SPECIAL STUDY

BICYCLE USE AS A HIGHWAY SAFETY PROBLEM

Adopted: April 5, 1972

NATIONAL TRANSPORTATION SAFETY BOARD
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16. Abstract The report reviews the magnitude of the problem, and emphasizes that the majority of losses and injuries are among children 5 to 14 years old. In each of the past 3 years, 800 or more fatalities occurred in collisions between bicycles and motor cars. The status of knowledge is reviewed, and the meagerness of this knowledge is pointed up. The need for much more study is part of the problem. No clearly feasible and effective countermeasures are readily at hand.

The authority and responsibility of the National Highway Traffic Safety Administration (NHTSA) are reviewed briefly, and the very limited actions. The role and responsibility of the Dept. of Health, Education and Welfare are reviewed briefly. Recommendations are made that NHTSA: 1) explore and develop effective methods of integrating training of young people for bicycle operation and automobile driving, 2) if 1) is successful, promulgate a highway safety program standard to implement it, and 3) coordinate its bicycle safety efforts with the Department of Health, Education and Welfare (DHEW), particularly with respect to bicycle design. It is recommended that DHEW's research focus on injury potential of specific design features as well as operator behavior associated with specific features. It is recommended that the Federal Highway Administration (FHWA) and NHTSA be actively involved in the Department of Transportation's efforts to encourage the use of bicycles to assure that safety is given full consideration.

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I BACKGROUND AND MAGNITUDE OF THE PROBLEM

In each of the 3 years 1968-70, collisions between motor vehicles and bicycles resulted in more fatalities than from railroad transportation [1, 2, 6],[1] thus:

Year	Fatalities in Railroad Transportation[2]	Fatalities in Bicycle Collisions with Motor Vehicles
1968	737	800
1969	724	800
1970	706	820

This reflects, in part, the increased use of the bicycle, both as a recreational vehicle and a transportation vehicle, as well as the increased number of motor vehicles in operation in this country. The Bicycle Institute of America estimates the number of bicycle users as over 60 million [9] and this number is increasing. A recent article in Time magazine [16] calls attention to the upsurge in purchase of new bicycles in the United States. Manufacturers' production is not keeping up with demand. ". . . for the first time since the 1890's, nearly one-half of all bicycle production is geared for adults." Sales are expected to reach 8½ million in 1971. More than 90 percent of children in grades 2 through 8 ride bicycles [18, 19, 20].

[1]The numbers in brackets throughout this study identify references appearing on pages 15-16.

[2]This excludes nontrain accident data and grade-crossing accident data.

Since 1933, with the exception of only 2 years, no fewer than 400 fatalities resulted each year from this source [2]. An additional 45 to 80 annual fatalities result from bicycle accidents which do not involve motor vehicles [10], and as many as 75 more fatalities occur to persons other than the pedal cyclist. Injuries from bicycle-motor vehicle accidents are estimated to be no less than 34,000 annually in the past 5 years [2]. This compares with about 14,000 to 18,000 from railroad transportation [1].

II SIGNIFICANT CHARACTERISTICS OF THE PROBLEM

Sex of Cyclist.

About 90 percent of the cyclist fatalities due to bicycle-motorcar collisions are males [10, 21]; for the accidents not involving motorcars, about 75 percent of the fatalities are males [10]. In a Canadian study of 275 collisions with motorcars, 93 percent involved male bicyclists [3].

Rural-Urban.

For the 5 years, 1965-69, only 1 year, 1967, shows an even division between urban and rural areas for bicycle-motorcar fatalities [2]; for the other 4 years, somewhat more than one half occurred in rural areas (defined as having less than 2,500 inhabitants, except those areas classified "urban" by the U. S. Census Bureau).

Age of Cyclist.

In each of the years 1965-69, over 60 percent of the bicycle-motorcar fatalities, and about 75 percent of the injuries, were in the age group 5 through 14 [2]. In a study in North Carolina [21], nonfatal accidents were somewhat more characteristic of the younger cyclist, and it is speculated

> " . . . Younger riders probably stay closer to home (residential areas) where it has been previously noted that nonfatal bicycle accidents are more likely to occur. This finding is also consistent with the fact that daytime bicycle accidents are less likely to result in fatalities; that is, younger riders would be unlikely to be out at night."

The Canadian study [3] also found a mild tendency for the more distant collisions to involve older children.

Time (of the Year, Week, Day).

The frequency of both fatal and nonfatal accidents increases during the months of May to September, when children are out of school and the weather is good. Saturday is a high-frequency day, and also the after-school hours from 3 to 7 p.m. [21]. Although these findings pertain to North Carolina, they would be expected to be approximately true of the American scene. After-school and early evening hours were also peak periods for collisions in the Canadian study [3].

Light Conditions and Visibility.

Approximately 30 to 40 percent of cyclists of elementary school age say that they ride after dark [18, 19]. Accidents which occur during hours of darkness on unlighted roads are much more likely to result in fatalities than are accidents during daylight, dusk, or during hours of darkness on lighted roads, according to the North Carolina data [21]. In the Canadian study, in 20 percent of 28 cases involving nighttime riding, a bicycle with no forward or side lighting was in collision with a motor vehicle approaching from a frontal or side direction at an intersection. In a "significant proportion" of collisions which involved the bicyclist on an intersecting path with the motorist, there were obstructions to mutual view [3].

