are best served by a suboptimal course. Such needs are referred to here as "competing needs" because they are in direct competition with the need for safety. A need to conserve time is an example of a competing need. Every bicyclist knows that stopping for stop signs serves to frustrate a need to conserve time; the need is better served by failing to stop. Even though a bicyclist is fully aware of the risk associated with both courses and has a normal need for safety, he will always choose to ride through a stop sign when his need to conserve time becomes very strong. If the bicyclist is rushing to the aid of a sick relative, his decision to ride through a stop sign may be altogether rational.

How does one induce bicyclists to select the optimal course when competing needs are present? In principle, this can be done in two ways: increase the composite need satisfaction associated with the optimal course, or decrease the composite need satisfaction associated with suboptimal courses. There is much uncertainty about how to achieve either of these results through education. One potential technique is to educate bicyclists about undesirable consequences of selecting a suboptimal course *other* than accidents. At present, the number of other undesirable consequences are few. However, with effective law enforcement, parental guidance, and school programs, the relative need satisfaction associated with optimal and suboptimal courses might be modified by informing bicyclists of the likelihood and consequences of receiving a traffic citation and/or getting caught and punished by parents, school authorities, or both. In principle, this technique would serve to increase the *positive* value of the optimal course and increase the *negative* value of the suboptimal courses.

Another approach is to reduce the *perceived* need satisfaction associated with a suboptimal course. For instance, bicyclists might be presented with objective data that demonstrate the small amount of time saved and energy conserved by failing to stop for stop signs, taking a shortcut that requires riding against traffic, and so on.

There is no reason to expect that it will be easy to develop educational methods that will be effective in offsetting the influence of competing needs on course selection. Hopefully, one or more readers will be able to offer suggestions about how best to deal with this difficult problem.

Visual obstructions. A course that is optimal under ordinary circumstances may be highly hazardous when an object is present that obstructs the bicyclist's view, the motorist's view, or both. The failure to adopt a course that best offsets the effects of a visual obstruction may be due to the bicyclist's failure to observe the obstructing object, his failure to recognize that the object obstructs his view of a critical part of the traffic environment, or his lack of knowledge about the course that minimizes accident likelihood in such situations. Therefore, education is needed to accomplish the following:

- Increase bicyclists' ability and inclination to search for and recognize objects that obstruct their view, the motorist's view, or both.
- Increase bicyclists' understanding of the degree to which visual obstructions may reduce response time and, thereby, decrease the possibility of successful evasive action.
- Teach bicyclists the best course to follow to compensate for visual obstructions.

Teaching bicyclists to recognize and cope with visual obstructions is a special case of the education to increase their ability to identify the optimal course through an area (discussed above). In order to accomplish the above objectives, bicyclists must be taught the types of objects that frequently obstruct vehicle operators' views, the types of locations where critical visual obstructions are frequently encountered, the types of accidents that most frequently result (wholly or in part) from visual obstructions, the relationship between the size of the obscured field and the size and distance of the obstructing object, and the exact course (speed and path) that should be followed in each of a wide range of the traffic contexts where visual obstructions often contribute to accidents. Young bicyclists have the most urgent need for such education, but the need is by no means limited to juveniles.

Invalid expectations. All vehicle operators develop a set of expectations about the physical characteristics of the traffic system and about the behavior of those who use the traffic system. This set of expectations has an important influence on both the path and speed a vehicle operator chooses to travel. Some expectations are developed from a knowledge of the laws and ordinances that govern the behavior of the various users of the traffic system. Other expectations are based upon direct observations of the physical characteristics of the traffic system and the behavior of persons who use it. Vehicle operators frequently develop expectations that do not correspond with reality. These invalid expectations usually stem from the assumption that the physical characteristics of the traffic system and the behavior patterns of roadway users are more predictable and uniform than they are in fact.

The results of the study of bicycle/motor-vehicle accidents showed that invalid expectations were a frequent contributing factor to bicyclists' selection of a suboptimal course.[8] Invalid expectations most often led bicyclists to travel at an excessive speed, but path selection was adversely affected in a significant number of cases. Invalid expectations that frequently had an adverse influence on course selection include: expectations that an area will be void of motor-vehicle traffic, expectations that motor-vehicle operators can and will observe bicyclists, and expectations that motor-vehicle operators will always behave in a lawful manner. There were a small, but important, number of bicyclists whose suboptimal course resulted from invalid expectations about the behavior of another bicyclist. The most important expectations that must be corrected through education include:

- The expectation that all traffic on intersecting roadways will stop/yield in accordance with the law.
- The expectation that all traffic in opposing lanes will yield before turning left--in accordance with the law.
- The expectation that a riding companion will select a safe course.
- The expectation that a specific roadway will be void of all traffic at a specific time.
- The expectation that bicyclists will always be observed by motorists when visibility conditions are good.
- The expectation that lawful lighting equipment on a bicycle ensures that it will be observed at night by all motorists.
- The expectation that parallel-parked vehicles will not be occupied.

Probably the best way to eliminate invalid expectations is to illustrate and discuss the types of accidents that result from invalid expectations. Invalid expectations *cannot* be eliminated by instructing the bicyclist to "expect the unexpected." Such worthless bits of advice are worse than no education at all.

Time/space required to respond to threat. Much of the instruction discussed above presumes that bicyclists will be taught to estimate, with reasonable accuracy, the time and space required to stop and to change directions as a function of such factors as: bicycle speed, roadway-surface condition, the direction and magnitude of the roadway slope, the bicyclist's reaction time and vehicle-handling skill, the type of bicycle, and the type of brakes. It would be quite impossible to define a safe course without knowing the amount of time and space required to reduce the bicycle's speed and/or change directions in response to an actual or potential threat.

[8] Invalid assumptions also had an adverse effect on bicyclists' assessment of the need to search for hazards and the need for evasive action once a potential threat had been observed. However, these are Reactive-Phase functions and will not be discussed until later.

Unfortunately, no data are available to use in estimating the frequency with which bicyclists select a suboptimal course because they underestimate the time/space required to stop or to turn. However, there is evidence that bicyclists sometimes delay the initiation of evasive action unnecessarily because they misjudge their ability to stop or turn under unusual conditions. The study of bicycle/motor-vehicle accidents revealed a small, but significant, number of accidents that were caused partly by the bicyclist's misjudgment of the time/space required to stop/turn when riding on a wet roadway, when riding with wet caliper brakes, when riding down a steep slope, and when riding on a roadway surface covered by sand or gravel. There were also a few cases in which the bicyclist misjudged the amount of time required to grasp and manipulate the caliper-brake levers. If these misjudgments adversely affect evasive actions, it seems reasonable to assume they also would adversely affect course selection.

Some attention has been given to educating bicyclists about the stopping distance of both bicycles and motor vehicles. Several films have been produced for this purpose. Additionally, tables and graphs have been developed for use in demonstrating the relationship between stopping distance and vehicle velocity. In the author's view, classroom instruction must be supplemented with outdoor training and demonstrations. To be maximally effective, the training must cover a wide range of speeds and a wide range of conditions (wet roadway, wet caliper brakes, traveling downhill, and sand-covered roadway surface). Moreover, the training must address both stopping distance and turning radius.

Length of amber-signal phase. In order to counter the bicycle/motor-vehicle accidents that occur at signalized intersections, bicyclists must be taught to avoid entering the intersection after the onset of the amber phase. An important part of this education is to inform bicyclists of the length of the amber phase and the distance a bicyclist can travel during this brief period. Since the length of the amber phase is variable, bicyclists should be taught to base their decisions on the shortest amber phase that may be used for roadways with two, four, and more than four lanes. Bicyclists must also be taught exactly what to do if they are unable to clear the intersection before the light turns red. The primary objective, however, is to teach bicyclists to avoid this situation.

EDUCATION TO ENHANCE REACTIVE-PHASE FUNCTIONS

The Reactive-Phase functions are those required for a bicyclist to observe a motor vehicle that poses a threat and to perform the actions necessary to avoid a collision with that motor vehicle. Specifically, the bicyclist must: (a) search the relevant portions of the environment for threatening vehicles, (b) detect the presence of vehicles that constitute a threat, (c) assess the velocity vector of the other vehicle with respect to his own and judge whether the vehicles are on a collision course, (d) if the vehicles are not on a collision course, determine whether a probable action by the motor-vehicle operator could place the vehicles on a collision course, (e) identify the action that is most likely to result in accident avoidance, and (e) perform the motor behavior required to implement the action decided upon. When defining accident causation, a function failure during the

Reactive Phase can occur only if the threatening motor vehicle could have been observed soon enough for the bicyclist to have successfully completed all of the Reactive-Phase functions. Thus, when critical visual obstructions are present, it must be said that the critical function failure occurred during the Anticipatory rather than the Reactive Phase.

The types of Reactive-Phase function failures that most often contribute to bicycle/motor-vehicle accidents are reflected in the educational objectives that were formulated to enhance the performance of the Reactive-Phase functions. In the following discussion of these objectives, the description of each Level I objective is followed immediately by a description of the associated Level II objectives. The Level I and Level II objectives are summarized in Table 24.

Education to Enhance Search Behavior

The first Level I objective listed in Table 24 is to "increase bicyclists' ability and inclination to search effectively for motor vehicles that pose a threat." This is the most important single objective discussed in this report. The data on bicycle/motor-vehicle

TABLE 24

EDUCATIONAL OBJECTIVES FOR ENHANCING PERFORMANCE OF REACTIVE-PHASE FUNCTIONS

LEVEL I OBJECTIVES	LEVEL II OBJECTIVES
Increase bicyclists' ability and inclination to search effectively for motor vehicles that pose a threat.	Increase knowledge of the limitations of the visual system. Increase inclination and ability to search selectively and to recognize cues signaling the presence of a threat. Increase validity of expectations that may influence bicyclists' assessment of the need to search. Increase knowledge of stimuli that may distract attention, and increase ability to cope with distractions. Increase ability to cope in situations where information-processing capacity is overloaded. Increase the validity of bicyclists' assessment of the degree of risk associated with failures to search.
Increase bicyclists' ability to evaluate situations and to recognize the need for evasive action.	Increase validity of expectations that may influence bicyclists' assessment of the need for evasive action. Increase bicyclists' ability to make critical spatial judgments.
Increase bicyclists' ability to select and execute optimal evasive action.	Increase bicyclists' ability to estimate stopping distance and maximum turning radius as a function of speed, roadway gradient, type of bicycle, type of brakes, roadway-surface condition, and condition of brakes. Increase bicyclists' ability to execute emergency braking, turning, and controlled slides.

accidents showed that a search failure by the bicyclist contributed to 50% of the fatal and 41% of the non-fatal accidents. In all of these cases, the motor vehicle with which the bicyclist collided could have been observed early enough for the bicyclist to have avoided the accident; the accident occurred because the bicyclist failed to search in the motor vehicle's direction until it was too late to avoid the collision. Unquestionably, education to enhance bicyclists' search behavior has great potential for reducing bicycle/motor-vehicle accidents; it is probable that such education would effect a reduction in NMV accidents as well.

