lated to an increase in the bus, walking, and automobile passenger modes than to an increase in the automobile driver mode. While it is unlikely that this is due to the individual's lack of access to an automobile (5), it may reflect the person's desire or need to leave the automobile at home for use by another household member.

CONCLUSIONS

The results of this study indicate that further empirical investigations of this nature should prove fruitful. If appropriate data were available for time periods throughout the year, we could gain considerable insight into the way in which daily weather conditions impact the demand for bicycle travel. Although the data on which this exploratory study was based were limited, they did afford a glimpse of the kinds of processes that can and should be uncovered, if we are to understand the relation between weather and bicycle use.

The expectation at the outset was that weather conditions would have some impact on the use of the bicycle as an urban transportation mode. Although the dearth of rainy days during the study period precluded any meaningful insight into the impact of precipitation on bicycle use, this paper has shown that both temperature and cloud coverage are related to the proportion of daily travel done by bicycle in the study area. Perhaps more important is the finding that weather affects bicycle ridership differentially in accordance with the type of travel in question; discretionary travel by bicycle is more sensitive to temperature changes and less sensitive to cloud coverage than bicycle use for the journey to work is. This paper has also shown that several different modes of transportation are used as alternatives to the bicycle on days when bicycle ridership is low. Finally, although bicycle use does decline with falling temperatures, a substantial portion of travel to work is done by bicycle even when temperatures are below freezing. It is apparent that for the work trip, in particular, people can and will use bicycle facilities (if they are provided) under variable weather conditions. It appears that attitudes constitute a more formidable deterrent to bicycle use than the weather does.

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Abridgment

Development of a Bicycle Accident Rate in Arizona

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The climate in Arizona allows bicycling to be a year-round activity in the most populous areas of the state. The number of accidents in the state has increased from 383 in 1967 to 1124 in 1975. More than 90 percent of these accidents occurred in urban areas. In the last few years, the growing concern and previous lack of planning have motivated state and local authorities to conduct extensive surveys and to finance research for recommendations and solutions to this problem. Data are now categorically collected and stored at state and local levels for analyzing the location, probable cause, time of day, and conditions at the time of the accident. Extensive surveys have yielded data such as predicted ownership, location, and usage of bicycles. Projected bicycle usage and projected accidents indicate that solutions to the growing accident problem must be found.

STATEMENT OF PROBLEM

Statistics frequently used to measure effectiveness are the number of accidents or injuries occurring in a defined area during a specified time. These statistics are compared with previous results or with results from other areas. This method does not account for changes in usage nor trends that may have influenced the results. A rate relating bicycle usage with the number of accidents occurring during a specified time span or for a specified area would be a more meaningful statistic.

SCOPE OF STUDY

This study encompasses only reported accidents that involve bicycles and motor vehicles in Arizona. The availability of data limits the rate analysis to the period of January 1973 through December 1975 (1).

Although the bicycle accident problem is increasing each year, no literature equating accidents as a function of usage is found. Statistical reports present the increase of bicycle accidents as a percentage of accidents in previous years, and the majority of other consulted literature pertains to the design and implementation of bikeway systems. Most statistical accident reports present data on the number of injuries and deaths attributed to bicycle accidents. One report (2) did attempt to develop a relation between bicycle accident deaths and the number of pedal-cycles in use. However, this rate does not equate the accidents with usage.

STUDY AREA

Approximately 70 percent of the population in Arizona live in urban areas where populations exceed 10 000 people, and over 90 percent of all bicycle accidents occur in these urban areas. The state was divided into two major categories. Cities with a population exceeding 10 000 were classified as urban, and all other areas and communities were classified as rural. Accident summaries for 1973 to 1975 for the state, urban and rural areas, and major cities of interest are given in Table 1.

DEVELOPMENT OF BICYCLE USAGE

In November 1972, the Behavior Research Center of Phoenix conducted a survey of 1041 randomly selected households throughout Arizona. The results of this survey were used by Bivens and Associates (3) to help determine bicycle usage in the state. Some of the findings of this survey are given below.

