we allow for the times that a light truck hits one of the 79.7 percent of the vehicles that are not trucks or is hit by one of these vehicles, we should expect about 5.10 percent of all two-vehicle accidents to involve a light truck and a nontruck in one way or another. The total involvement of light trucks in two-vehicle accidents should be about 6.29 percent, which is not significantly different from the 6.2 percent of fatal accidents reported in the paper but somewhat greater than the 5.0 percent of all accidents actually attributed to light trucks.

There is a general formula for the expected distribution of types in n-vehicle collisions. If A, B, C, ... represents vehicle types and a, b, c, ... represents their relative proportions in the traffic stream, the expected fraction of collisions of vehicle types XYZ ... is the coefficient of XYZ ... when the expression $(aA + bB + cC + \ldots)^n$ is multiplied out. If we work out the expected distribution of two-vehicle accidents by using the VMT distribution given in Figure 4, we get the following:

Vehicles in Accident	Distribution (%)
Light truck-light truck	0.10
Light truck-heavy truck	1.09
Light truck-nontruck	5.10
Heavy truck-heavy truck	2.92
Heavy truck-nontruck	27.26
Nontruck-nontruck	63.52

We see that light trucks, heavy trucks, and nontrucks should be expected to be involved in 6.29, 31.27, and 95.88 percent, respectively, of all two-vehicle accidents. Meyers reports that light trucks were actually involved in 6.2 percent of the fatal accidents and 5.0 percent of all accidents; heavy trucks were involved in 29.1 percent of the fatal accidents and 24.0 percent of all accidents. If all the accidents involved two vehicles, it would appear that trucks are not significantly different from other vehicles in their fatal accident experience and are better than other vehicles for nonfatal accidents. However, a firm conclusion on this subject cannot be reached without knowing what proportion of the accidents were single-vehicle, two-vehicle, three-vehicle accidents, etc.

Accident rates cannot be compared (except for single-vehicle accidents) simply on the basis of VMT, since this always overstates the accident rates of individual components of the traffic stream, especially those components that constitute very small proportions of the traffic stream. For example, suppose that ordained ministers drove about 1 percent of the total vehicle miles. Then they can be expected to be involved in almost 2 percent of the two-vehicle accidents. If in fact ordained ministers were involved in only 1.5 percent of all two-vehicle accidents, it would indicate exceptionally safe behavior on their part. A comparison on the basis of VMT would, nevertheless, make it appear that ordained ministers were 50 percent more dangerous than average drivers.

Author's Closure

With regard to Ross's assumption that "all vehicle types are identical in accident potential," this is, unfortunately, a research-classroom type of supposition. The condition assumed does not exist on the road: All vehicles have varying steering, braking, and other operational characteristics and not every driver has the same driving proficiency. Further, it is generally recognized that statistical probability theory should not be used as a substitute for factual data.

On the other hand, Ross may have been misled by the labeling of Figures 4 and 5 in the preprint paper. I hope that any misunderstanding has been corrected by the refined labeling of Figures 4 and 5 in this paper and that this will show more adequately that the comparisons in these figures are for the percentage of vehicles actually involved in the fatal accidents.

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Relationship of Accident Frequency to Travel Exposure

WERNER BRÖG AND BERND KÜFFNER

An attempt is made to determine the accident risk for persons who use various modes of transportation. The number of persons injured or killed in traffic not only is calculated in proportion to the total population but also is related to three different factors that pertain to travel exposure: the number of trips made, the number of kilometers traveled, and the amount of time spent traveling. The results of a survey done in the Federal Republic of Germany in 1976 (KONTIV) were the data base. The survey technique is shown that was applied to use data on the behavior of individuals on random sampling days to determine yearly values for traffic exposure. The accident rates for different modes vary according to the factors used to determine traffic exposure. Thus, by using kilometers traveled, the accident risk is least for persons who travel by car. However, by using number of trips made and time spent traveling, the accident risk is least for pedestrians. The evaluation shows that the individual accident rate does not give a complete and accurate picture of accident risk. Only the combined analysis of all three accident rates can do this. An increased international exchange of data and experiences that pertain to this subject would be desirable.

In transportation safety research, it is very important to identify the accident risks for specific groups of persons as well as for persons who use different modes. Accident rates are an important criterion by which to pinpoint the target groups at which transportation safety work should be aimed. The absolute number of accidents does not show the accident rates for specific groups or modes. In order to determine different accident rates that can be used as the measure of the accident risk, different statistical indicators of accident risk must be taken into consideration.