Significant improvements in bicyclists' search behavior cannot be achieved by merely informing them of the importance of visual search and advising them to increase their search activity. Such instruction has no more effect on bicyclists' behavior than telling them to "ride safely." Rather, what is needed is highly specific instruction on where bicyclists must search in various traffic contexts, the types of factors and events that may momentarily disrupt search behavior, and the types of situations in which effective search is difficult or impossible without a substantial reduction in speed. The Level II objectives described below reflect the author's views on the instruction needed to enhance bicyclists' search behavior. These objectives were formulated from a careful study of the various factors that contributed to the search failures that, in turn, led to a bicycle/motor-vehicle accident.

Limitations of the visual system. Vision is such a highly developed skill that it is difficult to keep in mind that the visual system has some highly important limitations. Because the eyes usually function without conscious effort, children and some adults tend to think of the visual system as an autonomous mechanism that automatically supplies them with all the visual information required to perform the task at hand. Because the eyes perform so many functions with such a high level of efficiency, it is difficult to avoid behaving as if the visual system is a perfectly functioning mechanism with no limitations whatsoever. These fallacious notions are not conducive to the development of effective search behavior. It is difficult to induce bicyclists to deliberately and systematically search the traffic environment if they believe that their eyes will automatically detect hazards, and it is difficult to teach bicyclists how to scan effectively if they have no understanding of the limitations of the visual system and the reasons for these limitations. Therefore, it was reasoned that a basic understanding of the limitations of the visual system is a prerequisite for the development of effective search behavior.

Listed below are the educational objectives that are considered most essential. These objectives were derived analytically from a consideration of what bicyclists in the primary target group (fourth graders) must know about the visual system in order to be fully receptive to education about the necessity for visual search and the techniques required to search effectively.

- Teach bicyclists the concepts of central and peripheral vision and demonstrate differences in visual acuity for central and peripheral vision.
- Teach bicyclists the functions served by central and peripheral vision and why both are essential for the safe operation of a bicycle in traffic.

- Teach bicyclists the size of the central and peripheral fields of view and the extent to which these fields of view are increased by eye, head, and torso rotation.
- Teach bicyclists the concepts of scanning and fixation and demonstrate (a) the amount of time required for the eyes to search for and fixate on an object and (b) the limited number of objects the eye can locate and fixate upon per unit of time.
- Introduce the concept of information overload and explain how and why the visual system may become overloaded when riding in traffic.
- Teach bicyclists that increasing bicycle speed increases the information-processing load on the visual system; also, demonstrate this fact by exposing bicyclists to conditions that overload the visual system (high speeds, complex traffic environments, and a combination of the two).
- Teach bicyclists how to determine when their visual system is overloaded and how to compensate when this occurs.

Education on the above topics should provide the background knowledge needed for bicyclists to understand why they must learn to search selectively, why they must avoid overloading their visual system, and how visual-system overload can be avoided. Education about the limitations of the visual system is also needed to teach bicyclists why they may not be observed by motor-vehicle operators.

Selective search and threat detection. In discussing the Anticipatory-Phase functions, it was stated that searching the environment is necessary to select an optimal course through an area. The purpose of search during the Reactive Phase is to detect visual cues that signal the presence of an actual or potential threat. Because of the complexity of the visual environment and the limitations of the visual system, the likelihood of threat detection would be low if the bicyclist searched the visual scene in a random or unsystematic manner; instead, the bicyclist must learn to search selectively. Selective search means the maximum allocation of available search time to the areas where cues signaling the presence of a threat are most likely to appear.

In some instances, the cue to a threat is a motor vehicle traveling in the bicyclist's direction that obviously is on a collision course with the bicyclist. The threat is so obvious in such instances that it is unnecessary to teach bicyclists that an approaching motor vehicle is a cue to threat. However, there are many valid cues to threat that are less obvious. That is, a significant portion of the bicycling population has not learned to associate a cue with the occurrence of a threatening event. Some cues to threat are recognized by most adults but few children; others are recognized by only the most experienced bicyclist. For instance, most adult bicyclists recognize that a standing motor vehicle in the opposing traffic lane constitutes a potential threat because that motor vehicle may turn left into the bicyclist's path. This cue to threat is less apparent to young bicyclists who have not yet learned that motorists sometimes fail to observe bicyclists. Highly experienced bicyclists report that they attend to such subtle cues as:

- The scan patterns of motorists, including the direction of head movements and length of pause.
- The direction and length of the bicyclist's shadow in daytime (a long shadow pointing in a motorist's direction indicates that the motorist may be blinded by sun glare).

- The movement of the bicyclist's shadow at night (an overtaking motor vehicle is on a collision course with the bicyclist if the bicyclist's shadow, cast by the motor-vehicle's headlights, fails to move in a right-hand direction).
- The presence of movement in the side mirror of a parallel-parked motor vehicle (signals the presence of an occupant that may open the vehicle's door).
- The presence of activated stop or backup lights or the movement of the front wheels of a parallel-parked vehicle (signaling that the vehicle may emerge from the parking space).

It is believed that the method used to enhance bicyclists' selective search and threat detection skills must meet four important requirements. First, it must provide for the teaching of selective search and threat detection in concert. It would be difficult to teach bicyclists when they should search without telling them what they are searching for. Secondly, the education must be highly specific in both its content and context. Bicyclists must be instructed on exactly where to search and what to search for, rather than being taught abstract rules and principles about selective search and threat detection; this specific instruction must be administered in a real-world context or within the context of a high-fidelity simulation of real-world imagery. Thirdly, the instruction should be aimed specifically at the types of traffic contexts in which accidents most frequently occur. The relevant traffic contexts for bicycle/motor-vehicle accidents are illustrated and described in Section V. Finally, the method should enable bicyclists to actively practice the selective search and threat detection tasks, with provision for immediate feedback after each practice trial. Lectures are useful to a point, but active practice with immediate and detailed feedback probably will be required to refine the skills to an acceptable level.

Invalid expectations. The invalid expectations that lead bicyclists to select a suboptimal course also lead them to fail to search when it is appropriate to do so. Because of invalid assumptions, bicyclists incorrectly conclude that it is unnecessary to search in a particular direction. As was stated above, most of the invalid expectations are that an area or location will be void of motor-vehicle traffic, that bicyclists will be observed by motorists, that motorists will adhere to the law, and that a riding companion will search for and detect threats.

Many of the bicyclists' invalid expectations will be eliminated by the education on selective search and threat detection. An important part of learning to search effectively and to detect threats consistently is the recognition that behavior must be guided by a consideration of both the typical and the atypical events that occur in the traffic environment.

Coping with distractions. It was found that about one-half of the search failures by bicyclists were due partly to the presence of a momentary distraction. In the vast majority of cases, the bicyclist was distracted by a riding companion. Other distractions include: another vehicle considered an accident threat, non-traffic-related mental activity, abnormal street-surface condition, unfamiliar vehicle, carrying object in hands, malfunctioning vehicle, improper size bicycle, scenic attractions, hostile animal, and inclement weather.[9]

[9]These distractions are listed in the approximate order of their importance.

One can only guess how many of the bicyclists would have searched effectively if the distraction had not been present, but it is likely that many would have searched. If so, considerable benefit would be realized from education that would serve to offset the effects of momentary distractions. In considering methods of accomplishing this educational objective, it must be kept in mind that few of the distractors were of the type that cause a reflexive or involuntary shift of attention, such as a gunshot, an elephant in the roadway, and so on. Rather, the distractors were common persons or things that the bicyclist voluntarily attended to because, at the moment, the distracting person or thing was considered of greater importance than traffic-related stimuli. In other words, the bicyclist was voluntarily directing his attention to environmental stimuli in accordance with his system of priorities at the moment. It follows that the only way to offset the effect of such distractors is to modify the bicyclist's system of priorities; the perceived importance of traffic-related stimuli must be increased or the perceived importance of distractors must be decreased.

Some benefit may result from a straightforward explanation of this problem, including: a description of the meaning of the word distractor, the types of distractors that are most important, the manner in which distractors may influence search behavior, and the consequences of being momentarily distracted from the search task. However, it is believed that some more active form of education and practice is needed to produce the desired behavioral changes. Unfortunately, no definitive ideas about an effective educational approach can be offered at this time.

Information overload. Some search failures occurred because bicyclists simply had insufficient time to search for and detect all of the relevant stimuli in the environment; the search requirements exceeded the bicyclist's information-processing capacity. Information overload is a joint function of the complexity of the traffic environment and the bicyclist's speed. An educational solution to this problem requires that bicyclists be taught to recognize when their information-processing capacity is becoming overloaded. That is, bicyclists must be taught to recognize when they have insufficient time to accomplish all the search tasks that are necessary in order to ride safely. If this difficult objective can be accomplished, it then becomes necessary to teach bicyclists that speed reduction is usually the best way to decrease the information-processing load to a manageable level.

The author knows of no educational techniques that have been developed to teach bicyclists, or any other vehicle operator, to recognize when their information-processing capacity has become overloaded. However, it should not be too difficult to develop a useful technique. One promising approach would involve the use of a simple cinematic simulator. A fairly low-cost system could be developed whereby bicyclists would be shown 16-mm films of typical street scenes on a variable-speed projector. With this system, the information-processing load could be increased systematically by increasing the speed of the projector from one frame per second to 24 frames per second. The information-processing load would also vary as a function of the visual complexity of the street scenes that are filmed. This system would provide the capability for increasing the information-processing load in a systematic manner, and could be used to demonstrate an information-overload condition for any bicyclist, regardless of his individual information-processing capacity. A critical requirement of such a system is an objective performance measure that would provide a valid and precise indication of when the bicyclist's information-processing capacity was approaching an overload condition.

Risk assessment. Invalid risk assessment is another factor that sometimes contributes to bicyclists' search failures. Risk assessment is a particularly important factor for accidents that occur in quiet residential areas that appear very safe. As a consequence, education must focus on risk assessment in safe-appearing traffic contexts. The education must somehow convince bicyclists that the likelihood of an accident in such areas is great enough to warrant effective search behavior on every occasion, even though potentially threatening motor vehicles are present only rarely.

Education to Enhance Evaluation Behavior

An evaluation failure occurs when the bicyclist performs the search function and observes the threatening motor vehicle, but fails to recognize the need for evasive action. An evaluation failure was the precipitating cause of about seven percent of the fatal and 36% of the non-fatal bicycle/motor-vehicle accidents. In each of these cases, the bicyclist observed the motor vehicle early enough to have avoided the accident; the bicyclist failed to initiate evasive action soon enough because of a misjudgment or an invalid expectation concerning the motorist's behavior. These findings make it clear that there is an important need for education to increase bicyclists' ability to evaluate situations and to recognize the need for evasive action. This is the second of the three Level I objectives for enhancing the performance of the Reactive-Phase functions. The Level II objectives are discussed below.