Round Trips per Week	Percent State	Urban	Rural
1 to 2	30	30	26
3 to 4	16	16	22
5	21	24	8
6 to 9	18	17	22
> 10	15	13	22
Total	100	100	100

Item	State	Urban	Rural
Percent			
Households owning bicycles	51	54	42
Bicycle owners riding bicycles	90	91	87
Average number of bicycles in households owning bicycles	2.13	2.20	1.90

We used the above percentage of round-trip data to develop a trip generation formula per rider. The percentage of riders is multiplied by the average number of trips per week to find the number of trips per week the average rider takes. For instance, the average rider in the state takes 4.91 round trips per week as follows:

$$\text{number of trips per week per rider} = [0.3(1.5) + 0.16(3.5) + 0.21(5) + 0.18(7.5) + 0.15(10)] = 4.91 \quad (1)$$

The definition of a trip used in this report is a one-way trip; therefore, the average state rider makes 9.8 trips/week or 510.6 trips/year. Similarly, the average urban bicycle rider makes 9.6 trips/week or 497.6 trips/year.

Bicycle Accident Rate

The objective of this study is to develop a relation between the number of bicycle accidents that occur in a defined area for a specific time period and the bicycle usage for that time period. Calculating this rate for the same area for different time periods produced a standard or measure from which trends can be developed. These rates can also be used to compare trends in other areas. The units for the bicycle accident rate (BAR) used in this study are the number of accidents that occur per 1 000 000 bicycle trips.

From the 1970 census data, there were an average of 3.208 persons/household in Arizona. For this study, the assumption is made that the household size remains constant. From this assumption and the population figure, the number of trips per year in the state and in the urban and rural areas can be readily calculated by using the bicycle-ownership information. The bicycle usage summary for 1975 is given as follows:

Item	State	Urban	Rural
Population	2 224 000	1 522 708	701 292
Households	693 267	474 660	218 607
Riders	677 786	513 145	164 641
Trips per year	346 104 643	255 361 478	120 743 165

From the above information, it is possible to develop rates for the number of injuries and fatalities that occur each year.

BAR and Accident Projections

To accurately develop the regression equations for the state and the city of Tempe, we used accident data and population estimates for 1970 through 1975 to calculate the BARs for each year as shown in Table 2.

We used these BARs to derive the following regression equations for Arizona and for Tempe respectively.

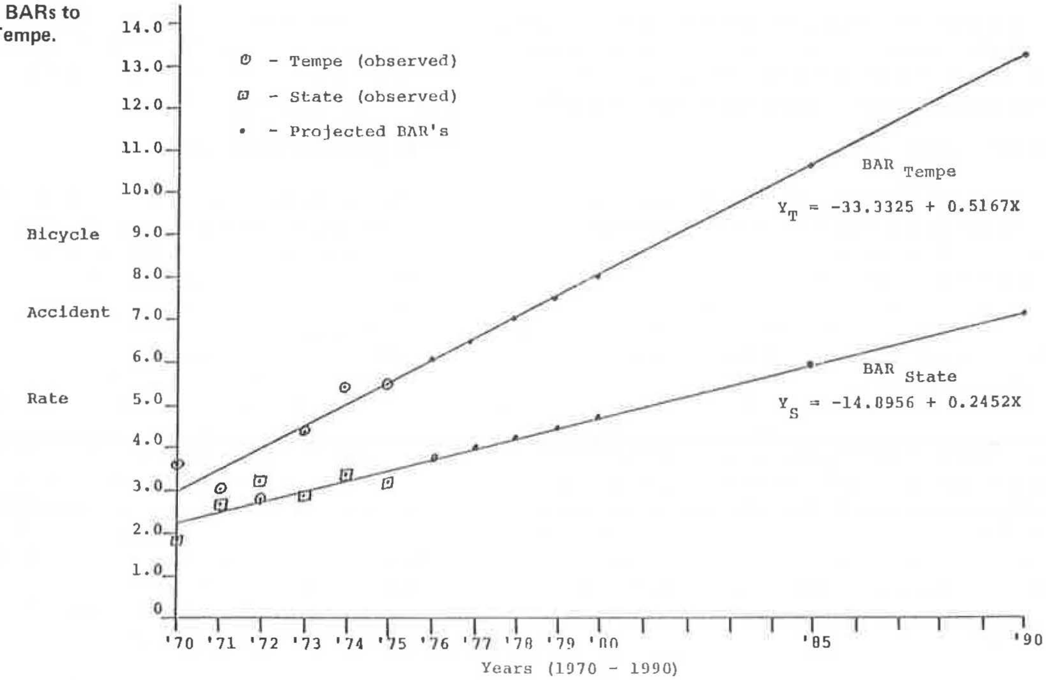
Table 1. Summary of bicycle accidents and BARs in Arizona.

