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Road User Information Needs, Pedestrian Movement, and Bicycle Travel Patterns

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Contents

Relation Between Roadside Signs and Traffic Accidents: Field Investigation

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The purpose of this study was to investigate systematically the relation between roadside signs located nearest to urban traffic intersections and traffic accidents. Specific sign elements studied were total number, type (public versus private), size, and color. The dependent variable was the number of accidents during 1975 at 60 intersection approaches where the driver who entered the intersection from the direction selected was determined to be at fault in the police accident investigation report. The intersections were selected randomly from cross intersections in the city of Austin where at least one accident occurred during 1975. Results indicate that a number of sign elements had a significant relation to accidents at intersections controlled by stop signs, but no relation was found between signs and accidents at intersections controlled by traffic signals. Possible interpretations of the findings are considered, and some practical suggestions for reducing the effects of distracting signs at stop-sign intersections are advanced.

The roadside environment in many urban and suburban areas is typified by a burgeoning visual complexity of advertising signs, neon lights, and gaudy billboards. Although some recent studies (1, 2) have evaluated the impact of such development from an essentially aesthetic perspective, surprisingly little research has examined the relation between this array of potential visual distractors in the roadside environment and traffic safety. This concern is underscored by three recent on-site accident investigation studies (3, 4, 5), which have estimated that a principal causal factor in 10 to 25 percent of automobile accidents was distraction.

A large body of research has examined perception of the target traffic stimulus (6, 7) (e.g., the color, size, and lettering of road signs), but almost no inquiry has investigated perception of the target traffic signal as a function of distractors in its environmental background. Thus, traffic engineers possess considerable knowledge relevant to the construction of adequate traffic signs isolated from their environmental context, but very little is known about how to evaluate features of the background environment that may contribute to or reduce road sign effectiveness. Ordinances in most local communities regulate the placement, size, and light intensity of commercial signs; however, such regulations are often very vague. One local regulation (8), for example, prohibits "any change in light intensity, motion, or color which subconsciously fixates or attracts the eyes of the motorist when they should be driving."

Very little inquiry has been directed toward visual distractors and traffic accidents in field settings, and those data that do exist are both contradictory and open to methodological criticism. Two studies (9, 10) reported positive correlations between the presence of advertising devices and automobile accidents on multilane highways. Two other studies (11, 12) indicated a positive relation between traffic accidents and the number of elements in the roadside environment, such as commercial establishments, intersections, driveways, and traffic signals. Other evidence, however, has reported no relation between highway accidents and advertising signs (13, 14). Two recent laboratory investigations offer some support for the view that distracting stimuli decrease driving performance significantly under controlled conditions (15, 16), although both studies note that the performance decrements were small and might not relate to a safety problem under actual driving conditions.

The present study is based on the results of the small number of available field studies. Signs were categorized in terms of a number of dimensions including (a) total number of signs, (b) type of sign (public versus private), (c) size of sign, and (d) color of sign. We hypothesized that increasing numbers of signs, larger size of signs, and greater similarity of color between signs and target traffic device would all relate positively to the number of traffic accidents.

METHOD

Sixty intersections were selected at random from a list of intersections within the city of Austin that had at least one accident during 1975. Both intersections controlled by traffic signs and those controlled by stop signs were studied. The stop-sign intersections were predominantly two-way stops, although some four-way stops were included in the sample. To control for extraneous variables, several criteria were used to restrict the sample. Only cross intersections, where two through streets intersected at a 90° angle, were examined. None of the intersections studied was characterized by unusual landscape features, such as an approach from a steep hill or visual obstructions due to natural or designed features. The sample was also restricted to intersections that had a recent 24-h traffic count of between 5000 and 30 000 vehicles; thus intersections of very high or very low traffic flows were eliminated.

A data sheet was developed to classify every sign observable at an intersection in terms of its type, size, and dominant color. Public signs were defined as signs erected by a governmental entity, such as street signs, restricted-parking signs, bus-stop signs, or bicycle-lane signs. Private signs were defined as signs erected by a nongovernment entity and included those on storefronts or in store windows. A small sign was defined as a sign whose size was equal to or smaller than a standard stop sign; a large sign was one that was larger than a stop sign. Signs were also categorized as either red or nonred, according to their dominant colors. Red signs had a red or partially red background, regardless of the letter color or any red letters or figures on a neutral background of white, black, brown, or clear (glass). All other signs were defined as nonred.

Dependent Variable

The dependent variable was the number of accidents during 1975 at 60 intersection approaches where the driver who entered the intersection from the direction selected was determined to be at fault in the police accident investigation report. The sample of intersection approaches investigated showed a range of from 1 to 12 at-fault accidents during the year. The distribution of accidents was positively skewed; 67 percent of intersection approaches had fewer than three accidents. The accident data were available from the urban transportation office and were derived from the reports of investigating police officers. For every accident, the data listed the direction of the vehicles involved, time of day, probable cause, and responsible party. Accidents that occurred at night when signs were not clearly visible were excluded from the count, as were accidents that were apparently not related to distraction (e.g., driving while intoxicated or speeding). The remaining at-fault accidents were due primarily to drivers failing to yield the right of way or ignoring stop signs.

Table 1. Mean number of signs under each distractor element for traffic-signal and stop-sign intersection approaches.

	Traffic Signal		Stop Sign	
Distractor Elements	Low Rate (N = 79)	High Rate (N = 66)	Low Rate (N = 26)	High Rate (N = 33)
Total signs	17.78	25.85	3.46	10.39
Public	7.38	9.74	1.85	6.61
Private	11.53	18.18	2.19	3.88
Large	11.21	15.71	1.04	3.33
Small	10.43	13.59	3.23	7.18
Red	7.86	11.62	1.46	3.82
Nonred	13.85	17.74	2.85	6.70

Table 2. Zero-order correlations between distractor elements and at-fault accidents at traffic-signal and stop-sign intersection approaches.

	Traffic Signal			Stop Sign		
Distractor Elements	Correlation	Degrees of Freedom	Probability	Correlation	Degrees of Freedom	Probability
Total signs	0.10	115	0.131	0.23	57	0.040
Public	0.09	115	0.171	0.17	57	0.100
Private	0.09	115	0.175	0.14	57	0.140
Large	0.10	115	0.137	0.22	57	0.047
Small	0.07	115	0.214	0.15	57	0.131
Red	0.12	115	0.107	0.13	57	0.170
Nonred	0.07	115	0.219	0.23	57	0.043

Table 3. Partial correlations between distractor elements and at-fault accidents when the influence of traffic flow is controlled at traffic-signal and stop-sign intersection approaches.

	Traffic Signal			Stop Sign		
Distractor Elements	Correlation	Degrees of Freedom	Probability	Correlation	Degrees of Freedom	Probability
Total signs	0.00	114	0.495	0.21	56	0.050
Public	-0.07	114	0.214	0.16	56	0.122
Private	0.02	114	0.424	0.14	56	0.156
Large	-0.01	114	0.478	0.21	56	0.058
Small	0.00	114	0.481	0.14	56	0.155
Red	0.05	114	0.308	0.11	56	0.212
Nonred	-0.04	114	0.335	0.22	56	0.050

Table 4. Partial correlations between distractor elements and at-fault accidents at stop-sign intersection approaches that have two or more accidents when the influence of traffic flow is controlled.

Distractor Elements	Correlation	Degrees of Freedom	Probability
Total signs	0.45	15	0.033
Public	0.11	15	0.337
Private	0.50	15	0.020
Large	0.59	15	0.006
Small	0.24	15	0.175
Red	0.07	15	0.400
Nonred	0.58	15	0.008

Procedure

Three undergraduate psychology students collected the data for the study. An observer stood at the right-hand curb, facing the intersection recording first at a point 61.0 m (200 ft) from the cross street. Every sign visible from that observation point within a 180° visual angle was classified along the three dimensions. The observer then advanced to a point 15.2 m (50 ft) from the cross street and recorded any additional signs within a 180° visual angle, but which had not been visible from the first observation point. The procedure was repeated for each of the other approaches to the intersection. (For a one-way street, observations were recorded only facing the same direction as vehicles traveling on the street.) All observations were conducted in the summer of 1975, during the day under good light conditions. The undergraduate observers received training from a skilled observer who served as a criterion observer. The sample intersections were observed only after each observer had achieved 90 percent agreement with the criterion observer. Periodic interrater reliability checks were conducted between each observer and the criterion observer throughout the study. Average agreement was 92 percent.

RESULTS

Table 1 shows the number of signs under each distractor element observed at accident-intersection approaches for both intersections controlled by traffic signals and intersections controlled by stop signs. At the traffic-signal approaches, low accidents was defined as one or less annual accidents and high accidents as two or more annual accidents. For the stop-sign approaches, low accidents was defined as zero annual accidents and high accidents as one or more annual accidents. For all distractor elements the number of signs at high at-fault accident intersection approaches exceeded the number of signs at low-accident approaches.

Table 2 shows the zero-order correlation between each distractor element and at-fault accidents for both intersection approaches controlled by traffic signals and those controlled by stop signs. At traffic-signal approaches, no distractor dimensions demonstrated a significant relation with at-fault accidents. At stop-sign intersections, in contrast, three distractor elements—total signs, large signs, and nonred signs—demonstrated a significant positive relation to at-fault accidents.

A problem in interpreting the data in Table 2 is the possibility that the positive relation between number of signs and traffic accidents may reflect a positive correlation between both of these variables and rate of traffic flow. In order to discount the possible influence of traffic flow, the data were reanalyzed and controlled statistically for the influence of traffic flow. Table 3 shows the partial correlations, when the rate of traffic flow is controlled, between each distractor element and at-fault accidents for both traffic-signal-controlled and stop-sign-controlled-intersection approaches. For all distractor elements, especially for traffic-signal approaches, the partial correlations are somewhat weaker than the zero-order correlations, which indicates that part of the relation between signs and accidents is explained by traffic flow. Nevertheless, at the stop-sign approaches, total signs and nonred signs remain statistically significant and large signs show a very strong statistical trend ($p = 0.058$).

A particularly strong picture of the relation between signs and traffic accidents emerges when we examine separately the sample of stop-sign approaches showing two or more annual accidents, controlling again for the effect of traffic flow. Table 4 shows the partial correlations when the rate of traffic flow was controlled, between each distractor element and at-fault accidents for stop-sign controlled approaches that had two or more annual accidents. Four distractor dimensions—total signs, private signs, large signs, and nonred signs—demonstrated a strongly significant positive relation with at-fault accidents.