Locality.

Nonfatal accidents are more likely to occur in residential areas (city streets), while fatal accidents are most likely to occur in open country (major and minor roads) – at least in the State of North Carolina [21]. This is probably related to the higher speeds of motorcars outside the city or town. Compared with all fatal motor vehicle accidents, fatal bicycle accidents show a larger proportion occurring where there is some kind of intersection of vehicle pathways. This is also true of nonfatal accidents [21].

The Canadian study [3] found 96 percent of all bicycle-motorcar collisions occurred within 1 mile of home, and 57 percent within 1 block; also, intersections of some kind were the most frequent site of collisions: " . . . 82% of collisions relate to manoeuvers by the bicyclist to enter into, to turn across or to cross through a flow of traffic."

Nonconformance of Cyclist to Rules of the Road.

In two studies [18, 19], about 40 percent of cyclists of grade-school age said they ride on the right side of the street, 40 to 50 percent said they ride on both sides, and 10 to 15 percent said they ride on the left side. Some ride on the sidewalk. Apparently, there is some confusion, lack of knowledge, or disregard with respect to rules and regulations or safe operating procedures.

Driver Behavior in Bicycle-Motorcar Collisions.

In the North Carolina study [21], in the great majority of motorcar-bicycle collisions, both fatal and nonfatal, the driver was not charged with a violation. This suggests that the bicyclist was usually judged to be at fault in such accidents.

Behavior of Bicyclists Related to Accidents.

In the Canadian study, 20 percent of collisions with motorcars involved the carrying of a passenger or some hand-held load [3]. In the passenger ca ‿s, 65 percent of the bicycles were equipped with high-rise handlebars and banana seats (see Fig. 1), including some large-wheel bicylces which had been modified by their owners.

In the Vermont study [20], 37 percent of the 104 injuries occurred to cyclists who were not riding their own bikes and over 75 percent of injuries involving passengers occurred on borrowed bikes. Horseplay, as a circumstance leading o accident and injury, was more characteristic of the high-rise bike than of the standard; this was true of owned bikes, but not of borrowed bikes. Among injuries sustained with owned bikes, "hit an obstacle" was more characteristic of standard bikes than of high-rise; for borrowed bikes, the difference was reversed, "hit an obstacle" being more characteristic of high-rise bikes, but not significantly so. Getting a foot caught was more characte ʾstic of cyclists riding borrowed bikes, but not significantly so. Collisions with automobiles were more characteristic of standard bikes than high-rise.

III BICYCLE CONFIGURATION, SIZE, AND DESIGN

The Canadian Study.

In the Canadian study of urban bicylce collisions [3], about one-third of the bicycles owned by 8- to 13-year-old males had standard

Conventional

Light Weight

High-Rise

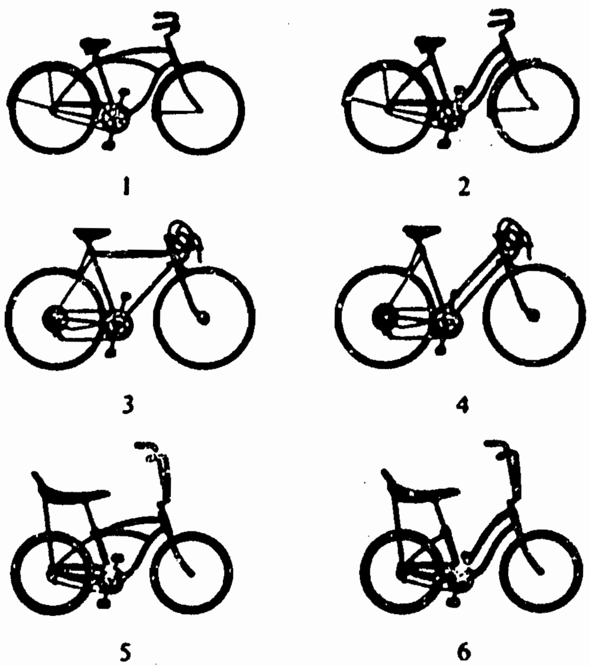

Figure 1. TYPES OF BICYCLES

handlebar and seat configurations. About one-third were "high-rise" types and one-third were owner-modified standard bicycles. The high-rise was the most popular among the 8- to 10-year-olds, but was also popular in the 11- to 15-year-old group. Riders on high-rise bicycles sit considerably closer to the ground -- 4 inches in the case of older boys – and have somewhat lower handlebar height than their age group counterparts on standard size bicycles. The 8- to 10-year-olds were found to be generally better fitted to the bicycles than the 11- to 13-year-olds, although a significant problem for the younger group was excessive ground clearance[3] for larger bicycles. For older bicyclists, the ground clearance was more likely to be too small. This disaccommodation of vehicle and rider was shown to be a major safety hazard [3].