	Number of Accidents			Bicycle Accident Rate		
Location	1973	1974	1975	1973	1974	1975
Arizona	942	1130	1124	2.9201	3.3616	3.2476
Urban	864	1045	1053	3.6219	4.2087	4.1236
Rural	78	85	71	0.9279	0.9676	0.5880
Phoenix	410	441	453	3.8159	3.9854	4.0435
Tucson	155	198	160	3.1660	4.0198	3.2166
Tempe	59	79	86	4.3553	5.3901	5.5184

Table 2. BARs for Arizona and Tempe from 1970 through 1975 and projected for 1980 and 1990.

	Number of Accidents		Bicycle Accident Rate	
Year	Arizona	Tempe	Arizona	Tempe
1970	524	38	1.8965	3.6021
1971	773	35	2.6576	3.0674
1972	979	35	3.2047	2.8216
1973	942	59	2.9201	4.3550
1974	1130	79	3.3616	5.3901
1975	1124	86	3.2476	5.5184
1980	1943	151	4.7204	8.0035
1990	3773	324	7.1724	13.1705

Figure 1. Projection of BARs to 1990 for Arizona and Tempe.



$$Y_S = -14.8956 + 0.2452X \quad (2)$$

$$Y_T = -33.3325 + 0.5167X \quad (3)$$

where Y_S and Y_T are the predicted BARs for Arizona and Tempe respectively, and X is the year of the predicted BAR. Table 2 also gives the predicted BARs and the number of accidents to be expected for 1980 and 1990 if bicycling conditions remain constant and if future population estimates are realized. The projection of Arizona and Tempe BARs is shown in Figure 1.

ANALYSIS AND APPLICATION OF BARs

As given in Table 1, the majority of bicycle accidents occur in urban areas, and the number of accidents is increasing yearly. Phoenix and Tucson appear to be the least safe cities for riding bicycles. In the last 3 years, 44 percent of the urban accidents occurred in Phoenix and Tucson; however, 65 percent of the urban population is located in these two cities. The BARs for Phoenix and Tucson are actually lower than the urban BARs for 1974 and 1975. By using the BARs, it is possible to develop trends and determine where the problem is increasing.

The importance of the BAR is not in the quantitative value calculated but rather in the trends that the BAR exemplifies. The techniques presented in this study can also be used to categorically calculate rates for bicycle accidents by age of rider, by time of day, and by the number of injuries or fatalities resulting from the accidents.

In large metropolitan areas such as Phoenix and Tucson, it may be desirable to further delineate the city into sectors and to study trends that occur within the city. By using this procedure, it is possible to determine which areas need emphasis and to recommend to the city management where projects and programs are needed. In this manner, the priority of efforts can be determined. At the state or regional level, this procedure can also be used to develop trends and measure the effectiveness of ongoing programs.

Administrators can use the BARs and statistical analyses as supportive information when requesting funds for improvement programs. The BAR is a statistical tool, and the use of it can be tailored to the needs of the state or community.

CONCLUSIONS AND RECOMMENDATIONS

The BAR is a better measure for developing trends than the present use of percentages. It has been shown in this study that the cities experiencing the majority of accidents are not necessarily in those areas where the bicycle accident problem is increasing.

1. The BAR is representative of the relation between the number of bicycle accidents and bicycle usage.
2. The bicycle accident problem is increasing in urban areas and decreasing in rural areas.
3. Metropolitan urban areas collectively have more of a bicycle accident problem than the separate urban areas.
4. If current trends continue and conditions remain constant, bicycle accidents will triple in the state of Arizona and quadruple in Tempe by 1990.
5. Better bicycle safety programs are needed.
6. Further study and research of the bicycle accident rate are warranted.