Invalid expectations. In the preceding paragraphs, it was explained that invalid expectations may adversely influence bicyclists' selection of a course and their assessment of the need to search. The same types of invalid expectations often have an adverse influence on bicyclists' assessment of the need for evasive action. That is, invalid expectations lead bicyclists to the conclusion that there is no need for evasive action when, in fact, an accident is about to happen. The invalid expectations most often reported by bicyclists involved in bicycle/motor-vehicle accidents of this kind are:

- The expectation that the motorist had or would observe the bicyclist.
- The expectation that a stationary motor vehicle would remain stationary until the bicyclist had passed.
- The expectation that a turning vehicle would proceed straight ahead.
- The expectation that a stopping/slowing vehicle would proceed at a constant velocity.
- The expectation that occupants in parallel-parked motor vehicles would not open the vehicle's door until the bicyclist had passed.
- The expectation that a motor vehicle was going to turn when, in fact, it proceeded straight ahead.
- The expectation that a motor vehicle was going to turn in a direction opposite to that of its actual turn.

- The expectation that lawful lighting equipment on the bicycle would ensure that the bicyclist would be observed by the motorist.

The most important of the invalid expectations is the expectation that the bicyclist had been or would be perceived by the motorist. In recognition of this fact, some existing educational materials instruct bicyclists to establish eye contact with the motorist before assuming that they have been observed. This education implies that the bicyclist can safely assume that he has been observed by the motorist if he can see that the motorist has scanned in his direction. This education is counterproductive; many instances were found in which bicyclists reported that they decided to proceed only because they observed that the motorist had looked directly at them. Most motorists involved in accidents of this kind verified the bicyclist's claim that they had searched in the bicyclist's direction, but still insisted that they had not observed the bicyclist. In short, the direction of a motorist's search is *not* a valid indication of what he has observed.

The education on the limitations of the human visual system should prove useful in increasing the validity of bicyclists' expectations about being observed by motorists. That is, bicyclists who clearly understand that a motorist's visual system is subject to the same limitations as their own will be less likely to assume that they have been or will be observed by motorists. However, education on the limitations of the visual system is not enough. Bicyclists must also be given highly explicit instructions on how to behave when the actions of motorists cannot be predicted with a high degree of reliability. For instance, when a bicyclist encounters a motor vehicle waiting to enter the roadway from a driveway or alley, the bicyclist must be taught that the motor vehicle may proceed into the roadway without having observed the bicyclist. But, what is a bicyclist supposed to do when confronted with this situation? The bicyclist must be taught to modify his speed and/or path in a manner that provides sufficient time for evasive action in the event that the motor vehicle does, in fact, proceed into the bicyclist's path. Decreasing speed, in turn, decreases stopping distance; moving left increases the buffer zone between the bicyclist and motorist and thereby provides additional time and space for evasive action. Since it is not possible to formulate any generalized principles or rules about the best way to respond in situations of this kind, bicyclists must be instructed on how to respond in each of a wide range of specific situations and traffic contexts.

It has been suggested that bicyclists should be taught methods for attracting motorists' attention in situations where accidents could occur because the motorists fail to observe the bicyclists. Hand signals, voice warnings, and the use of auditory-warning devices (bells or horns) have been suggested. Few expert bicyclists are enthusiastic about this approach to the problem. Although voice warnings are effective in some situations, they cannot be relied upon in all situations because motorists often drive with their windows closed and with their radio playing at a high volume. Hand signals require the bicyclist to remove one hand from the handlebars at a time when control of the bicycle may be highly critical. Although hand signals may be used effectively in some situations, there are other situations in which the hands would be more effectively used in steering the bicycle, braking, or both. Auditory-warning devices have the disadvantages of both voice warnings and hand signals; they require that the bicyclist remove one hand from the handlebars in order to operate them, and one cannot depend upon the motorist hearing the warning device under all conditions.

One expert bicyclist reported that he installed a powerful air horn on his bicycle for use in alerting motorists of his presence. His first opportunity to use his air horn came when a motor vehicle in the opposing traffic lane turned left in front of him. The blast of the air horn startled the motorist to such an extent that he came to a complete stop in the bicyclist's path, making it impossible for the bicyclist to avoid an accident. Anecdotal evidence such as this suggests that extreme caution should be used before deciding to teach bicyclists to use some form of signal to attract motorists' attention.

Critical spatial judgments. There were relatively few bicycle/motor-vehicle accidents that resulted from faulty spatial judgments. A small number of bicyclists misjudged the space required to clear an opening door of a parallel-parked motor vehicle. Additionally, there were a few instances in which a bicyclist was clearly riding too far to the left because he misjudged the space required for a motor vehicle to overtake and pass him. This type of misjudgment is most often a factor in night accidents on narrow roads; bicyclists are inclined to ride as far left as possible to avoid roadside debris that would be difficult to see at night, so they sometimes ride so far left that they are well within the path of overtaking motor vehicles.

Although it is believed that some attention should be devoted to increasing bicyclists' ability to make such spatial judgments, this educational objective appears to be among the least important objectives discussed in this report.

Education to Enhance Selection/Performance of Evasive Actions

The evidence on bicycle/motor-vehicle accidents indicated that only about three percent of the accidents were clearly the result of an incorrect choice of evasive actions or an inability to execute the evasive action decided upon. In most of these cases, some type of unusual condition contributed to the bicyclist's failure to select the correct evasive action or his failure to initiate the evasive action soon enough to avoid the accident.

It must be admitted that it is extremely difficult to evaluate the appropriateness and effectiveness of a bicyclist's evasive actions from post-accident interview data. It is particularly difficult to judge whether or not a high level of proficiency in performing emergency turns and stops would have enabled a bicyclist to avoid the accident. As a consequence, the potential benefits of increasing bicyclists' ability to select and execute optimal evasive actions remains somewhat uncertain. This Level I objective was included because much of the education needed to accomplish this objective is also required to educate bicyclists on course selection. The Level II objectives are described below.

Stopping distance and turning radius. Judicial decisions about the optimal evasive action must be based upon an ability to estimate accurately the stopping distance and maximum turning radius of the bicycle. Since stopping distance and turning radius are influenced by a variety of factors, the education should teach bicyclists to estimate stopping distance and turning radius as a function of such factors as: bicycle speed, roadway gradient, type of bicycle, type of brakes, condition of brakes, and roadway-surface condition.

There appears to be no type of classroom instruction that would be effective in enhancing bicyclists' ability to judge stopping distance and turning radius. Outdoor training with repetitive trials under a range of conditions appears to be the most effective way to teach bicyclists the necessary judgmental skills, but this approach would be highly costly and time consuming. If it is impossible to develop a less costly educational approach, there is serious reason to question whether or not this objective should be included in an educational program.

Emergency stops, turns, and slides. Expert bicyclists report that the ability to execute emergency stops, turns, and slides has enabled them to avoid accidents that could not have been avoided by bicyclists who do not possess these skills. Although no empirical data are available to verify these opinions, the anecdotal evidence is sufficiently impelling to consider training in emergency evasive action as a possible objective. Based upon the author's limited knowledge, it appears that training in emergency evasive action requires that bicyclists be instructed on the appropriate vehicle-handling procedures and be given the opportunity for supervised practice until the skills have been refined. No information is available on the amount of time that would be required to acquire the necessary skills, but it is probable that a considerable amount of practice would be required to achieve a high level of proficiency. Clearly, it will be necessary to make a more objective assessment of the accident-reduction potential and the training time/costs before it will be possible to evaluate the cost-effectiveness of training in emergency evasive actions.

OBJECTIVES OF MOTORIST EDUCATION

In some respects, motorists are more easily educated than bicyclists. As a group, motorists are older and therefore more capable than bicyclists of understanding explanations of complex concepts, applying abstract rules and principles to decisions about the behavior that is appropriate for specific situations, and synthesizing instructional information with the body of knowledge acquired through direct experience in the traffic system. By the time persons reach driving age, they have acquired a reasonably high level of perceptual and motor skills and have acquired a reasonably extensive knowledge of the physical and operational characteristics of the traffic system. For these reasons, there is no necessity to spend valuable education time developing motorists' fundamental perceptual and motor skills and teaching them about the basic physical and operational characteristics of the traffic system.

Although motorists may be more easily educated than bicyclists, the job of educating motorists is complicated by the sheer size of the motorist population and, more importantly, by the inaccessibility of motorists for education. Access to a large portion of the bicycling population is possible through the public school system and perhaps other institutions as well. However, there is no one or small number of institutions that provides easy access to a large proportion of the motorist population. The accessibility of motorists is such a critical issue that it seems worthwhile to comment briefly on possible methods for conveying educational material to motorists before proceeding to the discussion of motorist educational objectives.

The discussion of educational objectives for motorists follows the same format used for discussing educational objectives for bicyclists; objectives for enhancing Preparatory-Phase functions, Anticipatory-Phase functions, and Reactive-Phase functions are discussed in turn.

POTENTIAL METHODS FOR EDUCATING MOTORISTS

The methods that appear to have some potential value for educating motorists include: (a) incorporate bicycle-safety education into the existing driver-training programs taught in the public high schools or taught by commercial driver-training organizations, (b) convey educational messages through the public communications media (newspapers, magazines, radio, and television), and (c) convey the educational materials through special publications developed for widespread distribution. Each of these methods has important advantages and disadvantages; so all may be required to do an effective job of educating motorists. The advantages and disadvantages of each method are discussed briefly below.

Incorporating bicycle-safety education into existing driver-training programs has several important advantages: this method ensures a captive audience of motorists who are motivated to learn (because learning is a prerequisite for driving privileges); it provides an opportunity for face-to-face instruction and interaction between instructors and students; it provides access to stduents for a sufficient amount of time for reasonably comprehensive education; it enables education to be administered before undesirable behavior patterns have become firmly entrenched; and it could be easily implemented at a relatively low cost. The obvious disadvantage of this method is that many years would pass before a substantial proportion of the motorist population would have been educated. For instance, after the onset of a driver-training program in high school, it would be about 20 years before one-half of all licensed motorists would have received the education; more than 35 years would pass before three-fourths of all licensed motorists would have been educated.

The public media provides widespread exposure of educational materials and may prove to be a highly cost-effective method for accomplishing some educational objectives. However, educational messages conveyed through the public media must be brief, simple, and highly engaging. Some of the necessary educational information could easily be drafted in the form of a brief, straightforward message; other information is too complex to be stated in a brief message. Even if it is possible to develop brief messages with educational value, considerable expertise will be required to develop materials that have sufficient appeal to attract and maintain the interest of the motoring public. The material drafted for publication in newspapers and magazines must compete for motorists' attention with news articles about inflation, Proposition 13, the mid-East conflict, earthquakes, and so on. Messages prepared for radio and television must compete with product commercials, rock music, Charlie's Angels, and so on.

Educational publications provide an effective and low-cost method of conveying information if motorists can be induced to read them carefully. Even if an effective publication was developed and distributed widely, it seems unlikely that a substantial proportion of the motoring public would read it unless there was some impelling reason to do so. One approach is to distribute such publications through the Department of Motor Vehicles and require motorists to pass an examination on the publication in order to obtain a driver's license. Another approach is to distribute the publication through insurance companies and provide reduced insurance rates to motorists who pass an examination on the publication. The difficulties in implementing either of these approaches are so obvious that there is no need to enumerate them here.