The relative risk rates for riders classified according to ground clearance levels indicated that excess risk was associated with both underaccommodation and overaccommodation for males 8 to 10 years old. For this group, the risk of collision involvement associated with more than 3.5 inches of ground clearance was 5 times that associated with a ground clearance of .5 to 3 inches; for a zero ground clearance, the risk was 3.4 times as high as for .5 to 3 inches. For male bicyclists 11 to 13 years old, the excess risk due to disaccommodation became significant when ground clearance exceeded 5½ inches (which corresponds to the minimum ground clearance of pedals on larger size bicycles), but there was no increased risk associated with zero clearance. Ground-clearance level was significantly related to relative risk, when age, sex, bicycle size, and exposure are controlled, among 8- to 10-year-olds using bicycles with 18- 20-inch rear wheels: about 3 times as high for clearances of more than 3.5 inches or zero, compared with a clearance of .5 to 3 inches.

Disaccommodation was found to be associated with higher excess risks for bicyclists living on arterial or collector streets than those living on local or residential streets. The study showed that 45 percent of 8- to 10-year-olds who ride bicycles are disaccommodated to the extent that they experience excess collision risk [3].

In an examination of the high-rise type versus the standard type and modified standard type bicycles among the 8- to 10-year-olds, no important difference in risk experience was found. Among 11- to 13-year-olds, however, a lower collision involvement rate (approaching statistical significance) was found for high-rise bicycles compared with large rear-wheel-diameter standard bicycles.

In discussing the design characteristics related to risks, the authors of the Canadian study note that frequently the only distinguishing feature of a high-rise bicycle is that it is equipped with devices which provide a higher placement of the handlebar grips and a more rearward displacement of the rider on a frame and fork of conventional size and configuration. In other cases, subtle changes in steering or frame geometry or tire characteristics may bring about significant changes in the handling characteristics of the bicycle, requiring considerable rider adaptation; indeed, some of the new configurations cannot be ridden with hands off the handlebars. The authors point out that, on the other hand, there is a sound technical basis for predicting differences in risk experiences for bicycles with different braking systems, since front- and rear-wheel braking can provide demonstrably superior stopping capability to rear-wheel-only braking under a variety of operating conditions. When relative risk rates are computed for groups matched for age, sex, and bicycle size, an age interaction with brake type is observed, although the effect is not large enough to be statistically significant. Eight- to 10-year-olds, riding bicycles equipped with front and rear handbrakes, were observed to have a higher risk of collision than their age counterparts on the same size bicycles with footbrakes. Conversely, 11- to 13-year-olds riding bicycles with front and rear handbrakes

[3] Distance between cyclist's extended feet and the ground when he is seated and the bicycle is vertical.

had a lower risk of collision than their counterparts riding bicycles with footbrakes.

These findings were taken to suggest that while the technical superiority of two-wheel braking can be realized among older bicyclists, younger bicyclists may be disadvantaged by this configuration. The increased risk for younger riders supports experimental evidence that the mere provision of the two-wheel braking system by the method of hand actuation does not consistently yield superior stopping performance. An examination of the design, location, and force characteristics of handbraking systems in relation to the reach, strength, coordination, and braking habits of riders is justified in order to establish the practicability of this configuration for younger riders. Many of the youngest road users are using bicycles which make the task of riding much more difficult than it need be at that stage of learning. The practice of providing oversized bicycles for younger children so that they can grow into them is regarded as contrary to the child's interests since he needs the best suited bicycle when he is acquiring his early experiences of traffic. The authors emphasize that if learning to ride is to be more than a matter of mastering the balance and control with the bicycle in motion, then adult guidance is essential at the earliest stages of riding to help the child to understand and to respond to the full implication of traffic rules and environmental deficiencies. " . . . the humane and realistic integration of the child bicyclist as a vehicular road user requires the provision of special training in the use of the bicycle in road traffic."

Another issue of accommodation raised by the Canadian study was that, on many bicycles, the vertical riser part of high-rise handlebars was tilted back considerably. This adjustment appeared to be adopted, by smaller riders, to maintain a comfortable reach and, among older riders, to allow a rearward sitting location on the banana seat, which seems to be the position dictated by convention and one which facilitates effortless "wheelies." Such extreme rearward tilt changed the geometric relation between the handlebars and the rider, leading to interference of the grips with the rider's body during all low-speed maneuvers. In addition, if the rider tries to carry a passenger on the back of his banana seat he is forced to move forward into an awkward position that interferes with handlebar movement [3].

The Cornell Study.

The Cornell Aeronautical Laboratory conducted a study for the National Commission on Product Safety on the performance and handling qualities of bicycles [14]. Their summarized findings follow:

1. The bicycle may be likened to the automobile – the sportier the design, the more skill likely to be required for its safe operation.
2. Shorter wheelbase and smaller wheel size are detrimental to both lateral and vertical plane stability.
3. Protuberances (such as high handlebars, gear shift levers mounted on the horizontal frame member, and seat backs) which can be bumped or which inhibit the ability of the rider to get free of the bike are potential safety hazards.
4. Bicycles equipped with front wheel brakes can be stopped more quickly (that is, in shorter distances) than a similar bicycle equipped with coaster brakes. However, in some situations, such as when the rider stands upright on the pedals, hard front wheel braking can lead to forward pitch-over. When this occurs, the motion is so rapid that there is little which an unsuspecting rider, even a very experienced one, can do to avoid a bad fall. The counterpart to this in hard rear-wheel braking – a lateral breakaway – is much more easily handled.