Bicycle accident data have become more standardized and available; however, little effort has been made to accurately determine bicycle usage. Currently, there is no method for accurately determining bicycle ownership. One method to help determine usage would be mandatory registration of bicycles.

The validity of future projections can be increased by using a larger sample or by expanding the number of years used to make the projection. Further collection of data will yield a larger sample from which the projections can be made. It is recommended that future studies consider individual cities that have an increase in or higher than average bicycle accident rates.

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Effect of Bicycle Lane Usage on Vehicles in the Adjacent Lane

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This paper presents an approach for investigating the effect of bicycles in a bicycle lane on the characteristics of the traffic stream in the adjacent lane. Previous work related to this subject is reviewed, and a possible model to analyze the impact of bicycles on level of service is proposed. The model uses the difference in vehicle speed with and without the presence of bicycles. The application of this model to capacity analysis is discussed, and a program of expansion and testing is recommended. The method of data collection employed is presented. A limited data set from a field study is analyzed, and the results are tested for statistical significance. The results of this analysis indicate that there is a measurable reduction in speeds with bicycles present and reinforce the need for further study.

Bicycle sales in the United States more than doubled between 1968 and 1973. In the same period, automobile sales increased approximately 14 percent. In 1973, bicycle sales totaled 15.3 million while automobile sales were only 11.4 million. The Bicycle Institute of America reports that in 1969 only 15 percent of all bicycle riders were adults. However, one year later, adult bicycle ridership doubled to 30 percent. It is estimated that there is one bicycle for every two people in the United States (1).

Numerous surveys have indicated that a latent demand for bicycle commuting exists that is not realized because of the lack of adequate facilities (2). One survey (3) indicates that the majority of those persons who use on-street bicycle lanes are commuters, but the survey included only cities in which there were universities.

Increased use of bicycles is frequently advocated as a strategy to limit the increase in motor vehicle traffic. If one assumes that there is an increase in the number of bicyclists who use the streets, then the reduction in vehicle trips represented must be compared to the decrease in roadway vehicle capacity that is caused by the presence of bicycles. The primary situations that affect capacity include bicyclists riding in the traffic stream and bicyclists riding in adjacent striped bicycle lanes. In the first situation, the bicycle affects the traffic stream characteristics in a manner similar to the presence of trucks, buses, and turning vehicles. The effect on roadway capacity in the second situation results from both the effects of traffic stream characteristics and a reduction in the physical dimensions of the facility.

There has not been sufficient study devoted to this topic. Currently, it is difficult to provide more than a qualitative assessment of the impact that the large increase in bicycle use has had on roadway vehicle capacity. There are no quantitative adjustment factors that can be applied to a capacity relation to account for the presence of bicycles.

PURPOSE AND SCOPE OF STUDY

The purpose of this paper is to provide insight into the effect that the presence of bicycles in bicycle lanes has on the level of service on urban streets. The characteristics studied include the effect of street width, the interaction of vehicle and bicycle volumes, and the influence of weather. The reduction in approach width that results from the presence of a striped bicycle lane is taken into account by using accepted capacity analysis techniques. The problem of right-turning vehicles that cross through a bicycle lane and left-turning bicyclists who cross through the lanes is not dealt with in this study.

The data and discussion presented here are intended to describe a possible methodology of capacity analysis that would account for the presence of bicycles in bicycle lanes. Data were collected along bicycle lanes in Eugene, Oregon, under conditions with and without bicycles. The results are compared with data from a previous study in West Lafayette, Indiana. Inferences are made from the data collected, and possible applications to capacity analysis are explored. These inferences and applications are only preliminary in nature and are intended to stimulate further study that is more comprehensive in nature.

REVIEW OF PREVIOUS WORK

A literature search was conducted to determine the nature and extent of previous research in this area. The results of that search are included in an unpublished annotated bibliography (4). The articles on the location of bikeways primarily discuss the characteristics of streets that are compatible with bicycle lanes or the problems of locating streets where bicycle lanes would be most used. The articles dealing with operations are primarily concerned with the means for preventing automobiles from intruding into bicycle lanes and for dealing with the signing and traffic control problems within bicycle lanes.