Based on these findings, a summary picture of the relation between distracting signs in the roadside environment and traffic accidents can be presented. There is no evidence that signs presented a traffic safety problem at the intersections controlled by traffic signals. There was, however, evidence that signs were related to accidents at the intersections controlled by stop signs. The relation between the total number of signs and accidents was especially strong at stop-sign intersections characterized by a relatively high number of accidents. In addition, the present data indicated that the signs that predominated at these intersections were larger, private signs. The relation between nonred signs and accidents probably reflected both the influences of a diversity of colors in the distractor and the higher number of nonred signs in the environment.

The differential effects of signs on traffic signals and stop signs may be due to a number of factors. The present data do not directly address this issue, but we may speculate about some possible factors. Most important in the case of stop signs may be that distractors and target are of the same medium. Also, for most of the sites investigated, the placement of signals and stop signs relative to distractors differed. All stop signs were placed at the right-hand curb; however, almost all traffic signals were placed at mid-road on an extension arm. Thus, stop signs and distractors tended to be located together proximally in the visual field, but traffic signals tended to be located more distantly from distractors in the visual field.

The present results support a number of practical suggestions for traffic engineers concerned about reducing the effects of distracting stimuli in the roadside environment. In general, such feedback falls under two areas of application: (a) the establishment of appropriate ordinances to limit legislatively the effect of distractors, and (b) engineering decisions about design changes in the target signal oriented toward counteracting the potential negative effects of background distractors. These findings suggest the need for a wider range of engineering alternatives at some stop-sign intersections to counteract the effects of potential distractors, such as the design of a larger or brighter target traffic device or the employment of neutral background shields to contrast more effectively the target and its surrounding context. Where such design alternatives are not feasible at sites where a significant number of distractors are present, traffic signals should be employed rather than stop signs.

In summary, these results underscore the need for the traffic engineer to accept broader responsibility for the total traffic environment, including both the public roadway and the contingent environmental context in order to cope effectively with the dramatically increased visual complexity of today's roadside environment.

ACKNOWLEDGMENTS

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Abridgment

Advance Road Sign Messages for Highway Advisory Radio Systems

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Two laboratory studies of human factors were conducted to evaluate candidate messages to be displayed on an advance-notice road sign. The sign would be used to direct drivers to tune their radios for reception of traffic information, particularly in incident or construction situations that necessitate route diversion. Study 1 was conducted in Los Angeles and investigated the meanings implied by each of ten candidate messages by use of an independent group design. Study 2 was conducted in College Station, Texas, and investigated message preferences by use of the paired-comparisons method. The combined results suggest the briefest message to adequately alert drivers to adjust their radios to obtain traffic information.

A practical design question is the message content of an advance road sign to inform drivers to tune their radios to a particular AM frequency. Gatling (1) investigated distances between signing based on tuning time. His research suggested the need for two signs, one before the broadcast area and one after the area has been reached. He also studied the order of certain message elements but did not study specific message wording.

Brizell and Veale (2) studied three signs for the Walt Whitman Bridge highway advisory radio experiment. The first displayed RADIO TRAFFIC INFORMATION is AHEAD; the second also gave the distance and the frequency to set. The third repeated the information and added WHEN FLASHING. RADIO TRAFFIC INFORMATION was the only message studied and subjects were asked if the message was clear; no attempt was made to determine whether the messages were understood. A need existed to investigate specific content and wording of such a message with respect to both correct comprehension of the intended message and the preferences for messages and message elements.

METHOD

A study of understanding and interpretation of message content was conducted in Los Angeles with 247 subjects. Independent groups of approximately 25 subjects each were given one of ten candidate messages. They were required to complete a questionnaire of three to five questions. The first two questions asked for a write-in of the meaning of the message and the importance of responding immediately to the advisory. The other questions varied with the particular message and were designed to probe the connotations of specific message elements.

The second study was designed to determine preferences for ten candidate messages. Three of the messages employed in the Los Angeles study were either modified slightly or replaced, based on the findings of the previous study. Forty subjects from College Station, Texas, were given pairs of messages in random order on 3×5 cards. They were required to select the message that better prepared them to receive the radio message. Each subject evaluated all combinations of the messages, for a total of 45 comparisons. In this study, subjects were instructed that the radio message would concern an accident or construction blocking the highway and would advise them about a diversion route. They were allowed to hear several typical messages. This information was given to ensure that the subject's choice of words in the messages was based on the type of radio message expected.

RESULTS

In the Los Angeles study, each subject was asked to rate on a five-point scale the importance of responding immediately to the message. A rating of 5 was very urgent, 4 was urgent, 3 meant at my convenience, 2 was may ignore, and 1 was message irrelevant.

Table 1 presents the ten candidate messages. In the second column is the mean urgency rating. Messages were listed in order of decreasing urgency. The mean urgency rating was 4.0. Note that the first four messages contain the word ALERT; only one message that contained ALERT ranked as low as seventh. The moderately urgent messages contained ADVISORY, and ROUTE INFORMATION was more often in the at-my-convenience category.

The word alert has been reserved in our society for emergency or critical situations, such as TORNADO ALERT or AIR RAID ALERT, and by extension of meaning, it implies a direction to motorists to expect to do something that is not routine. TRAFFIC ADVISORY has been used for more routine traffic conditions, and ROUTE INFORMATION may be thought to mean guidance to visitors as at a tourist center, rather than point diversion-guidance information because of traffic conditions.

Column 3 of Table 1 presents the percentage of subjects who mentioned in their answers that a radio message was involved. All messages except C and H began with the word radio; however, these messages had as many or more mentions of radio as the other messages. Therefore, the advisory portion of the message may carry this meaning sufficiently.

Column 4 gives the percentages of those who thought the message to be given dealt with traffic conditions. Overall, the frequency of write-ins was low, but previous research suggests that a request for meaning is more often interpreted as asking what the motorist should do, rather than asking about the incident or the effects of it. However, message A (RADIO ALERT) was interpreted as giving traffic information by the lowest percentage; only 19 percent expected traffic information to be given. Another question found that 25 percent of the subjects read into this message an emergency unrelated to traffic conditions, whereas few subjects completely misunderstood other messages.

Probe questions supported the above findings that messages containing ALERT were seldom interpreted as routine information, whereas over 40 percent of the messages that contained either ADVISORY or ROUTE INFORMATION were classified as interpretations of routine information.

All except two messages displayed the number 1606 without explanation. The number was meant to imply 1606 KHz on the AM band. Answers to a probe question

Table 1. Average rating of message urgency and percentage of subjects understanding meaning.

Message	Urgency Rating	Radio Message Mentioned (%)	Traffic Conditions Mentioned (%)
A. RADIO ALERT TUNE 1606	4.5	95.2	19.0
B. RADIO TRAFFIC ALERT TUNE TO 1606 AM	4.4	81.0	66.7
C. TRAFFIC ALERT TUNE 1606	4.2	89.5	36.8
D. RADIO TRAFFIC ALERT TURN DIAL TO 1606	4.1	87.0	82.6
E. RADIO TRAFFIC ADVISORY 1606 ON YOUR AM DIAL	4.0	95.0	75.0
F. RADIO TRAFFIC ADVISORY TUNE 1606 FOR INFORMATION	4.0	68.8	50.0
G. RADIO TRAFFIC ALERT TUNE TO 1606	3.9	86.2	75.9
H. TRAFFIC ADVISORY TUNE 1606	3.8	100.0	42.1
I. RADIO ROUTE INFORMATION TURN DIAL TO 1606	3.7	76.2	71.4
J. RADIO ROUTE INFORMATION SET DIAL TO 1606	3.5	88.0	72.0

Table 2. Order of preferences for messages.

Message	Preference Rank	Preference Percent
RADIO TRAFFIC ALERT TUNE DIAL TO 1606	1	70.5
RADIO TRAFFIC ALERT TUNE TO 1606	2	68.6
TRAFFIC ADVISORY TUNE 1606	3.5	56.4
TRAFFIC ALERT TUNE 1606	3.5	56.3
RADIO TRAFFIC ADVISORY TUNE 1606 FOR INFORMATION	5	48.2
RADIO TRAFFIC INFORMATION SET DIAL 1606	6	45.8
RADIO ROUTE INFORMATION TUNE DIAL TO 1606	7	43.7
RADIO TRAFFIC ADVISORY 1606 ON YOUR AM DIAL	8	43.1
RADIO ROUTE INFORMATION SET DIAL TO 1606	9	35.2
RADIO ALERT TUNE 1606	10	31.7

revealed that 75 percent of subjects felt it meant AM only and all but one of the others felt it meant either AM or FM.

The second study investigated preferences among the messages by means of the paired-comparisons method. Table 2 presents the messages in rank order in terms of percentage of times the message was preferred to all other messages. The two messages preferred most often were almost identical. Messages containing RADIO ROUTE INFORMATION or RADIO TRAFFIC INFORMATION were preferred less often than by chance. The latter message was not investigated in Los Angeles but was included because it was used in the study by Brizell and Veale (2). Messages that involved TRAFFIC ADVISORY were intermediate in preference. The RADIO ALERT message was preferred the least. In general, the preference data, using an independent sample in a different state, supported the findings of the Los Angeles study.

RECOMMENDATIONS FOR MESSAGE DESIGN

When the design objective is to imply an urgency to tune to a radio frequency, the word alert is most effective. Both the interpretation and preference data suggest the word implies a nonroutine, incident-related situation that requires action.

Although the word radio is implied somewhat from the advisory, the preference data support its inclusion. Omission of the word traffic can result in misunderstanding the message RADIO ALERT. Based on the two studies, RADIO TRAFFIC ALERT is recommended for this purpose.

The advisory message may be understood effectively by simply stating, "TURN TO (frequency number)" or "TUNE DIAL TO (frequency number)." Long advisory messages with redundant words should be avoided. SET DIAL and TURN DIAL were not evaluated independently, but the single word tune is well understood.