5. In the tests which were performed to obtain quantitative measurements of handling qualities (and these included steady state cornering and serpentine path following), the high rise bicycle did not prove to be more maneuverable at moderate speeds (10-15 mph) than the conventional bike. This is not to say that all maneuvers can be performed equally well with each design; however, it does suggest that the high riser outperforms the conventional bike only in acrobatics and in situations where its shorter overall length is essential to success. Without gearing, the high riser is not a good design for transportation; it is just too tiring to pedal at speed for distance compared to the conventional design. In essence, it is a bike to have fun with and, by incorporating features which make this possible, it requires somewhat more skill for its operation.

6. As part of this program, a mathematical model of the bicycle with eight degrees of motion freedom, including the three translations and the three rotations of the whole system has been developed. The mathematical model provides a capability for the evaluation of bicycle designs and the investigation of the effects of a wide range of design factors on performance. Such features include wheel size, fork angle, wheelbase, total weight and weight distribution, height of center of gravity, and tire characteristics. In this short study, it has not been possible to do more than get the simulation working properly, but it is strongly recommended that it be used to study these effects in order to achieve a better understanding of the fundamentals of bicycle stability and control.

Hearings before the National Commission on Product Safety

The Commission held extensive hearings on product safety over a period of time. The hearings on March 4, 1970, elicited testimony on bicycle safety [7]. That bicycles are a product of considerable concern to the Commission is evidenced by some of the testimony by one member of the Commission staff, Dr. Robert Verhalen:

> "Bicycles led the list of products associated with injuries reported over a two-week period in a survey of physicians across the country conducted by the Commission last April, accounting for more than twice as many accidents as the second most frequently ranked product. On the basis of these data, extrapolated to include the entire year, it can be estimated that more than one-fourth million bicycle injuries are serious enough to require treatment by physicians in their offices. Bicycles have consistently ranked among the top five products in thirteen hospitals from Memphis, Tennessee and the D. C. Metropolitan area, reporting daily to the Commission's data bank on product-related injuries."

The testimony referred to a fairly wide range of bicycle design and performance characteristics which may be related to bicycle safety. The items regarded as most relevant to the present review are summarized briefly below. Since the findings of the Cornell study are summarized above, the testimony of the senior author of that study is not repeated here.

Mr. James B. Ellers, Jr., testified that in his study in Memphis, Tennessee, 40 percent of bicycle accidents in the lower socio-economic areas involved children riding double, most of these on spider bicycles with banana seats. In poor neighborhoods with large families and few bicycles, the banana seat is suspected of encouraging the children to ride double. Ellers felt that the safety of this seat should be studied. The desirability of using reflectors or fluorescent tape or fluorescent paint on bicycle body parts to make these vehicles visible from all angles at night was also suggested.

Testimony from Dr. T. R. Howell called attention to patterns of injury that appear to be related to specific bicycle design:

"Craniofacial injuries in bicycle riders in 8 selected cases have been evaluated . . . All of the patients were thrown forward over and/or through the handlebars. Each individual maintained a firm grip on the handlebars until striking the ground or pavement. In every case, the front wheel of the bicycle stopped rolling instantly.

"In every patient injured in falls from bicycles when they were thrown through or over the handle bars specific types of injuries were persistently seen.

"As information from each case history of craniofacial injury in bicycle riders was tabulated, there was an increasing awareness that bicycles with a small front wheel, low-set front axle, high, long, narrow seat, and high, wide handle bars were frequently being implicated. Should this type of injury be reported by physicians elsewhere, the likelihood that this relationship is significant increases. With the low-set front axle and small front wheel, small irregularities in the terrain have a tendency to cause the front wheel to become easily jammed, stopping its forward roll. When the hands are positioned to hold the grips on the high, wide handle bars, this completes an ideal situation for the child to be tossed forward through the handle bars when forward motion is suddently stopped. Also, some observers have stated, the neophyte bicyclist tends to have more difficulty in controlling the bicycle when the handle bar grips are set in a high, wide position."

Another style innovation mentioned in the hearings as potentially hazardous is the console gearbox on the frame of the bike. This necessitates the child's taking one hand off the handle bars in order to shift. This maneuver is considered potentially hazardous, and the gearshift levers on the frame constitute a hazard in case the rider strikes them with his body during an accident.

Some examples of how bicycles are involved in the generation of accidental injury were further provided by Dr. Verhalen from the Commission files:

"In one case . . . a 13-year old boy riding a 20-inch high-rise style, received extensive dental injury and painful facial lacerations, requiring 10 stitches, when the front fork of his bicycle snapped in two at the yoke. He was sent flying over the front of his bicycle, landing on his face on the street pavement. The machine was only 6 months old.

"In another case, a 6-year-old boy riding his 5-month old . . . bicycle for the first time without training wheels received painful hand injuries from the gear drive of his toy. He was riding down a small hill on the sidewalk in front of his house . . . and, because his bicycle was manufactured without brakes, he had to put his feet out to "brake" his movement. In doing so, he lost his balance and fell forward, driving his hand between the chain and the pedal sprocket.

"A third example concerns a 20-inch high-rise being ridden up an inclined street. The 8-year-old male victim downshifted his 5-speed bicycle and as he rose to put more pressure on the pedal, his machine reared and dumped bike and child over backwards. The boy was knocked unconscious as he landed on the back of his head in the street with his machine on top of him.