The above discussion will have accomplished its purpose if the reader recognizes that the method for educating motorists is a critically important problem that warrants the attention by knowledgeable and innovative persons in several different fields.

EDUCATION TO ENHANCE PREPARATORY-PHASE FUNCTIONS

The data from the study of bicycle/motor-vehicle accidents provided no indication that an important number of accidents could be prevented by education to enhance motorists' inclination and ability to perform the Preparatory-Phase functions. Fewer than one percent of the accidents involved a defective motor vehicle, and only a fraction of the motor-vehicle defects that were present were judged to be contributory. Neither vehicle-handling skill deficiencies nor operator-vehicle incompatibilities were found to be important contributors to accidents; together these factors were found to contribute to less than .1% of the accidents in the sample. With one exception, few accidents were caused wholly or in part by a motorist's permanent or temporary impairment. The exception was that a significant number of motorists were impaired by alcohol. Evidence that the motorist had been drinking was found in over three percent of the non-fatal accidents and about 17% of the fatal accidents.

In light of the above discussion, it is concluded that the only education on Preparatory-Phase functions that might prove beneficial is education to curtail driving while intoxicated. However, since there are many ongoing programs to curtail driving while intoxicated, it seems unnecessary to establish this as a primary objective for a bicycle-safety education program.

EDUCATION TO ENHANCE ANTICIPATORY-PHASE FUNCTIONS

It will be recalled that the Anticipatory-Phase functions are those that must be performed in order to select an optimal course (speed and path) through an area; by definition, the selection of a suboptimal course means that an Anticipatory-Phase function failure has occurred. The results of the bicycle/motor-vehicle accident study showed that Anticipatory-Phase function failures were much less frequent for motorists than bicyclists.

Even so, it was found that about 21% of the fatal and 11% of the non-fatal accidents were the direct or indirect result of the motorist's selection of a suboptimal course. Of the cases in which the motorist's course was suboptimal, about 80% involved a motorist who was traveling unnecessarily close to the right-hand edge of the roadway, traveling at an excessive speed, or both. Unlike bicyclists, there were few motorists who traveled through controlled intersections without stopping, followed an unusual or unexpected path when turning, or traveled against the flow of traffic.

The factors found to most often contribute to the motorist's selection of a suboptimal course include the following: the motorist's judgment was seriously impaired by alcohol, the motorist failed to observe a visual obstruction or failed to evaluate its implications for safety, and the motorist expected that the area would be void of bicycle traffic at the time the accident occurred. For the fatal cases, 80% of the motorists who selected a suboptimal course did so because their judgment was impaired by alcohol. Failure to observe/evaluate visual obstructions was the most important contributor to the selection of a suboptimal course by motorists in the non-fatal sample.

It is clear from the above discussion that some benefits would be realized from education that would induce motorists to drive at a safe speed and that would induce them to avoid drifting too far to the right of the roadway. Nothing whatsoever will be accomplished by simply telling motorists to avoid speeding and driving too far to the right; motorists are perfectly aware that such actions are dangerous and may result in a variety of different kinds of accidents. Instead, motorists must be given explicit instructions about where and when speeding and driving too far to the right are most likely to result in a bicycle/motor-vehicle accident. The education should be designed to accomplish the following objectives:

- Teach motorists to search for and recognize critical visual obstructions, including the standing motor vehicles that obstruct an operator's view in "multiple-threat" accidents.
- Modify motorists' expectations about the likelihood that a bicyclist will emerge suddenly from behind a visual obstruction.
- Teach motorists to reduce their speed and modify their path in a manner that best offsets the effects of a visual obstruction.
- Modify motorists' expectations about the likelihood of encountering a bicyclist at night.
- Teach motorists that when driving at night, they should (a) avoid driving farther to the right than is necessary for safety and (b) reduce their speed substantially when traveling on a narrow roadway.

Such education may also prove beneficial in reducing accidents for which the motorist's course cannot be judged suboptimal in the strict sense of the word. For instance, it was noted earlier that most of the motorists who were involved in bicycle-rideout accidents were traveling a path and at a speed that would be considered safe by normal standards. However, it is altogether possible that the incidence of bicycle-rideout accidents could be reduced by educating motorists to recognize the kinds of areas where bicycle-rideout accidents most often occur (quiet residential areas) and modify their course in such areas to provide an increased amount of time/space for evasive actions. Motorists should be taught to (a) drive in the center of the roadway when no vehicles are approaching in the opposing traffic lanes and (b) reduce their speed well below the legal limit when they are unable to drive in the center of the roadway and/or when visual obstructions are present.

It is believed that most motorists have both the ability and inclination to modify their course appropriately if they are able to anticipate a potentially hazardous situation. Thus, even motorists who ordinarily select a safe course would benefit from a detailed explanation of the accident-generation process for each of the important types of accidents and a description of the kinds of traffic contexts in which these accidents occur. This information, along with an increased expectation of encountering bicyclists, would enable motorists to recognize hazardous locations and to modify their speed and path accordingly. Indeed, this is the basic premise underlying all defensive-driving training.

EDUCATION TO ENHANCE REACTIVE-PHASE FUNCTIONS

It will be recalled from an earlier section that (a) the Reactive-Phase functions are those required to observe and respond to a potentially threatening vehicle that is visible, and (b) a function failure during the Reactive Phase is possible only if the threatening vehicle could have been observed early enough for a normal operator to have initiated successful evasive action (see pp. 123-124 for a description of the Reactive-Phase functions). The education to enhance the motorist's performance of the Reactive-Phase functions must be aimed primarily at the search function, the detection function, and the evaluation function. It was found that very few accidents resulted from the motorist's failure to perform the decision function or the action function in a proper manner.

Education to Enhance Search Behavior

The data from the bicycle/motor-vehicle accident study indicated that a search failure by the motorist contributed to about 20% of the fatal and 40% of the non-fatal accidents. About one-half of the motorists' search failures were the direct result of the bicyclist riding on the wrong side of the roadway; the motorist failed to search in the bicyclist's direction because he didn't expect a hazard to be approaching from that direction. When the bicyclist was riding lawfully, the motorist's search failure typically was due to one or more of the following contributory factors:

- The motorist was temporarily distracted--usually by a passenger or by a pedestrian or vehicle that the motorist considered an accident threat.
- The motorist's information-processing capacity was temporarily overloaded because of a highly complex traffic environment, excessive speed, or both.
- The motorist expected that all vehicles approaching on intersecting roadways would yield the right-of-way in accordance with the law.
- The motorist expected that the general area would be void of bicycle traffic.
- The motorist failed to search effectively enough to perceive the bicyclist, even though he scanned in the bicyclist's direction one or more times.

The objectives of education to enhance motorists' search behavior are quite similar to those established for enhancing bicyclists' search behavior (see Table 24, p. 124). It is believed that most mature and experienced motorists understand the limitations of the visual system and the need to search selectively for cues signaling the presence of a threat; so, general education on these topics could be limited to young and inexperienced motorists. The following objectives apply equally to all motorists:

- Increase validity of expectations that may influence motorists' assessment of the need to search.
- Increase knowledge of the stimuli that may distract attention, and increase ability to cope with distractions.
- Increase ability to cope in situations where information-processing capacity is overloaded.
- Increase the validity of motorists' assessment of the degree of risk associated with failures to search.

As has been emphasized repeatedly throughout this section, it is necessary that the instruction be highly specific; motorists must be informed of the specific situation in which search failures most often lead to accidents--including the traffic context and the pre-crash maneuvers of both vehicles. For each high-hazard situation discussed, motorists must be instructed on *exactly* where to search and what to search for. The contribution of motorists' search failures should be discussed for each of the problem types defined in Section V, but major emphasis should be placed on the following objectives:

- Teach motorists to search for bicyclists approaching on intersecting streets, driveways, and alleys.
- Teach motorists to search for bicyclists riding on parallel sidewalks and other off-street locations.
- Teach motorists to search more effectively for bicyclists during darkness.
- Teach motorists to search to the left-rear before opening the left-hand door of their (parallel-parked) vehicle.
- Teach motorists to search for bicyclists approaching in the opposing lane of traffic before initiating a left-hand turn.
- Teach motorists to search to the right-rear before initiating a right-hand turn.
- Teach motorists to search more effectively for bicyclists approaching from the right or left before entering a street from an intersecting street, driveway, or alley.

There is reason to question the advisability of educating motorists to search for wrong-way-riding bicyclists, even though such education is certain to reduce the number of bicycle/motor-vehicle accidents. It is possible that bicyclists would be more inclined to ride facing traffic if they knew that motorists were being educated to search for wrong-way-riding bicyclists. More importantly, requiring motorists to search for wrong-way-riding bicyclists increases their workload and may, in turn, cause an increase in other kinds of accidents.

Education to Enhance Detection of Bicyclists

A detection failure by the motorist was found in about 28% of the fatal and 10% of the non-fatal bicycle/motor-vehicle accidents. All of these cases occurred under conditions of degraded visibility. A small percentage involved sun glare; the remainder occurred during darkness. Although sun glare is not a major contributor to accidents, it is believed that minimal effort would be required to inform motorists that glare sometimes leads to bicycle/motor-vehicle accidents and that they must slow their speed and exercise extreme caution when temporarily blinded by sun glare.

It seems unlikely that any type of education would significantly increase a motorist's ability to detect bicycles at night that are not equipped with lawful lighting equipment. Moreover, it is unlikely that any type of education would increase the chances that an intoxicated motorist would detect a bicycle at night, whether or not it is equipped with lawful lighting equipment. However, it is altogether possible that motorist education would greatly increase the likelihood that sober motorists would detect properly equipped bicycles at night. This education should be aimed principally at overtaking accidents. Motorists should be informed of the frequency, consequences, and causes of overtaking accidents; they must be instructed about the necessity for searching the area ahead more thoroughly; and they must be instructed on what to search for.

Instructional films are available that show the appearance of a properly equipped bicycle at night. Unfortunately, the films show the appearance of the bicycle when it is illuminated by a motor-vehicle's high beams and when viewed against a totally black background. The films make it difficult to imagine how any motorist could fail to detect a bicycle at night. Obviously, such films have no instructional value. What is needed are methods that illustrate the visibility of bicycles under worst-case conditions. For instance, the appearance of bicycles should be shown when: the bicycle is equipped with lawful but marginal lighting equipment, the bicycle is illuminated by a motor-vehicle's low beams, the bicycle is viewed against a background that contains many light sources, the motorist's eyes have been exposed to the lights of an oncoming motor vehicle, and so on. If films are used for this purpose, considerable expertise will be required to produce films that accurately simulate real-world imagery.