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Abridgment

Legibility Study of a Lamp Matrix Sign

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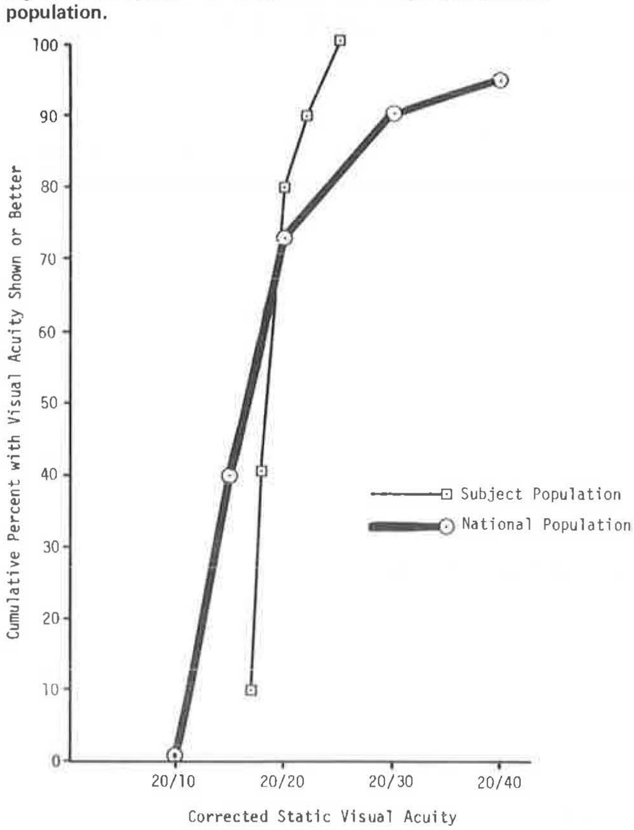
The legibility of painted signs has received considerable attention and thus has been well developed in recent years; however, a similar body of knowledge about the legibility of lamp matrix signs is nonexistent. This unfortunate circumstance has resulted in engineers' designing and installing lamp matrix displays according to rules of thumb or manufacturers' recommendations.

As a part of a study, the Texas Transportation Institute conducted numerous field studies using a lamp matrix sign (1). The availability of this display, which generated 46-cm (18-in) characters, afforded the opportunity to investigate legibility distance along with other display characteristics. As the study was limited to one sign and a relatively small number of subjects (20), the results of this research certainly do not constitute definitive guidelines for the design of lamp matrix signs. Rather, the study provides an indication of the approximate legibility of a 46-cm character lamp matrix sign. Inferences drawn from this study may be useful as a starting point in the design of other sizes of lamp matrix displays.

Figure 1. Subject vehicle approaching sign.

Figure 2. Comparison of visual acuities of subjects to national population.



BACKGROUND

The subject of legibility distance was first addressed when project researchers were concerned about the amount of time available to display information to a driver. Available reading time is determined by legibility distance and vehicle speed. As speed would be either a known or estimable quantity, legibility distance was the only factor that required definition.

The Illuminating Engineering Society recommends that letter height be computed as (2)

$$Hr = D/500 \qquad (1)$$

where

Hr = minimum letter height (m), and
D = maximum distance at which letter is legible to a majority of people (m).

This equation suggests an assumed legibility distance of 4.99 m/cm of letter height (41.7 ft/in). Bogdanoff and Thompson (3) concluded from an undocumented field study that a 46-cm character lamp matrix sign was readable at 243 m (800 ft) for the average motorist. This approximate distance translates to about 5.31 m/cm (44 ft/in) of letter height.

Although these sources did not provide definitive supporting data, they did serve as a basis for comparison. Further, we felt that not only should the average or majority legibility distances be investigated, but that the 85th percentile should also be investigated as it would probably more nearly represent a design value.

STUDY DESIGN

The field study consisted of a determination of the maximum distance at which each of 20 subjects could read a test word. Each subject read three test words, randomized in order between subjects. The test words used were BOAT, BOOK, and ROCK. These words were chosen because they had been shown to be of very nearly equal legibility in a previous Texas Transportation Institute study. The mean legibility distance of the three trials was used as the subject's legibility distance in further computations.

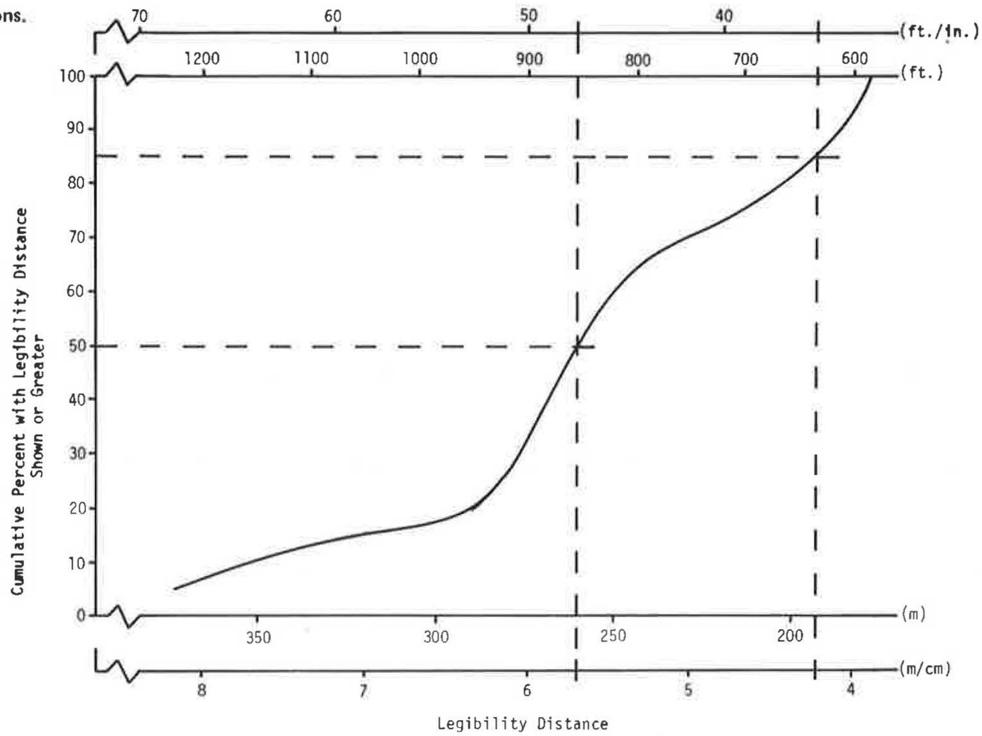
The field study was conducted at the Texas Transportation Institute's proving grounds. A trailer-mounted lamp matrix sign was set up and the study conducted to simulate, as nearly as possible, an actual driving situation (Figure 1). Subjects were tested one at a time while driving a 1976 Chevrolet sedan. Each subject made three test runs at 32 km/h (20 mph). A different legibility test word was used for each run.

Each of the 20 subjects was a licensed driver who had a known corrected static visual acuity. Subjects were chosen from a subject pool to replicate, as closely as practical, a national cross-section of drivers. As these subjects were used in several other field experiments during the testing period, corrected static visual acuity was only one of several selection criteria. However, as shown in Figure 2, their measured visual acuities were fairly close to that of the national driving population (4).

Procedure

Prior to the beginning of each individual study, the experimenter gave instructions to the subject and allowed him or her to become familiar with the vehicle. To be-

Figure 3. Legibility distance observations.



gin each trial run, the experimenter had the subject drive to a distance well beyond legibility distance of the sign [about 600 m (2000 ft)]. The subject then proceeded toward the sign at about 32 km/h. When the subject was approximately 486 m (1600 ft) from the sign, the second administrator displayed one of the three test words on the sign. As soon as the subject read the word displayed, he or she called out that word to the on-board experimenter, who noted the distance from the sign as indicated by markers alongside the roadway. This procedure was repeated for each of the other two words.

Results

The results of the study indicate that the previous estimates of legibility of lamp matrix signs were fairly accurate with respect to the average driver. However, it appears that a more conservative estimate of legibility distance may be in order for design purposes. As each of the test words had been shown to be fairly equal in legibility, the mean of the three distances was computed for each subject. These means were then plotted on a cumulative distribution (Figure 3).

The mean legibility distance for all subjects was about 255 m (840 ft). This distance translates to 5.58 m/cm (46.7 ft/in) of letter height. From Figure 3, the median legibility distance was 261 m (860 ft), but for the 85th percentile the legibility distance was 194 m (637 ft). These distances translate to 5.72 m/cm (47.8 ft/in) and 4.24 m/cm (35.4 ft/in) respectively.

DISCUSSION OF RESULTS

This analysis showed the 85th percentile legibility distance of a 46-cm matrix sign to be about 4.2 m/cm of letter height. The closeness of the corrected static visual acuities of the subject population and the national population and the general agreement between the study mean and previously reported averages further substantiate the results. The study considered only one size of lamp matrix display, so we cannot generalize the reported legibility distances to other sizes or types of matrix displays. However, these values may be considered as a base from which to conduct further investigations.

Although not addressed in this study, previous field experience has shown that the brightness of the lamps used has a considerable effect on legibility (5). It was found that the size of bulbs necessary to construct a seven-row matrix of less than about 25 cm (10 in) did not produce adequate brightness for effective legibility.

ACKNOWLEDGMENTS

This paper discusses one phase of a research project entitled "Human Factors Requirements for Real-Time Motorist Information Displays," conducted by the Texas Transportation Institute and sponsored by the Federal Highway Administration. The contents of this paper reflect our views and we are responsible for the facts and the accuracy of the data presented. The contents do not reflect the official views or policies of the Federal Highway Administration. The paper does not constitute a standard, specification, or regulation. We wish to express appreciation to Truman M. Mast of the Federal Highway Administration for his guidance throughout the project.

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Abridgment

Real-Time Diversion of Freeway Traffic During Maintenance Operations

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A changeable message signing system can be used to divert vehicles around an incident and to redistribute traffic to available capacity of an alternate route, such as a service road or parallel arterial street. This diversion will reduce motorists' travel time, improve the level of service on the freeway, and enhance safer operating conditions on the freeway by providing motorists with advance information of unusal traffic conditions.

Messages developed in previous studies were displayed in actual field operation in response to freeway maintenance to determine the relative effectiveness of each message. In addition to routing traffic on the service road around freeway incidents, diversion to alternate arterial routes off the freeway was planned.

The study site was the North Central Expressway, a fully access-controlled freeway, which may be described as a depressed freeway with diamond interchanges in all interchange locations except two. A full cloverleaf interchange is at loop 12 (Northwest Highway) and a directional interchange is at I-635 (LBJ Freeway).

Three study locations were identified for applying management measures, and collection of data was in the northbound (outbound) direction from Mockingbird to loop 12. All service road intersections are under computer control so that real-time operation changes could be made to complement freeway management activities.