"A final example involves a 6-year-old girl riding a 3-speed high-rise bicycle . . . who was hospitalized for injuries received when the front wheel of her bike failed to climb a curb she bumped. When her bike came to an abrupt halt, she was thrown forward, straddling the frame, incurring a painful vaginal injury. Minor surgery was necessary to stop the bleeding and she was confined to the hospital for a week."

Speaking of the so-called "new style" bicycles, Dr. Verhalen comments, "They encourage unsafe behavior and acrobatics (both in design and promotion) and they, by virtue of "gearing," permit even higher speeds to be achieved by their youthful riders."

Mr. Roy S. Rice, the senior author of the Cornell studies, made comments additional to the summary provided above that are relevant here:

"Our studies were directed towards the examination of variations in performance as a function of certain bicycle designs, and from our tests we can draw certain conclusions about accident potential. We do not have data to relate performance to safety; we can only suggest that there are combinations of conditions and modes of operation that produce a potential for difficulties. What is missing is a relating performance factor to safety and statistics on the incidence of accidents. . . .

"During the early learning process, it is most desirable that the bicycle have a high degree of inherent stability. Generally, high wheels, a high value of mechanical trail, a long wheelbase, and even weight distribution between the wheels help to provide this stability. This description better fits the conventional bicycle than the high-rise one.

"The bicycles which were used in the tests and a large array of other bicycles that we have examined, are structurally well-designed and well-built and the important load-carrying members of the frame assembly are strong and capable of standing up under severe use, such as that encountered in our test program. But maintenance is important. It is important that the handlebars are at the proper height, and as the boy or girl grows, handlebar height adjustments and proper brake adjustments should be made. All of these can produce potential problems in safety. ...

"We are unaware . . . of any total vehicle performance standards. For example, on braking capability or low-speed stability which give recommended values – and, again, there are no references to evaluate the particular design approaches. We should recommend that the industy develop and adopt such standards, and we believe that this can be accomplished by full-scale testing of a wide variety of bicycles to obtain quantitative measures of braking, cornering stability, and cornering capability. We recommend the use of the mathematical model [which was developed in the Cornell study] to evaluate the effects of special design features on these characteristics. . . .

"Front wheel brakes, regardless of bicycle size, can lead to problems in safe operation. To reduce the risk of injury rate, small boys, learners, and novice riders should use girl-style bikes. Bicycle designs making use of small front wheels must include compensating design features to avoid reducing the limits of safe operation. Design features which can be impacted by the rider, which can compromise the ability of the rider to get free of the bike in event of an accident should be avoided. ... Generally, what you face ... is a tradeoff between stability and maneuverability in the design of a bicycle in almost any bicycle that you can think of. ... it is not so much speed which is the problem as it is controllability and stability characteristics."

The bicycle manufacturing industry was also well represented at the hearings. Mr. F. C. Smith testified in his capacity as a representative of the

Bicycle Manufacturers Association of America (BMA). He stated:

"The industry has spent a great deal of time, money, and effort during the last 18 months developing a standard for acceptance by the American National Standards Institute. ... It is a standard, we believe, which will be high enough to meet this Commission's criteria that products be safe enough to foresee possible misuse, taking reasonable steps to minimize the occurrence of accidents from such misuse. ...

"Spurred on by the Commission's interest, we have nearly finished writing that standard. It contains formalized procedures and rigid testing specifications on forks, stems, frames, brakes and all principal parts, and ... our proposed standard will require all American manufacturers to reflectorize their pedals. ... Most of the states of the Nation require at present reflectors which we use, and I think all states require that a bike used at night be equipped with some kind of a device for lighting. We have concluded in examining this that it would be wise for us, in addition to using the reflectors that are required by the states, to use a piece or pieces of reflector material on the side of the bike, perhaps on the fork so that it could be seen, whether or not it was to the left or to the right."

It was brought out that the American bicycle manufacturing industry is a unique one, in that it is comprised of fewer than 10 manufacturers. The BMA is a nonprofit association whose members include the great majority of domestic manufacturers of bicycles. The BMA, in turn, is one of four member associations of the Bicycle Institute of America, (BIA), a unique organization which unites the bicycle manufacturers, parts manufacturers, and major domestic distributors of the domestic bicycle industry on many matters of common concern. Mr. Smith's testimony included the following:

"The high-rise bicycle went through ... tests by each manufacturer and each manufacturer concluded that the design was a safe one. ... Not one member company is experiencing high rise related injury claims at a greater proportional rate than claims related to other models. As a matter of fact, the 1968 ratio of claims (including those which are unfounded) to total bicycles of all models shipped by BMA members in that year was an extremely low average of 2.05 per 100,000 bicycles."