Education to Enhance Evaluation Behavior

An evaluation failure by the motorist occurred in about 20% of the fatal and 24% of the non-fatal bicycle/motor-vehicle accidents. In all of these cases, the motorist observed the bicyclist early enough to have easily avoided the accident. The motorist failed to initiate some form of evasive action because of an invalid expectation or because of some form of faulty judgment. About one-fourth of the evaluation failures resulted from a motorist's incorrect expectation that a bicyclist approaching on an intersecting roadway would stop or turn before riding into the motorist's path. About 10% of the evaluation failures were the result of a motorist's misjudgment of the space required to overtake and pass a bicyclist. The remaining cases were the result of a motorist's failure to anticipate a sudden left-hand turn by a bicyclist riding in front of him. That is, the motorist observed the bicyclist well in advance of the accident but expected the bicyclist to proceed straight ahead (rather than making an abrupt left-hand turn into the motorist's path).

Most readers will have observed many cases in which an alert motorist was able to avoid an accident because he anticipated the bicyclist's actions. Nearly every time the author discusses bicycle safety with a motorist, the motorist volunteers an anecdote about a serious accident that was avoided only because of the motorist's ability to anticipate a "crazy action" by a bicyclist. It is believed that such anecdotal evidence provides support for the assumption that the vast majority of motorists are both willing and capable of going to great lengths to avoid an accident with a bicyclist. It follows that motorists would be highly receptive to education that would help them better anticipate the bicyclist's actions and to develop defensive-driving skills that would enable them to counter these actions. The accident data indicate that education to enhance motorists' evaluation behavior should concentrate on the following objectives:

- Increase motorists' expectations that a bicyclist riding ahead of them will turn suddenly into their path. Teach motorists to slow their speed and give the bicyclist as wide a berth as is possible when overtaking and passing him.
- Increase motorists' expectations that bicyclists approaching on intersecting roadways will continue without stopping. Teach motorists to slow their speed and veer in a direction opposite to that of the approaching bicyclist as far as is possible under the circumstances.
- Increase motorists' ability to judge the width of their vehicle and the space required to overtake and pass a bicyclist safely. Teach motorists to avoid attempting to pass the bicyclist when space is marginal.

OBJECTIVES OF EDUCATION FOR BICYCLISTS' PARENTS

There are at least three important benefits of educating bicyclists' parents. First, parents can be educated to teach their children about bicycle safety. Secondly, parents can be taught the need for a greater amount of supervision and control of their child's bicycle-riding habits and practices. Thirdly, parents can be educated about the necessity for formal bicycle-safety education for the children and the need to support a comprehensive bicycle-safety education program for their community.

MINIMUM AGE FOR UNSUPERVISED RIDING

There are many parents who purchase their child a bicycle as soon as they feel he has the motor skills required to control it. In fact, the competitive spirit leads some parents to encourage their children to learn to ride a bicycle at an age younger than their child's peers. Parents must be taught that certain perceptual and cognitive skills are as essential to safe riding as vehicle-handling skills, and that juvenile bicyclists should be carefully supervised until they have acquired these essential skills. But, how are parents to know when their child possesses the fundamental perceptual and cognitive skills that must be present to form the foundation for specific instruction on bicycle safety?

Ideally, parents would be provided with an objective test that could be used to assess the adequacy of their child's perceptual and cognitive skills. Unfortunately, no such test has been developed. The only alternative is to define the average age at which the necessary skills are developed through the natural maturation process; more specifically, define the age that the normative child must reach before he has the perceptual and cognitive skills needed to understand the principles and rules of safe riding and perform the tasks required to implement these principles and rules. This age would be considered the minimum age for unsupervised riding on the public streets.

Defining the minimum age for unsupervised riding will be a difficult and highly controversial task, but it should be done. Based upon a careful study of the accident data and numerous discussions, the author believes that the minimum age should be about eight years old. Admittedly, there are many who believe the minimum age should be younger and a nearly equal number believe the minimum age should be older. However, there are few safety-education experts who believe that five- and six-year olds should be permitted to ride on public streets without being accompanied by an adult.

BICYCLE SIZE, TYPE, AND FIT

Parents who purchase their children a new bicycle are usually given expert advice about the appropriate size, type, and fit by the sales personnel. However, there are some parents who fail to follow this advice and buy their child a bicycle that he can "grow into." Parents must be educated about the risk associated with purchasing their child a bicycle that is too large, too sophisticated, or both. If parents are not taught the specific criteria for evaluating the size, type, and fit of the bicycle they purchase for their child, they certainly should be taught to seek the advice of an expert and to follow this advice.

Although the author knows of no data on young childrens' ability to operate hand brakes and to manipulate gear shifts on multi-speed bicycles, some persons have argued convincingly that young children cannot be taught to safely operate bicycles equipped with either hand brakes or multi-speed gears. It is claimed that operating hand brakes in an emergency situation requires a greater degree of strength and coordination than many young children possess. Similar claims are made about multi-speed gears. Not only does the manipulation of the gears require a relatively high level of skill, but the multi-speed gears enable young bicyclists to travel faster than they should be traveling. If these claims are supported by research, parents should be advised against purchasing their child a bicycle that is equipped with either caliper brakes or multi-speed gears.

ACCIDENT TYPES AND LOCATIONS

Parents are in a unique position to teach their children safe riding habits and to reinforce these habits. Education administered by parents can be particularly effective, because it can be administered within the specific traffic contexts where the child will be riding. However, before parents can be expected to educate their child effectively, it will be necessary to eliminate many misconceptions that could lead to counterproductive education. Specifically, parents must be educated about the types of accidents that most often involve young children, the factors that contribute to these accidents, and the types of traffic contexts in which they occur. This general information should enable parents to evaluate the area in which their child will be riding and formulate highly specific rules to guide his riding behavior. For instance, knowledge of the bicycle-rideout accidents may lead parents to recognize the importance of a hedge that obscures their driveway and the need for a rule that prohibits their child from riding into the roadway at that location without stopping. Parents may also see the danger in advising their child to ride on the sidewalk at certain locations, and certainly should learn that they should teach their child to never ride facing traffic.

NECESSITY FOR FORMAL EDUCATION ON BICYCLE SAFETY

Parents should be informed that some essential bicycle-safety education can best be accomplished by a highly trained instructor using equipment and materials specially designed for this purpose. Hopefully, the knowledge of this fact will lead parents to demand the establishment of a formal bicycle-safety education program in their community and to provide the support needed to implement such a program. In these days of tax revolt, it is unlikely that an effective bicycle-safety education program could ever be implemented in a community without widespread support by the parents of school-age children.

OBJECTIVES OF EDUCATION FOR LAW ENFORCEMENT OFFICERS

Most agree that an education program for bicyclists would lose much of its effectiveness if it was not reinforced by a good law enforcement program. In most communities, the patrol officers consider the enforcement of bicycle laws to be among the least important and least desirable part of their job. As a consequence, few bicyclists who are observed violating the law are stopped and admonished by patrol officers; fewer still are issued citations. Therefore, the first objective of an education program for law enforcement officers is to educate them about the necessity for enforcing bicycle laws. They must be given explicit and factual information about the magnitude of the bicycle-accident problem and the beneficial impact that enforcement has on curtailing accident-producing behavior.

A second objective is to inform law enforcement officers of the violations that are most likely to be accident producing, and to induce them to be particularly conscientious in citing or otherwise admonishing bicyclists who violate these critical laws. The violations most likely to be accident producing include:

- Bicyclist enters a roadway from a driveway, alley, or over a curb or shoulder without slowing or stopping for traffic on the roadway.
- Bicyclist rides into intersection against traffic control device (stop sign, yield sign, traffic signal).
- Bicyclist rides on the wrong side of the roadway, facing traffic.
- Bicyclist rides on sidewalk where prohibited by local ordinance.
- Bicyclist rides at night without lawful lighting equipment.
- Bicyclist initiates left-hand turn without signaling or searching for approaching motor vehicles.
- Bicyclist attempts to pass motorist on the right or left at a roadway junction.

OBJECTIVES OF EDUCATION FOR BICYCLE DESIGNERS

There is little question that bicycle designers have had a long-standing concern for the safety of the bicyclist. This concern has manifested itself in many innovative design characteristics that have increased the safety of the bicycle. Recently, considerable attention has been devoted to increasing the effectiveness of bicycle-lighting equipment, increasing the effectiveness of bicycle brakes (particularly caliper brakes), and increasing the structural strength of critical parts of the bicycle. It is believed that educating bicycle designers about the causes of accidents will motivate them to seek innovative solutions to the bicycle-design deficiencies that often contribute to accidents.

Perhaps the most important need is for one or more devices that will increase the bicycle's conspicuity during both daytime and at night. It is important to emphasize to bicycle designers that the criterion that should be used to evaluate potential devices is conspicuousness (attention-getting quality) rather than visibility. Some recent attention has been given to the development of devices to increase the conspicuity of motorcycles; it is possible that some of the insights gained from the study of motorcycle conspicuity will also apply to bicycles.

Another equipment item that should be given special attention by bicycle designers is rear-vision devices. The rear-vision mirrors that are presently on the market appear to have important disadvantages. The bicycle-mounted mirrors are subject to vibration and have such a limited view that the bicyclist may be unable to see the area of interest to him even if vibration were not present. The main disadvantage of the mirrors that are attached to eyeglasses or helmets is that it is difficult to induce young bicyclists to wear them each time they ride.

A third design feature that should receive attention is the braking efficiency of caliper brakes when wet. Apparently, this problem has received some attention by bicycle designers, and improved braking pads and rims may now be available.

SUMMARY OF CRITICAL PROBLEMS AND ISSUES

Throughout this report, a special attempt has been made to identify problems and issues that must be dealt with before it will be possible to develop and implement an effective bicycle-safety education program. The problems and issues considered of greatest importance are summarized below.

ADDITIONAL ACCIDENT DATA

NMV Accidents

It has been mentioned repeatedly that there is a great need for comprehensive data on the bicycle accidents that are *not* the result of a conflict between a bicycle and a motor vehicle (NMV accidents). Enough is known to conclude that NMV accidents represent an important problem, but there are insufficient data to define the type of education that is required to solve this problem. In order to obtain data on NMV accidents, it will be necessary to survey a large and representative sample of the general bicycling population.

Since there is evidence that NMV accidents occur with great frequency on college and university campuses, it is essential that a study of NMV accidents include a representative sample of college and university students who ride their bicycles on campus. The study of NMV accidents must provide data on the incidence, consequences, and causes of such accidents. Personal interviews with bicyclists will be required to obtain information that is detailed enough to identify the full range of factors and events that cause NMV accidents.

Unreported Bicycle/Motor-Vehicle Accidents

In order to more accurately assess the magnitude of the bicycle-accident problem, additional data are needed to estimate reliably the incidence and consequences of the bicycle/motor-vehicle accidents that are not reported to the police. If a survey was conducted to obtain data on NMV accidents, it would be a simple matter to include items that would provide data on the number of unreported bicycle/motor-vehicle accidents a bicyclist has had and the consequences of these accidents.

Reasons for Bicyclists' Failure to Search Behind Before Turning Left

In Section V, it was mentioned that additional data are needed to fully define the reasons why bicyclists frequently fail to search behind before initiating a left-hand turn. It was hypothesized that bicyclists' failure to search may be due to (a) fear that searching behind may result in a loss of control of the bicycle, and/or (b) fallacious belief that auditory cues will always signal the presence of an overtaking motor vehicle. Data are needed to support or refute this hypothesis. If it is found that fear of losing control is a factor, research will be required to determine whether bicyclists can be taught to search behind without losing control of their bicycle--particularly juvenile bicyclists.