STUDY DESIGN

One objective of this research effort is to establish incident management techniques for use in a freeway surveillance and control environment. The three elements to be defined for the incident management studies are (a) incident detection, (b) management measures of alternatives, and (c) measures of effectiveness. Detection of incidents along the study areas on North Central Expressway in Dallas was accomplished by a nine-camera closed-circuit television (CCTV) system; however, for this study information about maintenance operation was known beforehand in most cases.

After the detection and verification of an incident, it is desirable that the driver be given sufficient information to avoid delay and hazardous conditions. Candidate messages for diversion were evaluated by use of two management techniques:

1. The diversion of freeway traffic to the service road around the incident, and
2. The diversion of freeway traffic to arterials around the incident.

Measures of effectiveness for candidate messages were derived from two sources:

1. The change in diversion rates from natural diversion (nonmanagement) to diversion because of informational signing (management), and the varying candidate messages thereof, and
2. Questionnaires, which were distributed to drivers where duration of the incident allowed.

The changes in diversion rates provided a quantitative measure of the effectiveness of various candidate messages. By a comparison of diversion rates as measured at freeway ramps during nonmanagement and management incidents and during the display of various candidate messages, their relative effectiveness could be measured. Questionnaires distributed to drivers who actually passed the sign displays provided a qualitative measure of the adequacy of the information provided. Drivers were asked to evaluate the information displayed as well as to give their opinion about what further information would be helpful.

Hardware Systems

For purposes of this research, it was necessary to design and install sign hardware that would be sufficiently flexible to satisfy the objective of testing a variety of candidate messages.

Three trailer-mounted, computerized, bulb matrix displays (Figure 1) were employed to present diversion information along northbound North Central Expressway in Dallas. The use of these signs provided versatility in message length, display forms, and rate of display, which greatly increased the number and types of messages to be displayed. The ability to display a message is provided to the operator through the use of a digital computer located on the sign trailer in an environmental equipment cabinet.

Procedure

Based on previous studies, a catalogue of candidate messages for diversion was developed. These candidate messages were set in a priority order for testing during the research period. A message type (such as information only or information and diversion advice) was designated in this priority list; specifics such as exact location were to be determined by the exact location and nature of the incident.

Figure 2 shows the priority of messages to be displayed in conjunction with the freeway matrix signs. Sign 1 was located upstream of the study area, in an area where discontinuous service roads would not allow diversion and was, therefore, an information only or early warning sign.

Roadwork activities allowed testing through priority 3. No maintenance operation occurred at a location that would warrant diversion to alternate arterial routes under Phase 2. The evaluation data to be collected were of four different types: (a) freeway and ramp volumes, (b) intersection volumes, (c) freeway volumes and speeds, and (d) license plate studies for questionnaires.

Data Collection and Comparison

As originally contemplated, extensive data were to be collected on freeway maintenance both under management (informational and advisory signs) and nonmanagement (no sign) conditions to establish a statistical basis for comparison of the various candidate messages. A computer study was made of the freeway surveillance control detector system. The study gave flow rates over all entrance and exit ramp detectors upstream and downstream of the incident.

Because of the limited number of maintenance operations along North Central Expressway during the study, a statistical basis for comparison of the various candidate messages could not be made. Therefore, maintenance under nonmanagement and management operations were analyzed on a case study basis.

Figure 1. Trailer-mounted matrix sign.

Maintenance operations occurred at various times of day; therefore, measures of diversion of the off-ramps were taken in comparison to the flow rates immediately preceding the incident in order to maintain operation as nearly comparable as possible. Maintenance on the freeway in the study area provided the opportunity to collect both nonmanagement and management (with variable messages) data for the same incident. This was accomplished by leaving the sign blank for a period of time and then displaying various messages for approximately the same period of time. Questionnaire studies were made for two matrix-sign maintenance operations.

RESULTS

As previously described, incident management studies were segmented into two primary phases. Phase 1 involved routing traffic along the service road to avoid freeway incidents. This phase involved using matrix

Figure 2. Matrix sign messages to be displayed.

Priority	Sign 1	Sign 2	Sign 3
1	ROADWORK AT______	ROADWORK AT______	ROADWORK AT______
2	ROADWORK AT______	ROADWORK AT______ USE SERVICE RD.	ROADWORK AT______ USE SERVICE RD.
3	ROADWORK AT______	ROADWORK AT______ USE SERVICE RD. NEXT XX EXITS	ROADWORK AT______ USE SERVICE RD. NEXT XX EXITS
4	ROADWORK AT______ HEAVY CONGESTION	ROADWORK AT______ HEAVY CONGESTION	ROADWORK AT______ HEAVY CONGESTION
5	ROADWORK AT______	ROADWORK AT______ USE SERVICE RD. TO______	ROADWORK AT______ USE SERVICE RD. TO______
6	Best of Message 2, 3, 5		
7	For Phase II Same as 6, but use TEMP BYPASS Instead of SERVICE RD.		

Special Messages

When all lanes blocked use:

ROADWORK
AT______

FREEWAY
BLOCKED

Table 1. Case study results.

Case	Change of 5-min Flow Rates for Exiting Traffic (%)			Change in Upstream Demand Exiting (%)			Change of 5-min Flow Rates for Downstream On-Ramps (%)		
	Non-Management	Information Signs	Diversionary Signs	Non-Management	Information Signs	Diversionary Signs	Non-Management	Information Signs	Diversionary Signs
1	+19.0	+324.7	+343.8	+48.6	+146.3	+217.9	+48.6	+146.3	+217.9
2	-	-	-	-	-	-	-	-	-
3	+152.6	+176.3	+227.3	+51.4	+56.5	+58.9	+255.5	+282.0	+239.8
4	+96.2	+125.9	+147.3	+26.2	+36.8	+42.5	+52.3	+134.6	-

signs to inform freeway drivers of diversion from the freeway to the service road. Phase 2 was designed to route traffic to alternate arterial roads when continuous service roads were not available for diversion. Traffic would be diverted from the freeway via the matrix signs and then guided along the alternate route by trailblazer signs, as described in previous sections. No incidents of sufficient duration occurred in locations that would warrant routing to the alternate arterial route (Phase 2).

Data for the four roadwork studies are presented in Table 1. Case 2 data could not be evaluated because of a system breakdown of the freeway detector system during the study. However, questionnaire data were collected. Flow rates of 5-min duration were averaged prior to the maintenance and during each message. The change during each case is presented as the percent change in the table. The first available downstream entrance ramp was also analyzed to determine the effects on its operation during the maintenance.

In order to allow comparisons between different traffic conditions and volumes during each case, it was necessary to determine the percent of the upstream demand that exited. This measure of the exiting traffic negated any effects the demand might have on the number of drivers who diverted from the freeway.

SUMMARY

Many meaningful comparisons were cited in trends from the data collected for maintenance during the incident management studies. In every case comparison, exit ramp volumes increased for signed (managed) incidents compared to nonsigned (nonmanaged), natural diversion conditions. The results showed that diversion was greater under a managed condition than under a nonmanaged condition. For informational signs only, increases ranged from 125.9 to 324.7 percent for the four case studies. When diversion messages were presented, increases ranged from 147.3 to 343.8 percent.

In all case studies, exit volumes were greater for diversionary signs than for informational signs. This would indicate a preference by motorists for diversionary information. This was indicated in questionnaire results for case 1, where 33 percent of the motorists who responded desired alternate routing when no diversionary information was presented. However, none of the motorists who received alternate routing information cared for this type of information.

Downstream entrance ramp volumes also increased under the signed conditions. Increases were greater for diversionary messages than for informational messages. However, in case 3, results indicate motorists entered the freeway before they had cleared the blockage. Some of the drivers may have thought that this particular ramp would be their last opportunity to enter back on the freeway when, in fact, one more ramp downstream would have cleared them from the blockage. This indicates a need for a supplemental sign, such as trailblazing on the frontage road itself or advisories on the changeable messages signs such as, USE SERVICE ROAD TO CARUTH, to tell drivers where to reenter the freeway.

The management of traffic during maintenance conditions was demonstrated to be feasible and advantageous. The addition of diversion information proved to be a benefit. Although statistically sound data bases for comparison were not achievable, trend data were favorable in virtually every case. Questionnaire data show a preference by the motorists for some type of information along their route during maintenance operations. Motorists' preferences included diversionary information as well as advisory information. This was exemplified by the greater increase in diversion when diversionary signs were used.

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**Mr. Carvell was affiliated with the Texas Transportation Institute at the time of this research.*

Pedestrian Movement at the 1980 Winter Olympics Ski Jump

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This paper describes and evaluates options for the location of bus staging areas and the movement of pedestrians between bus staging areas and the Intervale ski jump site at the 1980 Winter Olympic Games at Lake Placid, New York. These options are analyzed in terms of impacts on the environment, spectators walking under winter conditions, traffic flow and accidents, cost, maintenance, and post-Olympic implementation considerations. A comparative analysis is made of these impacts on each of four options for pedestrian flow. Results show that either a pedestrian bridge or signal across the main route appears superior, because it minimizes pedestrian-vehicle conflicts, separates spectators from dignitaries and officials, and consolidates bus staging activities in a single adequately sized location. Options that assume joint use of the road by vehicles and pedestrians should be avoided because of the crucial requirement for maximum road capacity to handle bus circulation.

Lake Placid, a small community in the Adirondacks of upstate New York, will be the site of the 1980 Winter Olympic Games. It is located approximately 140 km south of Montreal and 400 km north of New York City (Figure 1). Highway access to Lake Placid is limited to two routes: NY-86 and NY-73. Because of significant capacity and flow problems anticipated from the planned daily influx of spectators, a 450-bus circulation system feeding peripheral parking lots has been proposed as the basic spectator transportation system for the games (1).

The Intervale ski jump, the site of the 70- and 90-m ski jump competitions, is located at the point where NY-73 crosses the west branch of the Ausable River (Figure 2). Estimated peak periods of use of the facility

Figure 1. Olympic transportation region.