STATISTICAL INDICATORS OF ACCIDENT RISK

The first accident rate is the relationship of the number of persons who have had accidents to the total population. This correlation makes it possible to judge the risk for an average person; it thus reflects the general risk of having an accident while traveling.

Another indicator that can be used to determine the accident risk is the total travel exposure. Total travel exposure consists of the number of trips a person has made, the distance traveled, and the amount of time spent traveling (1).

Each of the accident rates for the above indicators is a meaningful measurement of accident risk. When combined, they are a good basis for comparative evaluations:

1. The rate of accidents per trip shows the risk a person runs when participating in an out-of-home activity;
2. The rate of accidents per kilometers traveled shows that the greater the distance is that a person travels, the greater the risk is that there will be an accident; and
3. The rate of accidents related to travel time is especially useful to measure exposure to risk in cases in which (for example, pedestrians) the number of kilometers traveled is less important as a risk factor than is the amount of time a person is exposed to a potentially dangerous situation.

Since each of the four accident rates referred to above (including the general accident rate for an average person) shows only one particular aspect of the problem, it is usually advisable to combine all four as a basis for forecasting.

The problem is, however, that the data needed on travel behavior are rarely available and, when they are available, their quality and precision are often imperfect. This paper uses a specific data source to attempt to calculate the complete set of the four accident rates and to thereby identify accident risk.

DETERMINATION OF BEHAVIORAL DATA

Methodological Requirements

In order to calculate the accident rate, one needs data on accidents (in this case, the number of persons injured and fatalities in 1976 in the Federal Republic of Germany) as well as data on travel behavior.

Data on traffic accidents is readily available from the statistical data on accidents collected by local police departments. (However, it is important to note that since a certain percentage of accidents are not reported, the actual number of persons who have had accidents is larger than the number recorded in the statistical records.)

Although fairly accurate statistical data are thus available for accidents, this is not the case for data on travel behavior. If surveys that collect data on travel behavior are to be valid, they must meet certain minimal qualitative requirements. However, the question of the validity of the survey method is frequently neglected (2). Although it is not possible to discuss here all the possible sources of error that result from the use of inadequate methods (3), the following list (which includes the most important prerequisites for the collection of valid data on out-of-home activity patterns) gives some idea of what to look for in a survey (4):

1. The entire activity pattern of the interviewees must be recorded. Thus, all trips, including pedestrian trips, must be registered (5).
2. The interviewee's actual behavior during a specific period of time must be recorded. If one asks persons to report their "average behavior" (e.g., when preprinted multiple-choice lists are used), the result is that the responses reflect the interviewee's subjective self-estimation and not actual behavior (6).
3. Only when diarylike techniques are used can the problem of subjective self-evaluation be kept to a minimum (7).
4. It is preferable to use written questionnaires to collect data on travel behavior. Oral responses generally lead to greater distortions than do written questionnaires, and the distortions cannot be controlled (8).
5. Every survey appeals more to some persons and less to others. The problem of nonresponse leads to a systematic bias in survey results that must be taken into consideration when the results are processed (9-11).
6. Whenever possible, behavior should be continuously recorded over the period of an entire year in order to take seasonal differences in traveling into consideration (12).

Available Data Sources

The Continuous Survey of Travel Behavior (KONTIV) was used as the basis for the present evaluation. KONTIV was conducted at the request of the Federal Ministry of Transportation in 1976 and is representative of the Federal Republic of Germany. In this written survey, all out-of-home activities of 54 000 persons were recorded for 107 000 random sampling days throughout an entire year. The survey's return rate was 72 percent (13).

Necessary Corrective Measures

Although all the conditions necessary to ensure that the survey methodology was adequate were complied with in KONTIV, corrective measures were nonetheless necessary since, when behavioral data are processed, a number of factors can influence the quality of the survey. In KONTIV, as in all empirical surveys, the method of measurement used influences the results of the survey, for it is practically impossible to consider simultaneously all the factors that might influence the results of the survey and to weigh all of these factors equally.