Field Studies

The issue of bicycle design in relation to actual accidents and injuries has been insufficiently studied; evidence is fragmentary and uncertain. A study by the National Safety Council [18a] used questionnaire reports of (a) accident involvement in a single month and (b) type of bicycle used. For each sex, the high-rise bike was overrepresented in accidents: 58.7 percent of the accident-free boys used the high-rise, and 65.9 percent of the boys' accidents were on the high-rise (difference significant at $p < .0512$); 28.7 percent of the accident-free girls used high-rise bikes, and 42.7 percent of the girls' accidents were on the high-rise (difference significant at $p < .01$).[4] It is of interest that the overrepresentation is greater for girls ((42.7-28.7)/28.7 = 48.8 percent) than for the boys ((65.9-58.7)/58.7 = 12.3 percent).[4]

Another study [20], using a considerably different criterion, namely, medically-treated-injury accidents, over a 4-month period, showed no significant differences in rates of injuries on standard versus high-rise bikes, for boys or girls. For standard bikes, boys have a higher rate than girls (1.38 percent versus .57 percent, difference significant at .01 level);[5] but on high-rise bikes, the rates for boys and girls do not differ significantly (1.64 percent versus 1.1 percent).[5]

[4,5] Analyses by the National Transportation Safety Board.

Again, it seems that the increment in involvement rate from standard bike to high-rise may be greater for the girls than for the boys; but although the girls' rate doubles, the increment is not statistically significant. It is virtually impossible to differentiate the role of the nature of the equipment from the role of the nature of the user without an experiment. Presumably, the more adventuresome or aggressive boys and girls are more likely to choose the high-rise; it is a more maneuverable bike and more amenable to acrobatics. It could also be that the more skillful children choose the high-rise bike. In both studies, boys more often own the high-rise. In the Vermont study [20], 62 percent of the high-rise bikes were reported to have been purchased because of the desire of the child, while only 16 percent of the standards were purchased for that reason. The observation of a possibly greater increment of hazard for girls with respect to high-rise bikes, if confirmed in further studies, would be consistent with general experience that girls have greater difficulty than boys in tasks that require skill in physical manipulation. The issues of disaccommodation, age, experience, size of child, and specific behavior of the cycle operator are variables that must be taken into account in studies to determine risks of various bicycle designs. Further, a comparison of gross classes of vehicle, such as "high-rise" versus "standard", leaves wide open the question of the role of specific features of bicycle design in accidents and injuries.

In the Vermont study [20], about 10 percent of the injuries occurred when a rider (or passenger) caught his foot in the spokes of a wheel. Also, loose handle bars were mentioned as a possible factor in "lost control" type of accidents. These are design features which can, presumably, be easily improved.

IV RESPONSIBILITY, AUTHORITY, AND ACTIONS OF FEDERAL AGENCIES

The National Highway Traffic Safety Administration (NHTSA) derives its authority to establish motor vehicle safety standards from Public Law 89-563, entitled "National Traffic and Motor Vehicle Safety Act of 1966" [13]. The Act comprehends motor vehicles only; bicycles are not included. Public Law 89-564, entitled "Highway Safety Act of 1966" [8], authorizes and directs assistance and cooperation "with other Federal departments and agencies, State and local governments, private industry, and other interested parties to increase highway safety." Section 402 of this Act, "Highway Safety Programs" provides in subsection (a) that:

> "Each State shall have a highway safety program approved by the Secretary, designed to reduce traffic accidents and deaths, injuries, and property damage resulting therefrom. Such programs shall be in accordance with uniform standards promulgated by the Secretary. ... such uniform standards shall include, but not be limited to, provisions for ... traffic control, vehicle codes and laws ..."

It is under this authority that Highway Safety Program Standard 6, Codes and Laws, was issued June 27, 1967. The Standard provides that " ... each State shall undertake and maintain continuing comparisons of all State and local laws, statutes, and ordinances with the comparable provisions of the Rules of the Road Section of the Uniform Vehicle Code." Article XII of Chapter 11 of the Uniform Vehicle Code, "Operation of Bicycles and Play Vehicles," comprises nearly two pages of regulations which are intended to serve as a guide to State and local jurisdictions. Other than issuance of Standard 6, NHTSA has not taken any action specific to bicycle safety. An internal review of the issue in 1968 did not change its priority.

The Secretary of the Department of Health Education and Welfare, by virtue of Public Law 91-113, entitled "Child Protection and Toy Safety Act of 1969," has authority to ban from the market "Any toy or other article intended for use by children which the Secretary by regulation determines . . . presents an electrical, mechanical, or thermal hazard." [4] Bicycles are included in this definition, and technically this would include only bicycles intended for use by children (defined as 15 years of age or younger). Public Law 91-113 became effective in January 1970, and it is the Bureau of Product Safety in the Food and Drug Administration which has responsibility for administering the Act. The Bureau is presently engaged in collection and analysis of date on bicycle accidents and injuries. They have not yet taken any legal action or made recommendations.

V THE RENAISSANCE OF ADULT BICYCLING

There is a renewed interest in bicycles for use by adults, for purposes of commuting, as well as for recreation. Stemming from a number of urban problems—air pollution, noise pollution, traffic congestion, parking congestion—the bicycle has in recent years come to be looked upon as a vehicle which might alleviate all of these problems and contribute to the health of the Nation by way of the salutary exercise it provides. In addition to use as a predominantly recreational vehicle for children, it is being promoted as a commuter vehicle as well as a recreational vehicle for adults, especially in situations where the distances from home to work are no more than a few miles.