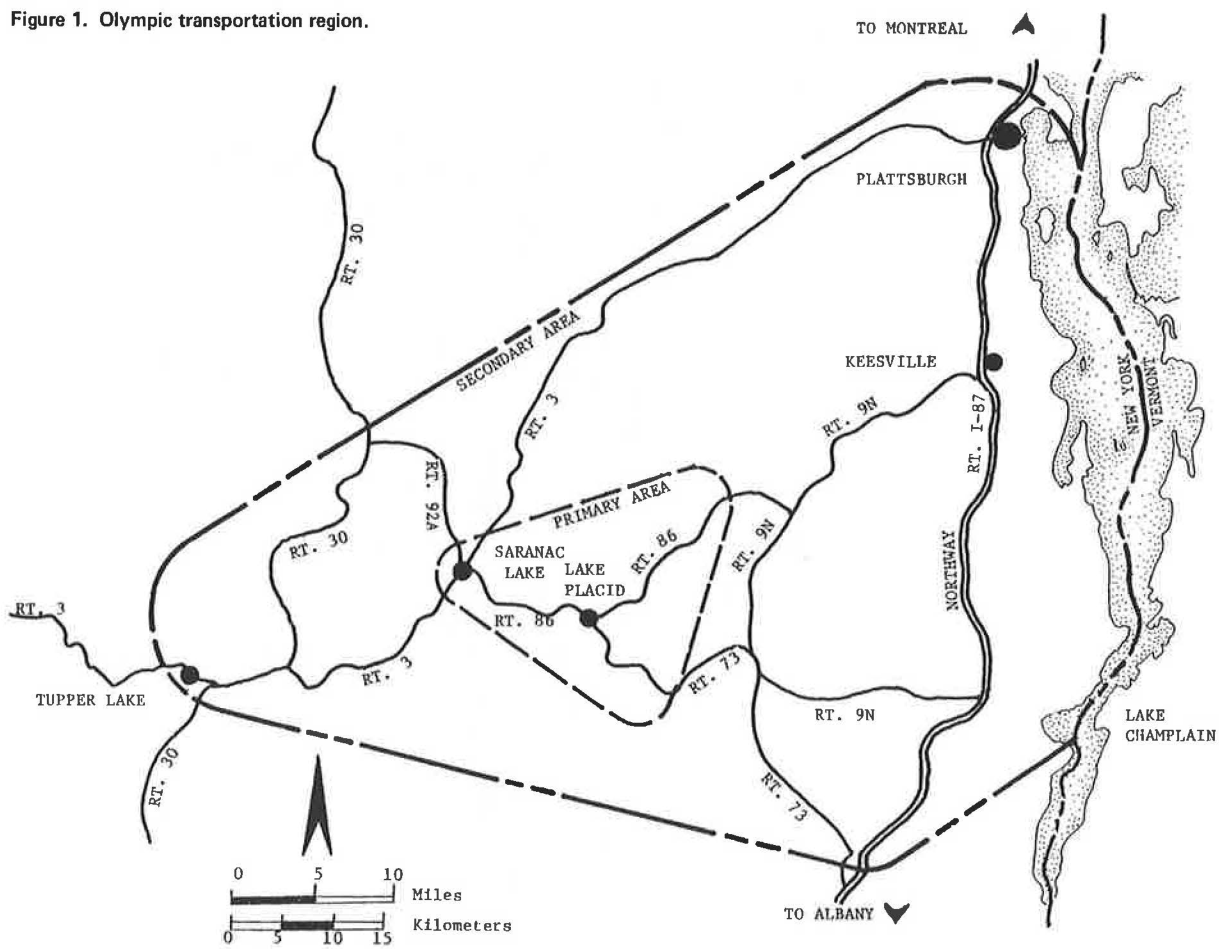


Figure 2. Olympic primary area.

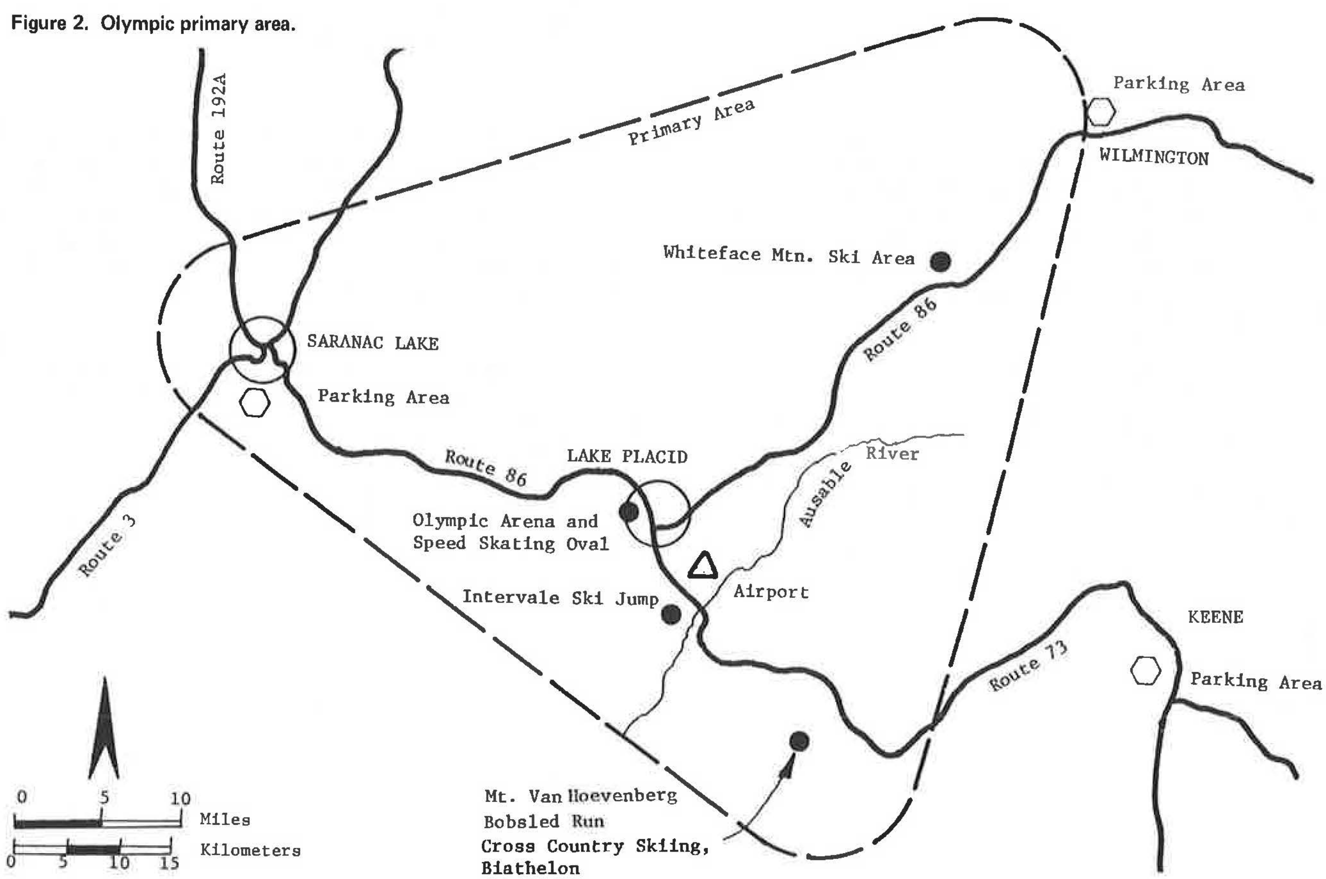
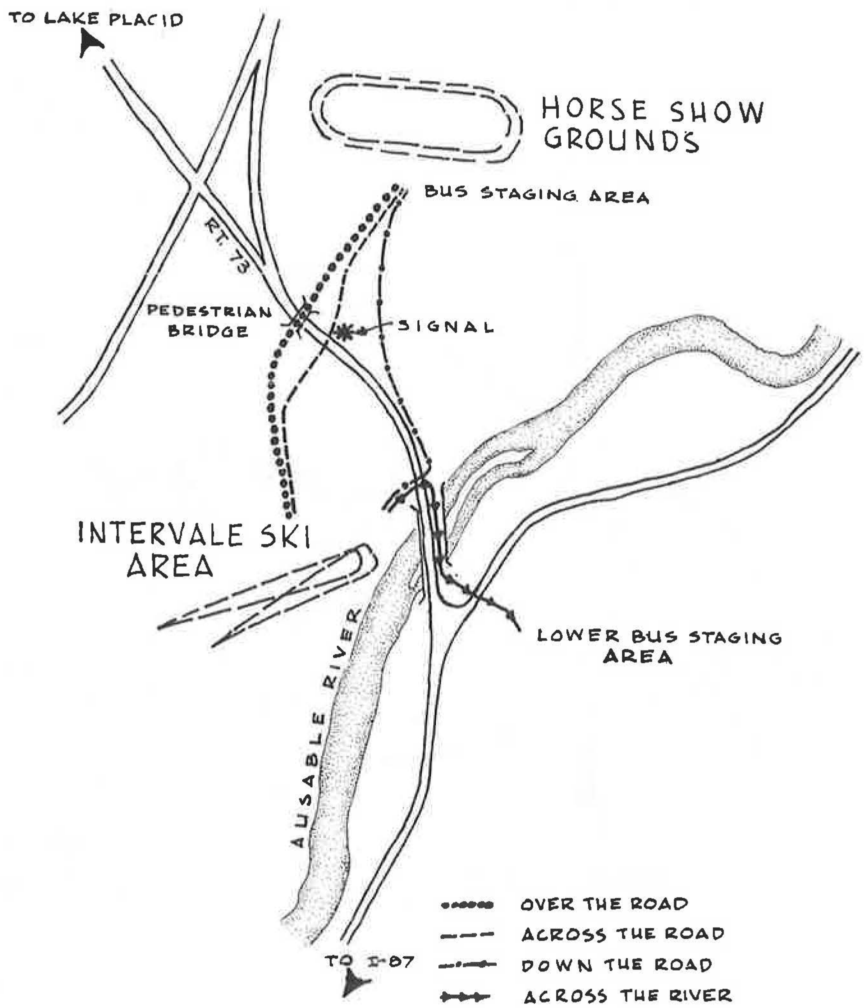


Figure 3. Options for pedestrian movement.



will occur on Sunday, February 17, between 1:00 and 3:00 p.m.; Monday, February 18, between 12:30 and 3:00 p.m.; and Sunday, February 24, between 12:30 and 3:30 p.m. (2). These three peak periods will involve, respectively 15 000, 10 000, and 15 000 spectators—15 000 is the largest number of spectators expected at any of the athletic events of the 1980 Winter Olympic Games (3). Approximately 44 percent of this traffic will approach the site from the south, up NY-73 (4).