ORGANIZATIONAL PROBLEMS AND ISSUES

Implementation Agency

Many persons, including the author, believe that a major part of bicycle-safety education must be accomplished within public and private schools. However, there is no one within a local district who has the formal responsibility for implementing and supervising bicycle-safety education. Even though the interest in bicycle-safety education is high in some areas, it is pure folly to assume that someone within each school district will voluntarily assume the responsibility for bicycle-safety education in thier district. The same is true for education that would be accomplished through the public media. That is, there is no person or agency that clearly has the responsibility for seeing to it that educational messages appear in local newspapers and magazines or are aired on local radio and television.

Essentially, the same condition exists for federal and state agencies. It might be supposed that the Department of Health, Education, and Welfare would be willing to establish an office that would be responsible for the implementation of safety education on a nationwide scale. However, no such office exists at this time. It also might be supposed that a safety-education office could be established within the Departments of Education for each state. Such offices exist in some states but not all of them. In short, there is no agency at any level of government that can be expected to champion bicycle-safety education and assume responsibility for its implementation on a broad scale.

There appears to be no simple and easy solution to this problem. It will be necessary to either establish an independent implementation organization or assign the responsibility for implementing bicycle-safety education to persons within existing agencies. Although both approaches would require a major effort, it is believed that even the best safety-education program will simply die on the vine if there is not an agency at the federal, state, and local level who has the formal responsibility for implementing it.

Sources of Funding

Traditionally, federal and state funds have been made available for the development and evaluation of educational materials, but have not been available to support the routine administration of education at the local level. Since it is unlikely that this tradition will change in the near future, it seems reasonable to assume that most, if not all, of the funding needed to administer a bicycle-safety education program must come from local sources. Local tax revenues are a logical source of funds for bicycle-safety education, but the combined forces of inflation and tax revolt have increased the competition for local funds and have caused local administrators to be extremely reluctant to adopt new programs of any type.

If public funds cannot be obtained, it will be necessary to support bicycle-safety education with private funds. There are many private agencies who are interested in the bicycle-accident problem and who would be willing to contribute funds to a program that would serve to curtail this problem. However, it would be difficult to maintain continuity of a bicycle-safety education program if it was necessary to depend solely upon annual contributions from individuals and private organizations.

It has been suggested that bicyclists should and would be willing to bear the cost of education; bicyclists could either be charged directly for their education, or revenues from bicycle registration could be used for bicycle-safety education. Since funding constraints will have a large impact on the type of educational materials and methods that will prove most effective, it is important that the problem of funding be dealt with during an early stage of a developmental program.

Instructor Qualifications

It is impossible to commence developing instructional methods and materials until assumptions are made about the qualifications of the persons who will serve as instructors. The job of developing instructional methods and materials would be easiest if the instructional staff was composed of persons who were accredited teachers, experienced bicyclists, and who had received specific training in bicycle-safety education. If instructors lack any one or more of these qualifications, it will be necessary to offset the deficiency by

(a) developing instructional materials that are more simple to use and more self-sufficient in technical content, and/or (b) providing additional training to offset the deficiency in knowledge and experience. In general, the less qualified the instructor, the more difficult and costly it will be to develop effective educational methods and materials, unless this deficiency is offset by instructor training.

A considerable amount of analytical study will be required to define the optimal strategy for selecting and training instructor personnel. However, it is believed that this is a task that can and must be done before any attempt is made to develop the educational methods and materials that will be administered by instructor personnel, either in the classroom or in the field.

Incentives to Learn

The effectiveness of any educational program is influenced greatly by the trainees' motivation to learn. Motivation is importantly influenced by the skill of the instructor and the quality of the instructional materials. However, educational efficiency might be increased greatly if it is possible to create incentives that would further motivate the trainees to acquire the necessary knowledge and skills.

It has been suggested that an effective incentive for both bicyclists and motorists could be created by making licensing contingent upon the acquisition of the necessary knowledge and skills. Whether this practice would prove cost-effective remains uncertain. The idea of licensing bicyclists is offensive to many because they consider it to be another attempt to create an unnecessary government bureaucracy and further stifle individual freedom. Moreover, it is unlikely that the Department of Motor Vehicles would be enthusiastic about assuming the extra burden of licensing bicyclists and making motorists' licensing contingent upon a knowledge of bicycle-safety principles and practices. Despite the obvious disadvantages of this approach, it cannot be discounted without further consideration.

The author would welcome ideas from readers about incentives that would increase the motivation to learn, particularly incentives for motorists. If motorists are to be educated through published materials, it is certain that effective incentives will be required to motivate them to spend the time needed to carefully study the instructional materials.

Legal Liability

The issue of legal liability arises when it becomes necessary to conduct any type of on-bike training, particularly when the training is to be conducted on public streets. There have been a number of instances in which school administrators have refused permission to conduct on-bike training because of their concern about the school's liability in the event of an accident. It is believed that this issue should be studied carefully by legal experts and an official opinion formed about the school's liability in the event that an accident occurred during the course of a bicycle-safety education program. If it is judged that the school would be held liable, insurance experts should determine the type and cost of additional insurance that would be required to protect the schools from significant financial loss in the event of a law suit. It is unlikely that any local school administrator is going to agree to routine on-bike training until he has detailed information about his school's liability in the event of an accident and the cost of insurance protection.

Access to Motorists and Bicyclists

Educational methods and materials are more dependent upon techniques for gaining educational access to motorists and bicyclists than any other factor. As a consequence, it is essential that considerable time and effort be spent identifying and evaluating potential techniques for gaining access to motorists and bicyclists for a sufficient amount of time to accomplish the educational objectives. When evaluating alternate methods, it is not sufficient to identify the approaches that are best; it also is necessary to determine if any of the approaches judged best are truly cost-effective. It is altogether possible that there is no cost-effective way for gaining educational access to bicyclists and/or motorists and that the best strategy is to simply abandon the notion of educating bicyclists, motorists, or both.

In an earlier part of this section, the author discussed the advantages and disadvantages of various techniques for educating bicyclists and motorists. Also, recommendations were made about the techniques that are considered most feasible. It is not recommended that the author's views on this important matter be accepted without further study. Rather, it is hoped that these recommendations will stimulate others to consider this important problem and to express their views about the best way to deal with it.

TECHNICAL PROBLEMS AND ISSUES

Discussed below are problems and issues that are more technical and less political than those discussed above. The reader may find the distinctions between organizational and technical problems somewhat arbitrary, since the solutions to both types of problems may require careful analytical study. The main difference is that the technical problems and issues, as defined here, can best be dealt with by persons who possess expertise in bicycling, educational methods, or both.

EDUCATIONAL TARGET GROUPS

One of the first technical issues that must be resolved in developing a bicycle-safety education program is to define specifically who is to be educated. The author's views about the factors that must be considered in defining the educational target groups were discussed in an earlier part of this section (see pp. 103-106), so there is no need to repeat them here. However, it is important to emphasize that these views represent one person's opinion and that a considerable amount of additional analytical study and discussion will be required to define the educational target groups to everyone's satisfaction.

DEFINITION OF OPTIMAL BEHAVIOR

It is generally recognized that the purpose of bicycle-safety education is to modify behavior in a manner that will reduce accident likelihood. In many instances, defining the manner in which bicyclists and motorists should be taught to behave is a simple and straightforward task. However, there are some situations in which it is difficult to specify the exact behavior that will minimize accident likelihood. Discussed below are situations in which there is some uncertainty about the behavior that is optimal.

Route Selection

Little is gained by instructing bicyclists to select the safe route if they are incapable of evaluating the relative safety of alternate routes to their destination. In the author's view, additional study is required to identify the criteria that should be used in evaluating alternate routes and the relative weight that should be placed on each criterion. This issue is discussed in more detail on pages 111-112.

Course Selection

Bicyclists. Since about three-quarters of all bicycle/motor-vehicle accidents were either the direct or indirect result of the bicyclist's selection of a suboptimal course, it is essential that bicyclists be taught the optimal course through an area and induced to follow that course on all occasions. Unfortunately, bicycling experts disagree on the course that is optimal for some traffic contexts. Thus, it will be necessary to conduct further study to define the course that is, in fact, safest for certain traffic contexts, maneuvers, and conditions. It is particularly important to define:

- The optimal course for making left-hand turns in a variety of traffic contexts.
- The optimal course when exiting driveways with visual obstructions nearby.
- The optimal course when riding along narrow roadways (during daytime and during nighttime).
- The optimal course when riding along a row of parallel-parked motor vehicles.

There also is a need to define the maximum speed that is safe when riding in a variety of traffic contexts and under a variety of different weather and lighting conditions. In some cases, it may be possible for a group of bicycling experts to define the safest course. In other cases, analytical or experimental study may be required to define the optimal course.

Motorists. Similar uncertainties about the optimal course exist for motorists. Additional study is required to define the optimal course for the following situations:

- When driving along residential roadways with many intersecting driveways and alleys (bicycle-rideout accidents).
- When driving on narrow rural-type roadways at night (motorist-overtaking accidents).
- When exiting a driveway or alley with visual obstructions present (motorist-driveout accidents).
- When preparing to make a right-hand turn at a location where an on-street bike lane is present.

Responding to Uncertainty

Bicyclists. There were a number of accidents in which the bicyclist observed the motorist well in advance but failed to initiate evasive action because of an invalid assumption about the motorist's intentions. Thus, an important objective of any bicycle-safety education program is to teach bicyclists to recognize when the motorist's actions cannot be predicted with certainty. However, teaching the bicyclist to recognize situations in which the motorist's actions are uncertain is not enough; bicyclists must also be taught exactly how to respond in the face of such uncertainties. For instance, what is the bicyclist to do when he observes a motor vehicle waiting to enter the roadway from an intersecting driveway and the bicyclist is uncertain about whether or not he has been observed by the motorist? Some bicycling experts believe that the bicyclist should attempt to attract the motorist's attention with some type of signal; others believe that the bicyclist should modify his path, his speed, or both.

In the author's view, additional study is required to answer questions such as these. That is, there is insufficient information to define precisely how a bicyclist should behave in the face of uncertainty. Therefore, an important technical issue that must be resolved is to define precisely how a bicyclist should be taught to behave when he is uncertain about the actions of a motorist in each of the following situations, and perhaps others as well:

- A motorist is stopped on an intersecting roadway and may drive out into the path of the bicyclist.
- A moving motor vehicle is approaching on an intersecting roadway and may continue into the path of the bicyclist.
- A motorist is approaching in an opposing traffic lane and may turn left into the path of the bicyclist.
- A motorist, traveling in the same direction as the bicyclist, may turn right into the path of the bicyclist.
- A parallel-parked motor vehicle may be occupied by a motorist who may open the car door into the path of the bicyclist.
- A parallel-parked motor vehicle may exit the parking space into the path of the bicyclist.