However, this is not necessary. It is possible to neglect specific factors if the manner and degree to which these factors influence the results are known and can be corrected. When corrective measures are used, it becomes possible to use data on individual travel behavior measured on certain random sampling days to calculate valid statistical universal data such as number of trips made per year, number of kilometers traveled per year, and amount of time spent traveling per year.

The final correction of the KONTIV data was done in the four steps summarized below (14):

1. The basis is the trips that the individual made on the day of random sampling. The number of trips was then calculated on a yearly basis for each individual. For this calculation, the following corrections are important:

   a. In surveys that take place on several consecutive days, the number of entries in the questionnaires falls off after the first day. (For the second day, about 4 percent fewer trips are reported.) This underreporting is corrected.

   b. In samples where the return rate is less than 100 percent, the samples contain a systematic bias. Special surveys have shown that persons who do not respond to surveys make fewer trips than those who do respond. This insight is used to correct the resulting data (15).

   c. Reported length and distance of trips are subjected to systematic errors in estimation. In special surveys, corrective measures that deal with specific modes of transportation were determined and used to correct the data (16).

2. As a next step, the foreign residents who had not been included in the survey were considered. Other surveys had shown that the travel behavior of foreign residents is different from that of Germans (17). These surveys were used as a basis for corrective measures.

3. Certain types of trips were purposely not fully recorded in the survey: private long-distance trips, especially vacation trips, and business and goods-movement trips. For these trips, specific sums were added to the calculations. At the same time, it was noted that some persons were not at home because they were on vacation (18).

4. Another problem was that prior to and following the use of a vehicle (especially public transportation), persons necessarily walk a certain distance. However, these pedestrian trips are usually not listed separately by the interviewees. Therefore, for trips made by using public transportation, estimations are made concerning the length of the walk to and from the public transportation stop (19). The sums calculated for the distance covered and time needed for these walks were then added to the number of pedestrian trips. [This interpretation of such trip segments leads to some conflicts among specialists. Without being able to spend more time in this paper defending the approach used, it should be noted that the attempt to have all these trip segments recorded in the diaries is not a better alternative, at least not in large-scale surveys. The approach used here (which could be improved technically) still seems to be the best solution to the problem.]

Table 1. Total amount of travel per person per year.

Mode	Avg No. of Trips[a]	Avg Distance[a] (km)	Avg Time Spent[a] (h)
Walking	251	364	96
Bicycle or mofa[b]	77	179	19
Motorcycle or moped[c]	7	48	2
Car	434	6811	171
Public transportation	106	1847	55
Total	875	9249	343

[a]Per person more than 10 years old per year.
[b]Mofa is a small motorcycle that has a maximum speed of 25 km/h.
[c]Moped is a small motorcycle that has a maximum speed of 40 km/h.

ACCIDENT RATES FOR SPECIFIC TYPES OF TRIPS

For Yearly Travel Exposure

The corrective measures described above make it possible to calculate yearly participation in travel, number of trips made, number of kilometers traveled, and the length of time spent traveling (Table 1).

Thus it becomes possible to determine the accident risks for different types of travel. [For public transportation, no accident rates were determined since some of this traffic is not considered to be street traffic. Therefore, only a portion of the accidents that involve public transportation vehicles (e.g., buses) is included in the accident statistics for street traffic.] The accident rates for the four remaining types of vehicles are shown in Table 2.

Table 2 shows that the number of accidents per capita is highest for persons that use cars. More than half of all traffic injuries were sustained by persons who were either driving cars or riding as passengers in cars. The relationship of the number of accidents to data on traffic participation (accident/mobility rate) gives a very different picture of the accident risk while using a car. The accident risk when walking is relatively small, that when using a car is average, and that when using a moped or motorcycle is relatively large. In the accident/distance rate, persons who use cars are less prone to accidents than are pedestrians, since the speed traveled by car is naturally much greater. The high rate of accidents for persons who use motorcycles is remarkable; the risk of having an accident is 30 times higher per kilometer than it is for cars. The amount of time spent traveling is the last factor to be taken into consideration (and completes the picture) when accident risk is calculated. Using a car presents a more-or-less average risk as far as travel time is concerned. Persons in cars have three times as many accidents as do pedestrians in the same time span.

Comparative View

In Table 2, the values of the accident rates are also compared by using indices. The accident rates differ according to factors taken into consideration in the calculation. Thus, it is not possible to say

Table 2. Accident rate according to mode of transportation.