An early burst of interest in the bicycle as a vehicle for adult recreation is evidenced in the Congressional Conference on Bicycling in America, held in 1964 [5]. Subsequent Federal legislation provided for assistance to States and municipalities in providing bike paths and trails for their citizenry [5]. In his message to the Congress in February 1965, the President urged construction of a system of hiking and biking trails to span the country [5]

In 1966, the Department of the Interior proposed a series of 1,000 miles of recreational trails for the Washington, D. C., region.[6] Part of this system is now in existence, and the implementation of the rest of the plan is being coordinated by the Washington, D. C., Council of Governments. The Department of Transportation and representatives of the Department of the Interior have identified several portions of this system which could serve as bicycle commuting routes. The most important segment—the bridle trails leading through Rock Creek Park—have been converted already by the Park Service into a permanent bicycle path [12].

Early in 1971, Secretary of the Interior Rogers C. B. Morton and Secretary of Transportation John A. Volpe made a joint decision to promote bicycling. In May, Secretary Volpe led a "bike-in" in Washington to inaugurate Transportation Week. He said, "We intend to make Washington a 'model city' for bicycles ... As you all know, the main problem with bike riding is the danger involved. We hope exclusive rights-of-way will solve the problem." [15]

Activity has not been confined to the Federal level. In May of 1971, the Oregon legislature approved a bill which requires expenditure of State Highway Fund money for establishment of footpaths and bicycle trails along highways, roads, and streets when constructed, reconstructed, or relocated. One percent of State highway money is authorized for construction and maintenance of bicycle trails and paths. Total money available to the State for bicycle lanes (including Federal funds) is estimated at

[6] This includes land in (a) C & O Canal Historic Park in Maryland, and (b) National Capital Parks in the District of Columbia, Maryland and Virginia.

$2.5 million per year. Bills which provide money to develop bikeways are pending or have been passed in California, Colorado, Iowa, Massachusetts, and Ohio [11, 15].

The Department of Transportation is concerned with the commuting aspects of bicycling; the Department of the Interior is emphasizing the recreational aspects [15]. Highway Trust Fund moneys administered by the Federal Highway Administration, may be used for constructing bicycle paths when they are built in conjunction with a Federal-aid highway project. The States are encouraged to include bike trails in their transportation plans [15].

As indicated earlier in this study, manufacturers' production of bicycles is not keeping up with demand, and nearly half of the demand is for adult bicycles. Sales were expected to reach 8.5 million in 1971. It is too early yet to know how this upsurge has affected the safety picture.

VI BICYCLE RIDING AS A PRELUDE TO AUTOMOBILE DRIVING

A review of the bicycle accident loss factors which have been described suggests that bicycle operator factors foreshadow later driver operation factors. A recent Safety Board study of youth involvement in highway accidents showed that youth in the age group of 15 to 24 years are heavily overinvolved in highway accidents and fatalities [22]. In that age group, the vast majority of fatalities and accidents are suffered by young males drivers. The bicycle study indicates the same pattern for young males riding bicycles, and the pattern appears at a very early age. The most evident explanation for this is the greater aggressiveness and activity of boys as compared with girls.

In the youth study, the question of the degree to which current driver education programs influence driver behavior and accident involvement was discussed. The need for improved programs of instruction designed for beginning young drivers was emphasized. There appears little doubt that in the younger (predriving) age group, the assessment of fault for collisions against bicycle riders is associated with lack of knowledge of the requirements and lack of training. In the age group 15 to 24, a very high percentage of youth is involved in automobile operation, and in the younger age group, 6 to 14, almost the entire group is involved in bicycle riding—for most young people, bicycling precedes automobile driving.

There is relatively little formal training in bicycle riding for the vast majority of the bicycle population which later will be driving passenger cars. In addition, the rules for operation of bicycles are very similar to the rules for operation of motor vehicles, and it appears that many of the same skills of observation of traffic and response to traffic situations are involved in both bicycle riding and motor vehicle operation. It is also apparent that the training of children to ride bicycles in traffic is largely in the hands of parents, and that police efforts to enforce rules or laws for bicycle operation are relatively lenient as compared to enforcement of motor vehicle laws. With a few exceptions, our present approach to bicycle operating safety is predominantly based upon reliance on parental training and placement of the primary responsibility for children's bicycle riding practices upon the parents. Access to systematic training information in bicycle riding is generally not available to the parents, but there do exist some unknown number of locally developed bicycle-training programs. For all practical purposes, the public effort to influence youth toward safe automobile-driving practices does not begin until they are at an age where they are considered capable of operating a motor vehicle.

The National Transportation Safety Board considers this general approach to be inadequate in two major aspects. First, although nearly all children are learning to ride bicycles, and are being exposed to street and highway traffic and other hazards, their preparation to meet these hazards appears far from adequate. Irrespective of whether the training of children to ride bicycles is a parental or local governmental responsibility, the children, by and large, are not receiving sufficient instruction to insure that they can operate their bicycles for their own safety, nor are they receiving the corrective action which visible enforcement of local bicycle rules and laws should provide.

Second, our national approach in providing bicycle training is probably limited by a narrow view of the long term benefit which might result. Bicycle training begins at a much earlier age than driver education, and in an age range where it may be possible to teach more desirable attitudes toward risk-taking and highway aggressiveness than can be developed in the high school age range. Attitudes toward highway rules and skills in perception of traffic situations which are developed during bicycle training might be more deeply ingrained and more effective than if the training begins in the high school years.