Motorists. Although motorists appear to be inclined to expect aberrant behavior by bicyclists, there is an important number of accidents that result from a motorist's uncertainty about the bicyclist's intentions. It is important to define precisely how a motorist should be taught to behave in the following situations:

- A bicyclist is approaching on an intersecting roadway and may continue into the path of the motorist.
- The motorist is preparing to overtake and pass a bicyclist who may suddenly turn left.
- The bicyclist is approaching in an opposing traffic lane and may turn left into the path of the motorist.

FINAL SELECTION OF EDUCATIONAL OBJECTIVES

The educational objectives discussed in this report must be considered potential objectives; further study will be necessary to identify which of these potential objectives will, in fact, be included in a bicycle-safety education program. Final decisions about the objectives to be included must be based upon the accident-reduction potential, the cost in time and resources to accomplish the educational objective, and the likelihood that the education will, in fact, produce the desired behavioral change. It is also necessary to consider whether changing behavior to reduce one type of accident may increase the likelihood of other types of accidents. Teaching motorists to search for wrong-way-riding bicyclists is an example of an education that may decrease one type of accident but increase others. It also will be necessary to consider whether a bicycle-safety education program should be limited to objectives that have accident-reduction potential. There are a number of reasons why it might be beneficial to include auxiliary objectives, such as teaching bicyclists to be more effective and efficient riders, and promoting bicycling. Furthermore, considerable thought and study will be required to define the rudimentary knowledge and skills that must be taught before it is possible to teach young bicyclists the safety concepts and skills that are more directly relevant to bicycle safety.

EDUCATIONAL TECHNIQUES

The educational objectives discussed earlier in this section identify what must be taught but not how best to teach it. Considerable work will be required to develop educational techniques that are both effective and efficient. Questions about educational technique can be posed for virtually every educational objective discussed in this section. However, technique is a more critical question for some educational objectives than for others. The need to develop innovative techniques is particularly great for the following objectives:

- Teaching bicyclists the precise course that is safest in a wide variety of traffic contexts.
- Motivating bicyclists to refrain from unsafe behavior, even though it is highly unlikely that such behavior will lead to an accident on a particular occasion.
- Teaching bicyclists and motorists to search selectively for features that dictate the optimal course and for cues that signal a potential hazard.
- Teaching bicyclists and motorists to recognize specific cues to actual or potential hazard.
- Teaching bicyclists and motorists to correctly assess the risk associated with specific accident-producing behavior.
- Increasing bicyclists' ability to make specific temporal and spatial judgments.
- Teaching bicyclists and motorists to cope with momentary distractions.
- Teaching bicyclists to cope with competing needs.
- Teaching bicyclists and motorists to respond correctly to situations in which the other operator's actions are uncertain.
- Teaching bicyclists and motorists to recognize and cope with information overload.
- Eliminating, through education, invalid expectations that often lead to accidents.
- Increasing bicyclists' vehicle-handling skills, including searching behind, emergency stops, and emergency swerves/turns.
- Teaching bicyclists' parents to educate their children and to exercise control over where and when they ride.

- Motivating law enforcement officers to apprehend and cite bicyclists who violate critical laws and ordinances.
- Increasing the likelihood that motorists will observe bicyclists when they scan in the direction of a clearly visible bicyclist.
- Motivating bicyclists to select the safest route when an alternate route is faster, shorter, flatter, or otherwise more desirable.

It is hoped that the readers who wish to pursue research in the bicycle-safety area will consider the study of one or more of the above problems. It also is hoped that readers who have opinions about one or more of the above problems will convey their opinions to the author.

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APPENDIX A
BASIS FOR ESTIMATING THE COST OF SOCIETAL LOSSES

Described below are the data and assumptions underlying the cost estimates for the losses that result from bicycle/motor-vehicle accidents. Most of the cost estimates presented in Table 7 were derived from cost data contained in a recent report on the cost of motor-vehicle accidents (Faigin, 1976). Cost estimates for most losses resulting from traffic accidents differ as a function of the age and sex distributions of the accident population, the average severity of injuries sustained in the accident, and the types of vehicles involved. Therefore, these factors were taken into consideration when estimating the cost of losses resulting from bicycle/motor-vehicle accidents. Information about age, sex, and injury distributions was taken from a recent study of bicycle/motor-vehicle accidents (Cross & Fisher, 1977).

No attempt was made to establish a monetary value for such losses as pain and suffering, grief, loss of personal relationships, and so on.

PRODUCTION LOSSES

When a person is disabled or killed, society is temporarily or permanently deprived of the goods and services that would have been produced by that individual if he had not been killed or injured. One component of lost production is that associated with the person's regular job. This component is referred to as "Market and Market-Proxy Production Losses." A second component--referred to as "Home, Family, and Community Services Production Losses"--is the lost production associated with a person's work in the home and community, apart from his income-producing job.

Market compensation (income) was used as the measure of Market and Market-Proxy Production Losses. Since market compensation varies as a function of both age and sex, the age and sex distributions of bicycle/motor-vehicle accident victims were taken into consideration in computing market compensation. The method used to estimate the market compensation losses resulting from fatal accidents is the same as that used by Faigin (1976). This method assumes that production commences at age 20 and continues to age 64. For males and females in each age group, the national average income was increased three percent per year and discounted at seven percent per year through age 64. The totals for each sex and age group were then averaged to produce the average loss figure shown in Table 7. The estimate of the market compensation losses resulting from non-fatal accidents was based on the following parameters:

- On the average, each non-fatal bicycle/motor-vehicle accident (police reported) results in 4.3 days missed work or school (Cross & Fisher, 1977).
- The average value of a missed work day is $65 (Faigin, 1976).
- The average value of a missed school day is $5 (assumption).
- Of all days lost as a result of bicycle/motor-vehicle accidents, 18% are work days and 82% are school days (Cross & Fisher, 1977).

Based upon the data reported by Faigin (1976), the value of Home, Family, and Community Services Production Losses was estimated to be 8.1% of the value of the Market and Market-Proxy Production Losses.

MEDICAL CARE COSTS

Faigin compiled data on the medical costs associated with the treatment of persons killed and injured in motor-vehicle accidents. The estimates of medical costs for persons killed in bicycle/motor-vehicle accidents was assumed to be the same as for persons killed in other types of motor-vehicle accidents. However, specific data on the severity of injuries was used in estimating the cost of medical care for non-fatal accidents. The parameters used in computing the cost of medical care for the average non-fatal accident are listed below.

- About one-third of all bicycle/motor-vehicle accidents result in an injured party being transported to the hospital in an ambulance (Cross & Fisher, 1977).
- Fifty-three percent of all bicycle/motor-vehicle accidents result in injuries that are treated in a hospital emergency room (Cross & Fisher, 1977).
- On the average, 1.4 days of hospital care are required as a result of each bicycle/motor-vehicle accident that is police reported (Cross & Fisher, 1977).
- On the average, 3.1 visits to a physician are required as a result of each bicycle/motor-vehicle accident that is reported to the police (Cross & Fisher, 1977).
- The average cost of a visit to a physician is $20 (estimate based upon discussions with a limited sample of physicians).

The above parameters were used in estimating (for an average non-fatal accident) the cost of emergency transportation, emergency room treatment, hospital care, and physician care.

FUNERAL COSTS

Since future money is worth less than present money, funeral costs experienced in the current year are higher than funeral costs experienced in future years. The funeral costs shown in Table 7 represent the difference between average funeral costs in the current year and the costs that would occur in a future year--assuming a normal life expectancy for the fatally injured person. The value shown in Table 7 is based on: the median age of males and females involved in bicycle/motor-vehicle accidents (16.2 years for males and 17.5 years for females); the remaining years of life expectancy for males and females (54.3 years for males and 60 years for females); the weighted average remaining years of life expectancy (55.2 years); average funeral costs for 1975 ($1,125); productivity price increase at three percent per year ($5,717); present worth factor, assuming a seven percent discount rate ($138); and net difference between present and future cost ($987).

LOSSES TO OTHERS

The costs of losses to others include employer losses (temporary or permanent replacement costs, time spent visiting patients, transportation for medical attention, home care, and time spent in vehicle repair and replacement. Faigin (1976) has estimated the cost of losses to others resulting from fatalities and from five different injury levels. The cost estimates shown in Table 7 are the same as Faigin's estimates for fatalities and for level-two injuries.

LEGAL AND COURT COSTS

No data are available on the proportion of bicycle/motor-vehicle accidents that result in litigation, so it was necessary to formulate a number of assumptions in order to estimate the legal and court costs associated with bicycle/motor-vehicle accidents. The most fundamental assumption is that the only bicycle/motor-vehicle accidents that result in litigation are those in which the motorist is clearly culpable. Data compiled by Cross and Fisher (1977) indicate that the motorist was clearly culpable in 34% of the fatal accidents and 28% of the non-fatal accidents. Other assumptions are as follows:

- A suit is filed against the motorist in all of the fatal cases in which the motorist is culpable and 20% of the non-fatal cases in which the motorist is culpable.
- Fifteen percent of the suits are tried in court.
- When a suit is filed against the motorist, a settlement in favor of the bicyclist is awarded in 90% of the fatal cases and 60% of the non-fatal cases.
- All motorists who are clearly culpable are issued a traffic citation.
- The average settlement is $50,000 for a fatal accident and $4,500 for a non-fatal accident.
- The plaintiff's legal costs are 25% of the settlement.
- The defendant's legal costs average $1,800 per suit.
- The average court cost for suits settled by trial is $7,370.
- The average citation costs are $50 for fatal accidents and $20 for non-fatal accidents.

All of the above estimates of costs are based upon cost data presented in Faigin's report (1976), and all cost estimates are in terms of 1975 dollars.

INSURANCE ADMINISTRATION COSTS

The insurance administration cost represents the cost of insurance overload that could be saved with the reduction of bicycle/motor-vehicle accidents. The cost estimates shown in Table 7 are based upon cost data presented in Faigin's report (1976).

ACCIDENT INVESTIGATION COSTS

The accident investigation costs refer to the cost of time and resources expended by enforcement officials in investigating the accident. The cost estimates are based upon cost data presented in Faigin's report.

VEHICLE DAMAGE

The estimates of the cost of vehicle damage are based upon data compiled by Cross and Fisher (1977).

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APPENDIX B
INVENTORY OF OBJECTIVES FROM A SAMPLE OF RECENT BICYCLE-SAFETY EDUCATION PROGRAMS

The following inventory of educational objectives was compiled from a study of ten bicycle-safety education programs. All the programs reviewed were developed since the onset of the "bike boom"; over half of them were developed within the past three years. For ease of interpretation, the objectives have been organized into 15 basic categories. The first category--rudimentary knowledge and skills--contains a listing of what might be considered prerequisite objectives for educating very young children. Since the rudimentary knowledge and skills are normally acquired through the standard education process, these objectives are relevant only if it *is* necessary to provide bicycle-safety education before the rudimentary knowledge and skills have been acquired in a normal fashion.