The ski jump site is bordered by the Ausable River on the east, NY-73 on the north, and steep ridges on the south (Figure 3). The spectator area at the base of the jump is about 212 x 60 m. Since adequate space does not exist for the loading and unloading of spectators at the immediate site, it will be necessary for spectators to to move on foot between bus staging areas and the ski jump site. At peak periods this will involve the flow of 15 000 pedestrians within a desired time period of 1.5 h, or at a rate of 10 000 pedestrians/h.

ISSUES

The issues involved in the implementation of a pedestrian system at Intervale can best be made clear through a discussion of the impacts that fall into each issue category. Thus each issue will be broken down into individual impacts.

Environmental

As stated by the Olympic Transportation Committee, all transportation work and development must be performed with an extreme sensitivity to environmental impacts (1). Although the site-related impacts at Intervale that fall into this category are not great, they must be considered in order to gain an environmental perspective of the pedestrian options. The impacts of the environmental category are explained below.

1. Trees, shrubs—This involves the degree to which implementation of an option (say, by widening a pedestrian path) would necessitate the removal of surrounding trees and shrubs.
2. Salt, sand—The degree to which salt or sand will be needed to properly maintain the road and walkways and the resulting average walking rates from such maintenance.
3. Staging areas—The number of and total area of staging areas used in each option. The less area used and maintained, the less the environmental impact. Different staging area options also differ in impact.

Walking

The conditions of the walk pedestrians must undertake between spectator facilities and the bus staging areas constitute the second issue. Harsh winter weather conditions of mid-February could severely jeopardize the proper functioning of the pedestrian system. The average February temperature is -8 °C, and temperatures of -26 °C occur nearly every February. It is speculated, however, that the colder temperatures will have little significant effect on average walking speeds. Average February snowfall is 0.5 m; the seasonal average is 2.8 m (1). It is also assumed that proper maintenance of the pedestrian system will keep it free of snow and ice obstacles, which would decrease system capacity and pedestrian speed. The impacts included in the walking category are explained below.

1. Distance—The distance each pedestrian must walk between the Intervale and spectator facilities and the bus staging areas.
2. Capacity—The walking area available for each system. The options using NY-73 as pedestrian access have greater capacity.
3. Slope—The relative degree to which a pedestrian will encounter slope difficulties on a walk between Intervale and the bus staging areas.
4. Pedestrian walking speed—The average pedestrian walking speed is dependent on the area available to each pedestrian, termed the module. A high speed is desirable.
5. Pedestrian delays—The delay caused to pedestrians by stops at signals located at crosswalks.
6. Pedestrian safety—The relative degree of safety to pedestrians on the different systems, taking account of use of NY-73 by both pedestrians (along or crossing) and vehicular traffic.
7. Bus Loading—The degree to which bus loading facilities and ease of pedestrian loading can be sited and arranged.

Traffic Flow on NY-73

The use of NY-73 for access to Intervale by pedestrians or the crossing of NY-73 by pedestrians will cause significant delays to bus traffic along NY-73 as well as impede official and emergency vehicle access to the ski jump site. For these reasons, options that use the road as a walkway may not be feasible.

1. Vehicle delay—The delay caused to vehicular traffic on NY-73 by signals located at pedestrian crosswalks or by pedestrian use of the road itself.
2. Emergency access—The degree of ease and speed at which emergency vehicles can enter the Intervale area, given pedestrian and vehicular queuing at or near the site.

Cost

The relative construction and maintenance costs of pedestrian access systems must be considered.

Post-Olympic Use

The impact of permanence is considered as well as the use of a system in the post-Olympic period by 5000 spectators.

1. Permanence—The degree to which components of each option will remain after the games and continue to produce impacts, environmental and otherwise.
2. Use of existing facilities—The degree to which existing facilities at or near the Intervale site are used (NY-73, existing Intervale entrance).
3. Post-Olympic usage—The degree to which a facility will be used for expected post-Olympic flow volumes (5000 spectators) and to what degree any changes will be necessary.

Maintenance

Since it is assumed that the pedestrian system will be properly maintained in order to ensure planned capacity and flow rates and the highest degree of safety possible, a comparison of how much maintenance each option would require is made. Degree of need is the amount of maintenance necessary to prevent pedestrian obstacles from snow and ice, which would reduce capacity and average walking rates.

OPTIONS

Four options exist as to where the buses will unload the 15 000 spectators who will attend the ski jump events. Each option is comprised of several components, some of which are unique to a specific system, others overlap in two or more of the options (Table 1 and Figure 3).

Over the Road and Through the Woods

Option 1 entails a bus staging area located at the Horse Show Grounds (HSG) north and upgrade of the Intervale site. The three components of this system are the staging area, the pedestrian bridge over NY-73 with stairway access 5.5-m wide, and the path through the woods.

The HSG is located on the opposite side of NY-73 from Intervale; approximately 360 m separates their entrances along NY-73. In this option, a pedestrian bridge over NY-73 would provide access to HSG. Assuming that the pedestrians enter the system at a flow rate of 10 000/h or 167/min, and the system will operate at a level of service D, as defined by Fruin (5), the stairway that connects ground level to the above-grade crossing will need to be about 5.5-m wide. The shortage of space would render a stairway access more feasible than ramp access, but ramps would permit easy light-truck maintenance.

Across the Road and Through the Woods

Option 2 also makes use of the HSG as a bus staging area and a path through the woods to provide access to Intervale. However, pedestrians would cross the road on a crosswalk, rather than on a bridge. A signal system and perhaps a warming shelter and traffic control people would be necessary to allow pedestrians to cross the road, and a pedestrian queuing area will be necessary on each end of the crosswalk. The queuing area will have to provide each pedestrian with 2.1 m^2 of area, given a level of service D. Since 2.78 pedestrians/s will be entering the queuing area, a queuing area of 5.8 m^2/s of pedestrian delay will be needed.

Down the Road

Option 3 makes use of NY-73 for pedestrian flow between the Intervale site and the bus staging area, again located at HSG. The width of NY-73 at this point (two lanes plus two shoulders) is 8.5 m (6). Therefore, one lane plus one shoulder (4.25 m) could easily handle a flow of 10 000 pedestrians/h.

This option may be broken into two options for eastside and westside use of NY-73. A double signal system will also be necessary to allow pedestrians to cross one of the lanes to keep the lane used by the pedestrians clear of traffic during the critical period. Even with such precautions, impacts on traffic flow would be high, as would be impacts on pedestrian safety. Because of the long length of the walkway and stragglers, NY-73 would have to be closed to traffic for significant periods.

Table 1. Components of options.

Option	Pedestrian Bridge Over NY-73	HSG Staging Area	Lower Staging Area	Path Through Woods	Pedestrian Crosswalk	Pedestrian-Traffic Conflict For Use on NY-73
1. Over the road	x	x		x		
2. Across the road		x		x	x	
3a. Down the road (east-side)		x			x[a]	x[b]
3b. Down the road (west-side)		x			x[a]	x[b]
4a. Across the bridge (east-side)			x		x[a]	x[b]
4b. Across the bridge (west-side)			x		x[a]	x[b]

[a]Two crosswalks required. [b]Conflict along NY-73.

Table 2. Comparative analysis.

Impacts	Option 1	2	3 a	3 b	4 a	4 b
Environmental						
Tree, shrubs	4	4	10	10	10	10
Salt, sand	5	5	2	2	2	2
Staging area	8	8	8	8	1	1
Average	5.7	5.7	6.7	6.7	4.3	4.3
Walking						
Distance	4	4	4	4	7	7
Capacity	7	7	10	10	10	10
Slope	5	6	7	7	8	8
Pedestrian walking speed	5	6	7	7	7	7
Pedestrian delay	10	5	6	6	6	6
Pedestrian safety	10	8	1	1	1	1
Average	6.8	6.0	5.8	5.8	6.5	6.5
Traffic on NY-73						
Vehicle delay	10	8	1	1	2	2
Emergency access	10	9	2	2	2	2
Average	10.0	8.5	1.5	1.5	2.0	2.0
Cost						
Construction	2	5	8	8	8	8
Maintenance						
Degree of need	3	4	2	2	2	2
Post-implementation						
Permanence	5	6	9	9	9	9
Use of existing facilities	3	4	8	8	8	8
Post-Olympic use	4	5	5	5	5	5
Average	3.0	4.0	7.1	7.1	7.1	7.1

Note: 0 = very high (negative) impact and 10 = very low (positive) impact.

Table 3. Comparative scores.

Option	Score	Positive Impacts	Negative Impacts
1. Pedestrian bridge	95	Vehicle delay and pedestrian safety	Cost and post-Olympic use
2. Crosswalk	94	Vehicle delay and pedestrian safety	Maintenance and post-Olympic use
3. Down the road	90	Cost and post-Olympic use, environmental	Vehicle delay
4. Lower staging area	88	Cost, walking, post-Olympic use	Vehicle delay

Across the River

The river referred to here is the Ausable River, just below the Intervale entrance. Option 4 also makes use of NY-73 as pedestrian access to the Intervale entrance, but from the south direction. This option is also broken down into two options for eastside and westside use of NY-73. The staging area is located approximately 180 m south of the Intervale entrance, on the opposite side of NY-73. The two options also necessitate a double signal system to allow pedestrians to cross one of the lanes and to keep the lane used by pedestrians clear of traffic during the critical period. As above, traffic impacts are high. The proposed staging area is steeper, smaller, and generally less accessible than the HSG area.

ANALYSIS AND CONCLUSION

The analysis of the different options must begin with a statement of assumptions to be made about the options and the situations each option is designed to handle. The assumptions made are as follows:

1. Pedestrians will enter the system from buses at a rate of 10 000/h or 167/min.
2. There will be little or no reverse traffic flow during high-volume periods. Pedestrian flow entering Intervale at the beginning of an event and leaving Intervale at the end of an event will be one directional. During the event, however, two-directional flow will occur.
3. There will be no pedestrian cross-conflicts or interference between pedestrians and vehicular flow, except when pedestrians cross or walk on NY-73.
4. A minimum number of handicapped persons will be in the flow.
5. Pedestrians in the flow will carry only lightweight, hand-carried items of small bulk.
6. An exercise of control in the form of signs and barriers will ensure orderly flow.
7. There is an assumed dead width of 0.3 m on each side of a pedestrian walkway and of 0.15 m on stairways to account for railings and containment barriers. Therefore, the net effective width will be assumed to be equal to the gross width minus 0.6 m on the pedestrian walkway and gross width minus 0.3 m on stairways.
8. Flow will be steady and even, with no minipeaks (except where caused by signaling).
9. Isolated signaling is assumed, except for the interconnected signals for use of NY-73 as a pathway.
10. The signaling at pedestrian crosswalks would be activated only for the 1.5-h critical periods, and then would follow a preplanned pattern. However, it should be able to be activated for individual crossing during a noncritical period.
11. There will be proper maintenance of the system so walking speeds and system capacity will not be decreased.