Mode	Accidents per 10 000 Persons	Accidents per Million Trips		Accidents per Million Kilometers		Accidents per Million Hours Traveled	
		Absolute Number	Index[a]	Absolute Number	Index[a]	Absolute Number	Index[a]
Walking	8.3	3.3	34	2.3	248	8.6	35
Bicycle or mofa	11.8	15.3	158	6.6	715	62.0	251
Moped or motorcycle	11.0	157.1	1624	22.9	2489	549.7	2226
Car	50.3	11.6	120	0.7	80	29.4	119
All[b]	84.8	9.7	100	0.9	100	24.7	100

[a]Total value = 100. [b]Includes public transportation.

which form of travel is safest simply by quoting one accident rate. However, all persons who use two-wheeled vehicles show a particularly high accident rate. This is especially true for those who use mopeds and motorcycles.

ACCIDENT RATES FOR DIFFERENT DEMOGRAPHIC GROUPS ACCORDING TO AGE AND SEX

Additional data can be collected for the evaluation of accident risks when interviewees are divided into different sociodemographic groups. There are gross differences among the groups in the rate of accidents and the exposure to situations in which accidents might occur. By using the available data, it is possible to depict accident rates for these different groups.

However, this causes a special problem. The method described earlier, in which aggregate data on individual behavior were collected on certain days, could not be used analogously in this situation, because the coefficients used have variable effects depending on sociodemographic group (this is assuming that vacation trips, business trips, errors in estimating distances, etc., vary for different age groups). Since no sufficiently differentiated data were available in this stage of the research, it was not possible to use the approach described earlier to calculate accident/time rates for the different age groups and sexes. Rather, only behavioral data determined for an average weekday were used, and the only corrective measure used pertained to the pedestrian trips to and from public transportation.

Although this approach is certainly not completely satisfactory, we feel that we are justified in presenting the results of the data processing and in discussing them. Although the absolute degree of the corrective measures is considerable (the yearly kilometers traveled in the Federal Republic of Germany was 108 billion in 1979), the individual factors can have opposite effects and can thus balance one another (the relative corrective measure for the yearly distance traveled is only 17 billion km).

To get an idea of the extent of accidents, these findings can be compared with the pertinent shares for the entire population. The results for 1976 in the Federal Republic of Germany for the characteristics considered are shown in Table 3, which shows that the accident risk for individual sociodemographic groups varies greatly according to the mode used.

In Tables 4-6 the accident risks for different groups is related to their traffic exposure.

In order to simplify the use of the tables, the average values for the number of trips, the time needed to make the trips, and the distances traveled were made equal to 100 and the pertinent index was determined for each age group.

This shows that younger and older persons travel more on foot than do others, that younger persons use bicycles and mofas much more frequently than the average, and that persons between 14 and 24 years use more mopeds and motorcycles whereas middle-aged persons and men as a group tend to use cars more frequently than the average. These results already give one a more in-depth view of the relationship between the frequency with which specific modes are used and the accident rate related to this use.

However, accident statisticians are confronted not only with the problem that sufficient behavioral data are not yet available but also with the fact that it is important that statistics be kept so that they can be used and understood by as broad a base of interested persons and users as possible.

Table 3. Percentage of fatalities and injuries by age and sex for different modes.

Characteristic	Fatalities and Injuries (%) Total Population (N = 5 369 000)	All Modes (N = 455 510 000)	Walking (N = 44 705 000)	Bicycle[a] or Mofa (N = 63 416 000)	Moped[a] or Motorcycle (N = 59 159 000)	Car (N = 270 248 000)
Age						
10-14	9.6	6.1	14.7	21.2	1.5	2.4
15-17	5.2	13.0	6.0	23.6	46.5	5.0
18-24	11.1	27.6	9.5	10.0	34.8	33.8
25-64	57.3	46.1	41.8	36.1	15.4	54.5
64 and older	16.8	7.2	28.0	9.1	1.7	4.3
Sex						
Male	47.1	66.0	49.0	NS	NS	61.7
Female	52.9	34.0	51.0	NS	NS	38.3

Note: NS = not shown in accident statistics.
[a]As driver or passenger.

Table 4. Accidents and amount of travel according to age and sex for all persons.