1. DEVELOP/ENHANCE RUDIMENTARY KNOWLEDGE AND SKILLS

BASIC DISCRIMINATION AND RECOGNITION SKILLS

- Basic colors
- Basic shapes
- Distance
- Direction (right, left, and cardinal directions)
- Absolute and relative size of objects
- Absolute and relative velocity of moving objects
- Basic auditory stimuli
- Bicycle types
- Motor-vehicle types
- Types of vehicle operators (e.g., young vs. old)

KNOWLEDGE OF BASIC RELATIONSHIPS AND ASSOCIATIONS

- Size-distance relationships
- Associate colors with basic actions
- Associate shape and meaning of traffic signs
- Associate colors with position on signal
- Relationship between speed and accuracy in performing complex psychomotor tasks
- Effect of roadway surface defects (sand, water, ice, snow) on stopping distance
- Effect of weather and lighting on vision
- Relationship between safety and effective vision
- Relationship between safety and effective hearing
- Relationship between safety and vehicle speed

KNOWLEDGE OF BASIC WORDS AND CONCEPTS

- Words and concepts needed to describe the physical and operational characteristics of the roadway system (lanes, one-way streets, turn pockets, permanent markings, etc.)
- Words and concepts needed to describe the capabilities and limitations of the human visual system (central/peripheral vision, focus, fixation, scan, search, light/dark adaptation, etc.)
- Words and concepts needed to describe the capabilities and limitations of the human auditory system (pitch, amplitude, auditory masking, etc.)
- Words and concepts needed to describe human response time (search time, decision time, and reaction time)

- Words and concepts needed to describe the formal and informal rules of the road (law, ordinance, safety rule, yield, right-of-way, etc.)
- Words and concepts needed to describe human perceptual processes (attention, selective attention, distractions, information-processing overload, etc.)
- Other key words and concepts (visual obstruction, reflection, glare, visibility, conspicuity, fault, culpability, prediction, anticipation, defensive driving, balance, friction, dawn/dusk, etc.)

BASIC PSYCHOMOTOR SKILLS

- Practice balancing on beam or narrow line on floor
- Basic visual search/scan exercises
- Basic eye-hand coordination exercises

BASIC ATTITUDES AND VALUES

- Generate respect for police officers and safety patrols
- Generate respect for laws, ordinances, and safety rules
- Modify subjective belief in own invulnerability
- Modify subjective assessment of accident likelihood
- Develop attitude that a bicycle is a vehicle rather than a toy
- Develop attitude that bicyclists are vehicle *drivers*
- Develop attitude that accidents are avoidable

2. DEVELOP/ENHANCE KNOWLEDGE OF HUMAN PERCEPTION AND INFORMATION PROCESSING

CAPABILITIES AND LIMITATIONS OF THE VISUAL SYSTEM

CAPABILITIES AND LIMITATIONS OF THE AUDITORY SYSTEM

ATTENTION AND ATTENTIONAL CONFLICT

NFORMATION-PROCESSING LIMITATIONS

SELECTIVE PERCEPTION

3. DEVELOP/ENHANCE KNOWLEDGE OF ACCIDENT PROBLEM

TYPES AND NUMBER OF BICYCLE ACCIDENTS AT LOCAL, STATE, AND NATIONAL LEVEL

CONSEQUENCES OF BICYCLE ACCIDENTS (DEATHS, INJURIES, PROPERTY DAMAGE, AND OTHER)

ACCIDENT TARGET GROUPS

4. DEVELOP/ENHANCE KNOWLEDGE OF THE BICYCLE

ELEMENTARY

- History of bicycle development
- Benefits of bicycling
- Past and present trends in bicycle usage
- Bicycle types
- Advantages and disadvantages of each type of bicycle
- Name and function of bicycle parts (standard)
- Name and function of optional accessories
- Performance of bicycle-safety check
- Selection of bicycle type and size
- Adjustment of seat and handlebars to fit rider

ADVANCED

- Performance of bicycle repair and maintenance
- Selection of gear configuration
- Selection of special-purpose equipment

5. DEVELOP/ENHANCE VEHICLE-HANDLING SKILLS

ELEMENTARY

- Mounting/dismounting
- Balancing at slow speed
- Straight-line riding
- Circling/weaving
- Riding in a narrow space
- Stopping at a designated spot
- Balancing while scanning behind
- Balancing while signaling
- Balancing while shifting gears

ADVANCED

- Special pedaling techniques
- Mountain-riding techniques
- Cross-country touring techniques
- Bicycle racing techniques
- Bicycle commuting techniques
- Inclement weather techniques
- Emergency swerving
- Emergency braking

6. DEVELOP/ENHANCE KNOWLEDGE OF ROADWAY SYSTEM

PHYSICAL CHARACTERISTICS

- Signs/signals
- Roadway types
- Intersection types
- Special-use lanes
- Bicycle paths and lanes

OPERATIONAL CHARACTERISTICS

- Formal laws and rules-of-the-road
- Informal rules and practices
- Traffic density as a function of time and location of roadway
- Operating speeds as a function of type and location of roadway
- Hazardous locations
- When and where DWI drivers are most often encountered

7. DEVELOP/ENHANCE ABILITY TO SELECT SAFE ROUTES

ROUTE-SELECTION CRITERIA (ROADWAY WIDTH, PARKED, CARS, TRAFFIC VOLUME, OPERATING SPEED, NUMBER AND TYPE OF INTERSECTIONS, ETC.)

LOCATING AND USING MAPS

8. DEVELOP/ENHANCE ABILITY TO SEARCH FOR AND RECOGNIZE HAZARDS

OPTIMAL SEARCH BEHAVIOR

HAZARDOUS TRAFFIC CONTEXTS (STREET INTERSECTIONS, HIGH-SPEED RURAL ROADWAYS, ETC.)

HAZARDOUS MANEUVERS (EXITING DRIVEWAYS, LEFT TURNS, ETC.)

SPECIFIC CUES THAT FORECAST HAZARDOUS EVENTS/SITUATIONS (ACTIVATED TURN SIGNALS, OCCUPANT IN PARKED CAR AHEAD, ROAD-SURFACE DEFECTS)

9. CORRECT FAULTY ASSUMPTIONS AND JUDGMENTS

ASSUMPTION THAT MOTORISTS WILL ALWAYS ADHERE TO LAW

ASSUMPTION THAT MOTORISTS WILL ALWAYS SEARCH FOR AND OBSERVE BICYCLISTS

JUDGMENT OF STOPPING DISTANCE (BICYCLES AND MOTOR VEHICLES) AS A FUNCTION OF VELOCITY AND ROADWAY-SURFACE CONDITIONS

JUDGMENT OF SAFE GAP IN TRAFFIC

ASSUMPTION THAT RIDING COMPANION WILL SEARCH FOR AND DETECT HAZARDS

ASSUMPTION THAT A NORMALLY QUIET STREET WILL BE VOID OF TRAFFIC

JUDGMENT OF SPACE REQUIRED TO OVERTAKE AND PASS ANOTHER VEHICLE

JUDGMENT OF SPACE REQUIRED FOR ANOTHER VEHICLE TO OVERTAKE AND PASS BICYCLIST

10. DEVELOP/ENHANCE KNOWLEDGE OF GENERAL DO'S AND DON'TS

DON'T RIDE TWO OR MORE ABREAST

DON'T RIDE FACING TRAFFIC

ALWAYS STDP FOR STOP SIGNS AND RED TRAFFIC SIGNALS

DON'T HITCH A RIDE ON A MOTOR VEHICLE

DON'T CARRY A PASSENGER ON BICYCLE

DON'T PLAY GAMES OR CLOWN IN THE STREET

ALWAYS GIVE PROPER HAND SIGNAL BEFORE TURNING

KNOW ALTERNATE METHODS FOR MAKING A LEFT TURN AND ALWAYS USE THE METHOD THAT IS SAFE FOR THE SITUATION

WEAR CLOTHING THAT IS VISIBLE AND CONSPICUOUS (DAY/NIGHT)

WEAR A HELMET AND PROTECTIVE CLOTHING

RIDE AS FAR TO THE RIGHT AS PRACTICABLE

KEEP BICYCLE IN GOOD MECHANICAL CONDITION

OBEY ALL TRAFFIC RULES AND SIGNS

WALK BIKE ACROSS BUSY INTERSECTIONS

BE SURE ROADWAY IS CLEAR BEFORE ENTERING

WATCH FOR OPENING CAR DOORS

BE SURE LIGHTING EQUIPMENT IS IN GOOD REPAIR BEFORE RIDING AT NIGHT

AVOID RIDING AT NIGHT

AVOID BUSY STREETS AND INTERSECTIONS

YIELD RIGHT-OF-WAY TO PEDESTRIANS

RIDE DEFENSIVELY

WATCH FOR STORM DRAINS AND DEBRIS ON ROADWAY

DON'T RIDE OVER CURBS

DON'T COMPETE WITH MOTORISTS

ALWAYS BE PREPARED TO YIELD THE RIGHT-OF-WAY

DON'T RIDE TOO FAST WHEN TRAVELING DOWNHILL

DON'T RIDE TOO FAST FOR CONDITIONS

WATCH OUT FOR ANIMALS IN ROADWAY

PRACTICE RIDING IN A SAFE AREA

DON'T RIDE ON SIDEWALKS

11. DEVELOP/ENHANCE ABILITY TO RECOGNIZE AND CONTROL COMPETING NEEDS

TIME CONSERVATION
ENERGY CONSERVATION
NEED FOR EXCITEMENT/COMPETITION
NEED FOR SELF ASSERTION
NEED TO DEFY AUTHORITY

12. DEVELOP/ENHANCE ABILITY TO RECOGNIZE AND COPE WITH DISTRACTIONS

RIDING COMPANIONS
PEDESTRIANS
HOSTILE ANIMALS
TRAFFIC
ROAD-SURFACE HAZARDS

13. DEVELOP/ENHANCE ABILITY TO SELECT AND EXECUTE OPTIMAL EVASIVE ACTION

SPEEDY SITUATION ASSESSMENT
SPEEDY DECISION MAKING
EXECUTING EMERGENCY TURNS, STOPS, VOICE WARNINGS, AND CONTROLLED SKIDS/FALLS

14. DEVELOP/ENHANCE KNOWLEDGE OF ACCIDENT-GENERATION PROCESS FOR FREQUENTLY OCCURRING TYPES OF ACCIDENTS

TRAFFIC CONTEXT IN WHICH ACCIDENT OCCURS
PRE-CRASH COURSE (PATH AND SPEED) OF BOTH VEHICLES
FUNCTION FAILURE OF BOTH OPERATORS
COMBINATION OF ENVIRONMENTAL, VEHICLE, AND OPERATOR FACTORS LEADING TO FUNCTION FAILURES

15. MODIFY UNSAFE ATTITUDES

ANYONE CAN LEARN TO RIDE A BICYCLE SAFELY WITHOUT FORMAL TRAINING
RULES-OF-THE-ROAD DO NOT APPLY TO BICYCLISTS
INFORMAL SAFETY RULES ARE UNIMPORTANT
THE BICYCLE IS A TOY