Abridgment

Creation of Pedestrian Streets in City Centers

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On August 2, 1970, four downtown streets in Tokyo, including Ginza Street, were opened to pedestrians. By the end of 1975 the number of these original pedestrian streets had increased to 37 327 for a total length of 8535 km, and the trend is continuing. Most of these streets now ban vehicle traffic only for a certain period of the day.

The tendency to consider pedestrians in traffic planning is not unrelated to the motorization of Japan, which began in the late 1950s. As the rate of increase of motor vehicles was too high in comparison to that of the traffic safety facilities, the traffic accident rate increased almost proportionally to the number of motor vehicles. However, since pedestrian streets were instituted, in 1970, the number of deaths and injuries caused by traffic accidents has decreased steadily. Figure 1 shows the change in the number of motor vehicles and accidents, together with the total length of pedestrian streets. These indexes show that road safety and pedestrian convenience have improved simultaneously. This tendency should be encouraged in the future. For this purpose general traffic planning must consider the role of the streets within the city community.

CURRENT "PEDESTRIANIZATION" IN JAPAN

Japan has utilized the following three methods to turn streets into pedestrian streets:

1. Traffic ban—For certain periods of the day, traffic is banned on certain shopping streets, streets near schools, or other streets that have heavy pedestrian traffic.
2. Underground shopping centers—A vast number of pedestrians flow through these centers, which are located near large railway stations.
3. Arcaded shopping streets—Except for use by service vehicles in nonpeak hours, these roofed shopping streets are continuously free from traffic.

FUTURE PEDESTRIANIZATION OF THE NAGANO CITY CENTER

Pedestrianization of individual streets is now widespread throughout Japan (1). But a street should not be turned into a pedestrian street without considering the effects on other streets in that area; in other words, the pedestrianization should be planned within a framework of general traffic planning.

In Nagano City, a street that functions as both the main highway and the main shopping street is going to be pedestrianized as part of the general traffic plan of the city center (see Figure 2).

Nagano has 307 000 inhabitants and an area of 404 km^2. In its densely inhabited districts the population density is 683 inhabitants/km^2 (13 600 inhabitants/19.9 km^2). It is the capital city of the prefecture of Nagano and is famous for a large Buddhist temple that attracts 7 million religious people each year. Central Street, a 2-km long street, extends from the entrance gate of the temple to the railway station at the south end. The street is bordered by retail shops and department stores. The other streets at the city center are relatively narrow. The proportion of street area to the whole central area is only 13.5 percent. This causes difficulty for traffic flow in the city center. To relieve this problem, a 2.3-km-long section of highway has been under construction since 1974 on the site of a former local railway line. Completion is due by 1980. At the same time, a subway is being constructed beneath the road (A in Figure 2).

When this highway is completed, the traffic on Central Street should decrease and this should make it easier for Central Street to expand its pedestrianization from the present situation of once a month in nonwinter seasons.

The planning offices of Nagano City and the Police Headquarters have begun to make general traffic plans for the city center, in cooperation with the Chamber of Commerce and Industry of Nagano. I have made a presentation to these authorities about utilizing the traffic cell principle.

PRINCIPLE OF THE TRAFFIC CELL

Many cities in the Federal Republic of Germany have used the concept of traffic cells in the planning of central areas. An example of the scheme of traffic cells is shown in Figure 3. A city center whose area is at most 1 km^2 should be surrounded by a ring road in order to receive the in-city-oriented traffic. At the same time the city center is divided into four sectors by cross-shaped pedestrian streets, each sector of which is called a traffic cell. As a result, through traffic is eliminated from the city center and only those vehicles that have their destination in that cell enter the cell. Parking areas must be provided for these vehicles in each cell. Streets in a cell are usually old narrow medieval streets, so that these should be operated as one-way streets or dead-end streets, which terminate at multistory parking garages (2).

The pedestrian streets, which were originally main shopping streets, divide traffic cells and give safe and convenient areas for pedestrians. The pedestrianization makes the shopping street more attractive, and the number of pedestrians increases substantially.

ESTABLISHMENT OF TRAFFIC CELLS IN NAGANO CITY CENTER

The existence of a ring road that surrounds the central area is essential for the establishment of traffic cells in the city center. To form the ring road, a wide lateral street that crosses the northern end of Central Street should be constructed (B in Figure 2). The construction of this street has already been planned and will be completed by 1985. Thus, an inner ring road system will be formed. The traffic cells could be established in the northern and southern districts, both of which are surrounded by this inner ring road system and the lateral road (C in Figure 2). Thus two ring road systems can be formed.

A comparative analysis was made between the options by a consideration of the relative degree of the impacts of each option. The analysts scored each impact from 0 to 10 based on the relative degree of impact between that option and the others. High scores indicate a positive result or minimal impact on a given dimension. The scoring is given in Table 2. The options produced main impact scores given in Table 3.

As may be seen, although their total scores are quite close, the options vary widely in their impacts. Selection and recommendation thus depend on the relative importance placed on each impact and the degree to which system operation can be assured with maximum probability of success.

On this basis, the pedestrian bridge (Option 1) and the crosswalks (Option 2) would appear to be superior. Both of these options avoid the higher environmental costs of a lower staging area and ensure minimum pedestrian-vehicle conflict. Option 1 is more expensive, but the cost may be justified because pedestrian conflict is eliminated and maximum roadway capacity ensured. A possible permanent bridge (to tie together the HSG and ski-jump sites into a future winter complex area) also favor this option. Given the crucial need for roadway capacity to handle bus flow, those options that make use of NY-73 as a pedestrian path are less attractive and entail higher probability of failure in severe weather. Therefore, the recommended approach is

1. If cost is reasonable, the pedestrian bridge option should be pursued. Otherwise, a signalized crosswalk should be considered.
2. Bus staging and spectator circulation should be limited to the HSG area, leaving the second upper staging area for use by officials, dignitaries, and emergency vehicles.
3. Although the use of a pedestrian path through the woods would appear to have some environmental impact, traffic and pedestrian walking considerations generally outweigh these costs. The smooth operation of the transportation system during the games is too crucial to its success to consider joint use of NY-73 as a pedestrian path.

Several factors should be kept in mind when examining these results. First, the grouping of impacts meant that each issue had an unequal number of impacts grouped under it. This tends to bias the final decision toward the environmental and pedestrian factors. Second, certain salient impacts may not be properly scored within a 1 to 10 range or, more accurately, cannot be equated to other impacts on a numerical basis. For example, the vehicle delay impact is extremely high in the third and fourth options (low score), yet this does not truly begin to reflect the magnitude of vehicle delay caused by this option. In fact, traffic analysis may show the delay impact to be so critical as to become the key determinant and all other impacts must simply be accepted but minimized. Further, most of the analysis is not truly quantified. For example, cost and degree of maintenance necessary are issues that could be more easily and accurately scored if quantified, but the impacts that need quantification most are vehicle delay and pedestrian delay. The scores given in this analysis are based on intuitive relative scoring of the options as to those impacts. Quantification of these impacts would allow for a more accurate analysis.

Finally, the impacts and issues presented in this paper do not represent a total view of the problem: Many factors such as lighting, liability, environmental constraints, land availability, and a potential tie-in with a present path to Lake Placid Village must still be integrated into any final decision. This report is intended to provide a basis for these future concerns, in the form of approaches to follow as more information becomes available. Transportation needs for the Olympics are being developed and solutions recommended by a group of transportation professionals who are assisting the Lake Placid Olympic Organizing Committee. This group is the coordinator for the Olympics and is responsible for all phases of a successful Olympic operation. To operate the Olympics efficiently, they must make decisions for the best overall impact, and this problem is no exception. This paper will be input into such decision, but so will many other concerns, such as budgetary considerations and environmental restraints, outside the realm of purely transportation considerations.

ACKNOWLEDGMENTS

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**Mr. Wolf conducted this research as a student intern at the New York State Department of Transportation, from the Geography Department of the State University of New York at Albany.*

Figure 1. Motorization, traffic accidents, and pedestrian streets.

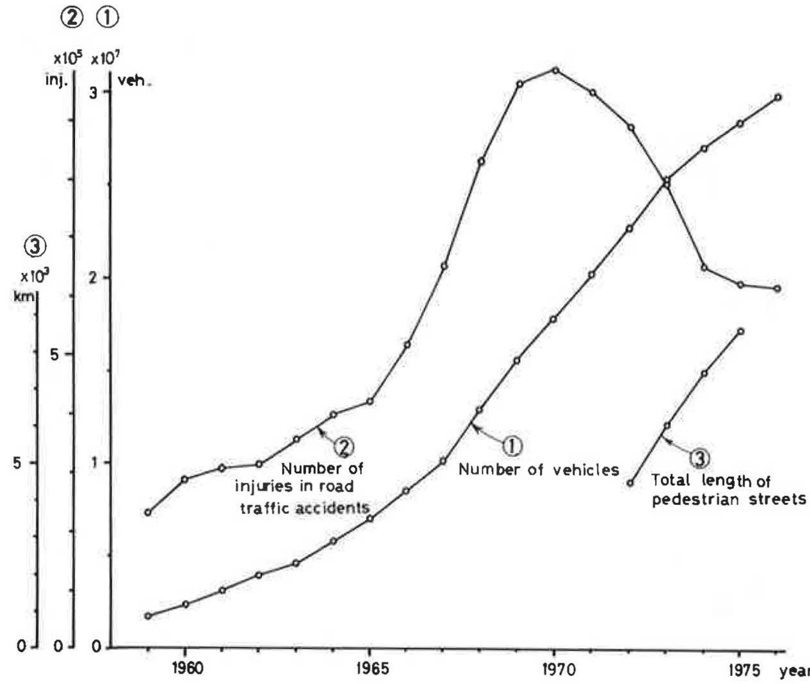


Figure 2. Road network in the Nagano city center.