Characteristic	Total Population N	Total Population Percentage	Injuries and Fatalities N	Injuries and Fatalities Percentage	Avg No. of Trips per Day	Avg Travel Time per Day (min)	Avg Distance per Day (km)	Index[a] Trips	Index[a] Time	Index[a] Distance
Age										
10-14	51 284 000	9.6	27 885 000	6.1	2.35	48.6	14.1	97.1	89.8	62.0
15-17	28 168 000	5.2	59 143 000	13.0	2.66	60.1	17.0	109.9	111.0	74.6
18-24	59 699 000	11.1	125 890 000	27.6	2.73	63.0	24.5	112.8	116.4	107.8
25-64	307 690 000	57.3	209 873 000	46.1	2.61	58.0	27.1	107.9	107.2	119.0
64 and older	90 048 000	16.8	32 719 000	7.2	1.54	37.0	9.2	63.6	68.4	40.3
Sex										
Male	253 078 000	47.1	300 679 000	66.0	2.66	62.8	30.4	109.9	116.1	133.4
Female	283 812 000	52.9	154 831 000	34.0	2.21	46.1	15.8	91.3	85.2	69.5
Total	536 890 000		455 510 000		2.42	54.1	22.8			

[a]For computation of index in the last three columns, the total average values of the previous three columns were made equal to 100.

Table 5. Accidents and amount of travel according to age and sex for persons walking and using bicycles and mofas.

	Total Population (%)		Injuries and Fatalities (%)		Index					
					Trips		Time		Distance	
Characteristic	B	C	B	C	B	C	B	C	B	C
Age										
10-14	9.6	9.6	14.7	21.2	114.9	322.5	116.5	262.9	116.8	241.4
15-17	5.2	5.2	6.0	23.6	108.1	334.8	126.2	340.0	127.1	389.7
18-24	11.1	11.1	9.5	10.0	75.7	100.0	82.3	105.7	83.2	119.0
25-64	57.3	57.3	41.8	36.1	97.3	73.9	92.7	68.6	94.4	69.0
64 and older	16.8	16.8	28.0	9.1	112.2	43.5	122.6	48.6	106.5	48.3
Sex										
Male	47.1	47.1	49.0	NS	79.7	NS	86.6	NS	88.8	NS
Female	52.9	52.9	51.0	NS	118.9	NS	112.2	NS	109.3	NS

Notes: B = persons walking; C = persons using bicycles and mofas.
NS = not shown in accident statistics.

Table 6. Accidents and amount of travel according to age and sex for persons using mopeds and motorcycles and using cars.

	Total Population (%)		Injuries and Fatalities (%)		Index					
					Trips		Time		Distance	
Characteristic	D	E	D	E	D	E	D	E	D	E
Age										
10-14	9.6	9.6	1.5	2.4	29.1	30.2	27.0	35.1	11.6	40.4
15-17	5.2	5.2	46.5	5.0	515.0	28.4	460.3	31.9	406.7	32.2
18-24	11.1	11.1	34.8	33.8	315.5	126.7	365.0	121.8	465.8	118.2
25-64	57.3	57.3	15.4	54.5	58.3	128.4	56.6	128.5	50.4	128.3
64 and older	16.8	16.8	1.7	4.3	34.5	31.0	32.6	31.9	21.8	27.7
Sex										
Male	47.1	47.1	NS	61.7	NS	132.8	NS	139.7	NS	140.5
Female	52.9	52.9	NS	38.3	NS	69.0	NS	64.2	NS	61.8

Notes: D = persons using mopeds and motorcycles; E = persons using cars.
NS = not shown in accident statistics.

Table 7. Accident rates according to age and sex for all persons, persons walking, and persons using bicycles and mofas.

	Index Value for Injuries and Fatalities											
	Per Inhabitant			Per Number of Trips			Per Distance Traveled			Per Time Spent Traveling		
Characteristic	A	B	C	A	B	C	A	B	C	A	B	C
Age												
10-14	64.1	153.8	222.1	66.0	133.9	68.9	103.4	131.7	92.0	71.4	132.0	84.5
15-17	247.3	114.5	450.2	225.0	105.9	134.5	331.5	90.1	115.5	222.8	90.7	132.4
18-24	248.5	85.1	89.7	220.3	112.4	89.7	230.5	102.3	75.4	213.4	103.4	85.0
25-64	80.4	73.0	63.0	74.5	75.0	85.3	67.6	77.3	91.3	75.0	78.8	91.8
64 and older	42.8	167.0	54.1	67.3	148.8	124.4	105.7	156.8	112.0	62.6	136.2	111.3
Sex												
Male	140.8	103.9	NS	128.1	130.4	NS	105.6	117.0	NS	121.3	120.0	NS
Female	64.3	96.5	NS	70.4	81.2	NS	92.5	88.3	NS	75.5	86.0	NS

Notes: Index values for A, all persons; B, persons walking; C, persons using bicycles and mofas. For the computation of the indices, the average value of the given accident rate was made equal to 100.
NS = not shown in accident statistics.