These considerations strongly suggest that with some research and development work, the present methods of bicycle training and the existing uniform rules and laws for bicycle operation might be employed as elements in an integrated system of training and enforcement which begins with bicycle usage, but is primarily organized and motivated to support later driver education and thus to reduce the heavy loss among youthful vehicle drivers. Such an approach is made both economically efficient and necessary by the high percentage of children involved in bicycle riding and who are later applicants for driver licenses. It also appears that training in a controlled traffic environment involving bicycles would be much less expensive than similar practical experience in automobiles – both from the point of view of equipment and instructor coverage. If practical problems of this nature could be worked out by definitive research and development programs of national scope, the result might be development of a training system of lower total cost and greater effectiveness than the present system.

The treatment of bicycle training as a form of primary training for automobile driving brings bicycle training into the field of driver education and under the jurisdiction of the authority given the NHTSA by Public Law 89-564. The Safety Board believes that after the development of such an integrated training system, it would be desirable to apply the system through the medium of a Federal highway safety program standard, or a change to an existing standard. The improved program standard would thus become effective for the vast majority of children and youth who pass through the bicycle-riding stage and become licensed drivers.

VII CONCLUSIONS

1. The vast majority of children of both sexes own and use bicycles by the time they are 6 or 7 years old. Usage drops markedly around 15 or 16, when youngsters become eligible to drive motor vehicles.

2. The victims of bicycle accidents are predominantly children. Most of the fatalities and most of the injuries occur to the age group 5 to 14.

3. Fatalities in bicycle accidents occur predominantly to males: about 90 percent of bicycle-motorcar fatalities and about 75 percent of bicycle-only fatalities.

4. The fair-weather months, weekends, and after-school hours are the peak periods of bicycle usage, accidents, injuries, and fatalities.

5. Although only a small percentage of accidents occur during hours of darkness (lower exposure rate), they are much more likely to result in fatalities.

6. Visibility, or degradation thereof, appears to be an important factor in nighttime bicycle-motorcar collisions.

7. The bicyclist is characteristically regarded as "at fault" in bicycle-motorcar collisions.

8. The fit of the bicycle to the operator, especially in terms of his or her ability to touch the ground while seated, is an important factor in bicycle accidents. This factor of disaccommodation appears more important for younger (smaller, less experienced) children than for the older (larger, more skillful) ones.

9. Although the issue has been insufficiently studied, there is reason to suspect—from anecdotal data, from engineering data, and from field studies—that the newer, so-called "high-rise" bicycle may be a more hazardous overall design than the conventional style. Part of the increased hazard—if it is ultimately established to be real—may be due to its attractiveness as a vehicle with which to engage in acrobatics, precisely because of its greater maneuverability—thus decreased stability. It is very important that specific design features be studied with respect to their accident/injury potential, as well as the kinds of operator behavior associated with given design features.

10. The National Highway Traffic Safety Administration has conducted a preliminary examination of the bicycle safety problem, but has not assigned it a sufficiently high priority to result in a program of action. The Administration does not have authority to regulate bicycle design, but does have authority to promulgate Highway Safety Program Standards with respect to bicycles and driver education.

11. The Department of Health, Education and Welfare, by virtue of the Child Protection and Toy Safety Act of 1969 (effective Jan. 1970) does have authority to regulate bicycle design—ban from the market those which are determined to present a "... mechanical ... hazard."

12. There is reason to suspect that a braking system which is superior for older cyclists may disadvantage the younger ones. Other design features may also be differentially optimal for different age groups, different sizes of children, and different sexes.

13. The great majority of bicycle fatalities occur in collisions with motorcars.

14. The increasing use of bicycles by adults can be expected to increase the magnitude of the bicycle safety problem.

VIII. RECOMMENDATIONS

The National Transportation Safety Board recommends that:

1. The National Highway Traffic Safety Administration employ part of its research funds to explore and develop effective methods of integrating training for bicycle operation and automobile driving. The effort should be directed to the needs and capabilities of children and young people as they pass successively through the ages typical of bicycle riding and into automobile driving.

2. The National Highway Traffic Safety Administration, when and if it develops a method of bicycle training which can support later driver education, reconsider the desirability of a highway safety program standard for bicycle safety in light of the potential value of bicycle training for safe motor vehicle operation.

3. The National Highway Traffic Safety Administration coordinate its activities in bicycle safety research and possible program standards with the Department of Health, Education and Welfare, particularly with respect to design characteristics of bicycles.

4. The Department of Health, Education and Welfare, in its research on bicycle safety, focus on specific design features and their combinations with respect to accident/injury potential, as well as the kinds of operators and operator behavior associated with given design features.

5. In the Department of Transportation's efforts to encourage the use of bicycles for reasons of reduction of traffic congestion and air pollution and promotion of healthful exercise, the National Highway Traffic Safety Administration and Federal Highway Administration be actively involved to assure that safety is given full consideration.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ **JOHN H. REED**
Chairman

/s/ **OSCAR M. LAUREL**
Member

/s/ **FRANCIS H. McADAMS**
Member

/s/ **LOUIS M. THAYER**
Member

/s/ **ISABEL A. BURGESS**
Member

April 5, 1972

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