Thus, Tables 7 and 8 are designed to be as understandable as possible. These tables compare the frequency of accident involvement with the degree of travel participation and enable one to summarize more adequately the accident risk.

Table 7, for example, shows that persons more than 64 years old do not have even half as many accidents as the average for all age groups (index = 42.8). However, this must be seen in relation to the fact that this age group travels much less than do other age groups. The risk of this group's having accidents increases very rapidly in relation to the number of trips made and the amount of time spent traveling (indices = 67.3 and 62.6). When the distance traveled is considered (which is comparatively low), the index is 105.7, an above-average value.

When these figures are differentiated according to mode, other important insights are gained. Thus, among pedestrians (Table 7), younger and older persons run an average risk of having an accident (indices = 153.8 and 167.0), but this risk is "relativized" when one considers the fact that more older and younger persons tend to walk to their destinations than do other age groups. On the other hand, those aged 18 through 24 only appear to take less than an average risk in having accidents when they walk, since they walk so rarely and for such short stretches. Actually, they therefore run an above-average risk of having an accident while walking (20).

This shift is even more obvious when one considers persons who use bicycles and mofas (Table 7). Children 10-14 years old who use bicycles and

Table 8. Accident rates according to age and sex for all persons, persons using mopeds and motorcycles, and persons using cars.

	Index Value for Injuries and Fatalities											
	Per Inhabitant			Per Number of Trips			Per Distance Traveled			Per Time Spent Traveling		
Characteristic	A	D	E	A	D	E	A	D	E	A	D	E
Age												
10-14	64.1	15.7	24.8	66.0	54.0	82.1	103.4	135.3	61.4	71.4	58.2	70.7
15-17	247.3	886.1	94.3	225.0	172.1	332.0	331.5	217.9	292.9	222.8	192.5	295.6
18-24	248.5	313.2	304.1	220.3	99.3	240.0	230.5	67.2	257.3	213.4	85.8	249.7
25-64	80.4	26.9	95.1	74.5	46.1	74.1	67.6	53.4	74.1	75.0	48.4	74.0
64 and older	42.8	10.2	25.9	67.3	29.6	83.6	105.7	46.8	93.5	62.6	31.3	81.2
Sex												
Male	140.8	NS	130.8	128.1	NS	98.5	105.6	NS	93.1	121.3	NS	93.6
Female	64.3	NS	72.5	70.4	NS	105.1	92.5	NS	117.3	75.5	NS	112.9

Notes: Index values for A, all persons; D, persons using mopeds and motorcycles; E, persons using cars. For the computation of the indices, the average value of the given accident rate was made equal to 100.
NS = not shown in accident statistics.

mofas are more than two times as likely as other age groups to have an accident. But when one considers the fact that they use these modes much more than other age groups do, they actually have less than an average number of accidents. Thus, although the risk that persons 15-17 years old would have an accident seems to be very high at first, it lessens when viewed in the light of their heavy use of bicycles and mofas. The opposite is the case with the group 64 years and older. At first it appears that the chance of their having an accident with a bicycle or mofa is very low, but this is because they use these modes so rarely. When one accounts for the frequency with which this age group uses these modes, the length of the trips, and the time of the trips, then this group actually has the second greatest risk of the different age groups in having an accident when using a bicycle or mofa.

Table 8 shows the same tendency for moped and motorcycle users. Persons aged 15-24 appear to run a very high risk of having accidents by using these modes. However, this is once again simply caused by the fact that they use these modes most frequently. Thus, the actual risk that members of this age group will have an accident is not so great as it appears to be at first. For all other age groups, the risk is greater than the relationship between the number of accident victims and the population.

As is true with other modes, when one looks at the figures that pertain to car drivers and car passengers, simple accident statistics differ from the results attained when behavioral data are used.

This is especially obvious when one compares the number of men who have accidents with the number of women who have accidents: 62 percent of all car passengers injured and killed are men (Table 4). But when accident rates are based on total travel exposure in cars, the accident rate is lower for men than for women.

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Bicycle as a Collector Mode for Commuter Rail Trips

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This study was designed to identify the potential of the bicycle as a collector mode for commuter rail trips and the conditions or circumstances that inhibit or fulfill realization of this potential. The study consisted of the development and distribution of a survey questionnaire to commuter rail passengers at five target stations and an analysis of the survey results. It was discovered that there is considerable potential for the bicycle to serve as a collector mode for commuter rail trips. Of all respondents, 46.6 percent claimed that they would consider commuting from home to rail station by bicycle. This would result in alleviation of parking congestion or freeing of parking spaces, which would permit increased rail ridership. The improvement that apparently would do the most to foster increased use of the bicycle for these trips is the provision of secure bicycle-parking facilities at rail stations. In some situations, this would have to be accompanied by improvements to the roadway system that leads to the station to make it more compatible to bicycles.

In this age of increasing cost and diminishing availability of fuel resources, American society in general and residents of New Jersey in particular must turn to energy-efficient modes when possible, not merely to extend scarce fuel supplies but also to reduce costs to individual consumers of transportation so they can maintain their mobility. The bicycle is potentially well suited to short-distance utilitarian trips such as collector-distributor trips between home and long-distance commuter rail transit. The bicycle is indeed an energy-efficient mode. It has, however, been an underused mode (1). Generally, it has been believed that one of the primary reasons for this underuse has been the lack of facilities, both bicycle-compatible roadways that lead to rail stations and devices at stations to secure bicycles from theft and vandalism.

In New Jersey, the New Jersey Department of Transportation (NJDOT) and New Jersey Transit (NJ Transit) wish to promote the increased use of the bicycle as a collector mode for commuter rail transit trips. In addition to the energy implications of this increased use, other objectives could conceivably be served. These include reduction in parking demand at commuter rail stations, alleviation of congestion, improved air quality (2), and equity considerations (i.e., the provision of rail services to those who for a variety of reasons cannot use other modes to reach the rail stations).

In order to proceed with a rational program of facilities (or other improvements) to foster the increased use of the bicycle, NJDOT and NJ Transit needed to know what conditions or circumstances inhibit use of the bicycle, what changes would best promote increased bicycle use, and what potential exists for increased levels of bicycle use.

METHODOLOGY

This study was designed to satisfy the needs listed above. The study consisted of the development and administration of a questionnaire distributed to rail passengers at selected commuter rail stations in New Jersey and the analysis of questionnaire responses.

The questionnaire was designed to determine the potential use of the bicycle as a collector mode for commuter rail transit stations and to identify those conditions or circumstances that inhibit the full realization of that potential. The questionnaire (Figure 1) was constructed to determine some characteristics of passengers at the target stations that might have a bearing on their predilection to use a bicycle for the trip to that station (questions 1 through 5). Such characteristics included sex, age, distance from station, length of time to station, and current modal choice for the trip to the station.

Additional questions were designed to elicit any tendencies in current modal-choice selection and to ascertain potential bicycle trip makers. Question 10 was designed to elicit the range and relative magnitude of improvements that might foster increased bicycle use. Questions 11 and 12 were designed to determine commuter preferences toward and potential use of various secure bicycle-parking facilities. Previous analysis by NJDOT personnel had indicated that having secure bicycle-parking facilities at rail stations was likely to be a necessary condition to expanded use of the bicycle for trips to commuter rail stations.

A number of criteria were postulated as having some relationship to the level of potential bicycle ridership and the level of potential demand for bicycle-parking facilities at rail stations. These are the following:

1. Condition of roads that lead to stations,
2. Availability of parking or deficiency of parking at the station,
3. Population clusters within 4 to 5 miles from the station,
4. Station ridership,
5. Existing bicycle use, and
6. Proximity to populations that do not use automobiles (e.g., college students).

By applying these criteria loosely and with the assistance of Stephen Hochman, senior planner of NJDOT's Bureau of Environmental Analysis (in charge of environmental work for NJ Transit's Rail Station Improvement Program), the following rail stations were identified as having significant potential for increased bicycle ridership: Metropark, Metuchen,