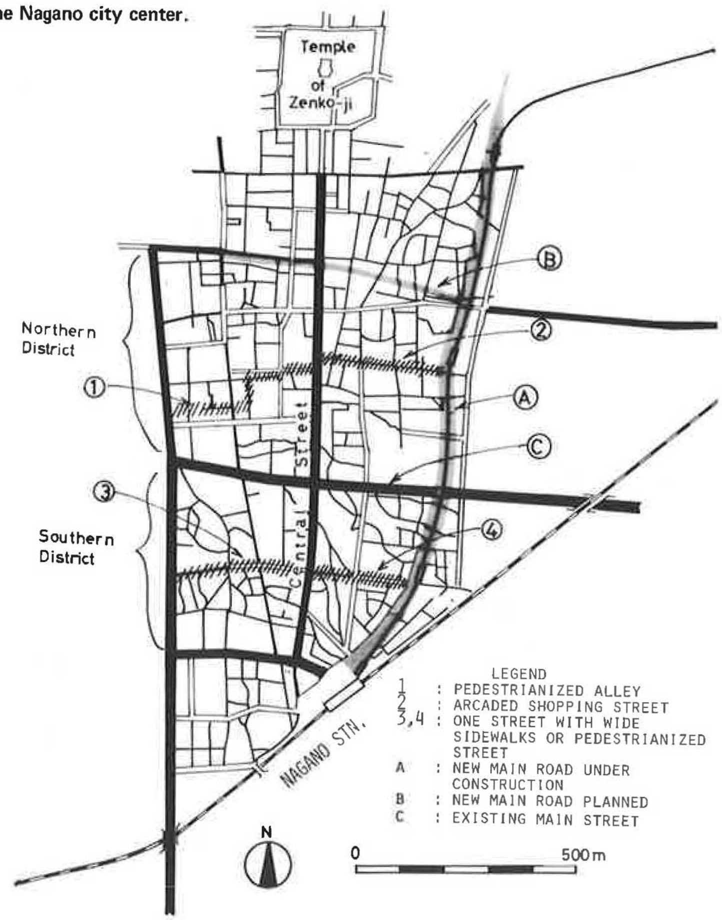
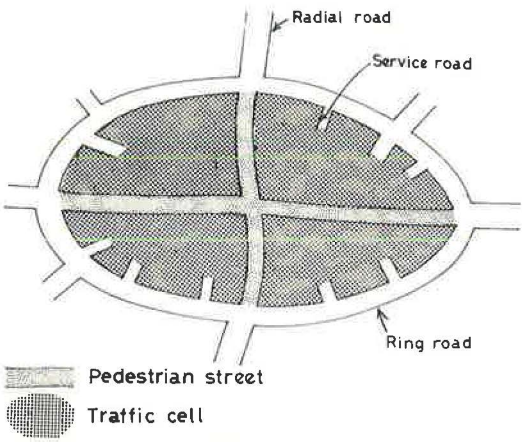


Figure 3. Scheme of traffic cell.



Together with the pedestrianization of Central Street, four lateral streets would be designated as the borders of traffic cells (1, 2, 3, and 4 in Figure 2). The street shown as 2 is now an arcaded shopping street; street 1 can be developed as a pedestrian alley; streets 3 and 4 can be developed as either one-way streets that have wide sidewalks or pedestrian shopping streets.

Within such a fundamental street network, it is now necessary to consider where to place multistory parking garages, how to change the bus routes that are now concentrated on Central Street, and how to redesign Central Street after its pedestrianization. In addition to traffic facilities, other plans such as redevelopment around the railway station and preservation of the historical area of the temple are related to the traffic cell system. The plan will be approved in a few years and, it is hoped, it will be realized by 1985.

ACKNOWLEDGMENT

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Abridgment

Treatments of Overpasses and Undercrossings for the Disabled: Early Report on the State of the Art

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This paper is based on an ongoing Federal Highway Administration (FHWA) study which began in March 1977. The main purpose of this 24-month study is to evaluate current facility treatments and recommend improvements. The primary objective of this paper is to report on the progress of one aspect of the study—evaluation of the state of the art of treatments for use by the disabled.

The general study approach for evaluating crossing treatments for the disabled used a team leader and panel of disabled persons. These persons contributed to discussions of on-site evaluations of facility treatments. This approach is a departure from recent practice. Much of the literature and standards reviewed were based on judgments of the nondisabled or perceptions of persons who have only one type of disability. Guidelines for treatments have generally not been based on empirical evaluation of behavior at facilities.

THE DISABLED POPULATION

At any one time, approximately 4.3 percent of the population has mobility limitations that affect pedestrian behavior. This estimate, derived from the 1972 National Health Survey, is based on respondents' self-appraisals of their mobility limitations (1, 2). The range of functional mobility limitations varies widely. However, mobility aids, such as handrails, can help several different disabled groups, such as semiambulatory or wheelchair-bound individuals and the visually impaired.

Recent studies and interviews of the disabled indicate that the walking mode may be more important to the mobility handicapped than to the nondisabled adult population. Walking and wheeling provide the disabled with exercise that is often crucial to good health (3). In addition, for a high percentage of disabled, the walking mode may be the only means of independent travel (4). One empirical study found that 63 percent of a sample of disabled respondents practically never drove an automobile.

The importance of the walking mode for the disabled was further substantiated by the FHWA study panel. All panel participants reported regular travel by walking or wheeling. Blind persons and those confined to wheelchairs indicated particular dependence on walking. The character of pedestrian travel by the disabled appears to vary by environmental setting, type of disability, and social role (e.g., employed, retired, student). The walking range of this study's disabled panel varied from a few blocks for a person using a walker to a small-sized city for a person in an electric wheelchair. Robert's study of visually and hearing impaired persons (5) showed that most persons with these impairments walked 10 to 14 blocks.

Evaluation Process

The first step of the evaluation process was a discussion among disabled panel members about their experiences (a) on crossings and (b) with the use of features associated with crossing situations, such as pedestrian ramps and handrails. This was followed by visits of the disabled panel to crossing facilities that exhibited current treatments. Observation sites were selected so that the panel could experience a variety of common situations. Panel members were asked to traverse the facilities and discuss their findings with project staff. Photographs were taken to illustrate major findings.

Results of panel visits to three sites will be summarized here. The sites selected for discussion are all overpasses in the San Francisco Bay Area that span major freeways. General characteristics of these sites (Millbrae Avenue in Millbrae, Mt. Diablo Avenue in San Mateo, and Awanhee Avenue in Sunnyvale) are shown in Table 1.

Millbrae Avenue

This pedestrian-motor vehicle overpass was regarded by disabled panelists as a hostile environment for pedestrians, particularly for the handicapped. State officials declared that this overpass met early 1977 standards for accessibility. However, it was clear from the evaluation that the only treatments made for nonmotorized travel were curb cuts on approach and structure sections.

Major deficiencies noted by the disabled panel were

1. No curb cuts at the west-end signalized intersection immediately adjacent to the structure. This was a problem for the wheelchair-bound evaluators.
2. No crosswalks or pedestrian warning signs to motorists and obstructed sight lines at the areas where high speed on- and off-ramps crossed the pedestrian pathway. This was a problem for all disabled groups, particularly since they moved more slowly than the nondisabled observers.
3. No railings to protect pedestrians from long dropoffs on the approaches. This was of most concern to wheelchair-bound and blind persons.
4. Greater than acceptable cross slopes on structure sidewalks. Manual wheelchairs required extra effort to maintain a straight course on pavement that has excess cross slope.
5. No level areas on either side of the freeway motor vehicle on- and off-ramps. Wheelchair-bound persons had to be assisted after crossing the on- and off-ramps to prevent chairs from rolling back onto the street.

The panel concluded that, although an attempt was made to accommodate wheelchairs, the facility presented hazards for this group more than for any other.

Mt. Diablo Avenue

This pedestrian overpass is about half the length of the Millbrae Avenue structure and connects two residential neighborhoods. The structure is not new and is accessible by two solid-core concrete spiral ramps, which rise to a height of about 4.6 m (15 ft). This facility was selected for evaluation because spiral ramps were thought of as one possible treatment to give the disabled access to areas where available land is limited. Although no curb cuts had been added to sidewalks leading to the structure, driveways allowed wheelchair-bound panelists to approach the facilities.

In general, the panel concluded from the on-site evaluation that spiral approaches are acceptable if designed with particular finesse. Major deficiencies of the facility as perceived by the panel include the following:

1. Level resting areas are needed on spirals for persons in manual wheelchairs and the semiambulatory, particularly persons using aids.
2. The bar stock 76-mm wide, 15.9-mm thick (3-in wide, 5/8-in thick) railing on the outside edge of the spiral was particularly difficult to grasp for the wheelchair users trying to slow their movement and for semiambulatory persons using aids, who tried to use the railings for stabilization while resting.
3. A major deficiency that affected all mobility groups was the inability to see or be seen by persons traveling in opposite directions on the spiral because of the spiral's solid concrete core. This was a particularly important deficiency as heavy cyclist and pedestrian traffic share use of the facility at certain hours of the day. One solution to this problem, which has been used

Table 1. Locations of on-site evaluations.

Characteristics	Millbrae Avenue	Mt. Diablo Avenue	Awanhee Avenue
Accessibility			
Pedestrian	x	x	x
Bicycle	x	x	x
Motor vehicle	x	-	-
Surrounding land uses			
Multi-unit residential	x	x	-
Single-unit residential	-	x	x
Commercial	x	-	-
Industrial	-	-	-
Open space	x	-	-
Adjacent major activity centers	-	-	-
Date of facility construction	1964	1953	1977
Date of retrofit	1976	N/A	N/A
End conditions	Four-lane signalized streets, sidewalks on one side	Two-lane residential streets	Two-lane residential streets
Approach conditions	Sidewalks on one side with abrupt dropoffs over 3 m; pathway crosses high-speed freeway ramps	Spiral ramps	Switchback ramps
Structural conditions	Sidewalks on one side with abrupt dropoffs over 3 m; low railings, no fence	Fenced pathway	Fenced pathway
Reasons for treatment for disabled	Followed accessibility standards when widening facility; local request for widening	N/A	Local request for construction of facility; followed draft state standards

Note: 1 m = 3.3 ft.

at other locations, is a see-through spiral. The core of the spiral is a set of pillars rather than a concrete cylinder.

4. Wheelchairs drifted to the outside of the spiral ramp. This problem could be alleviated by banking the ramp toward the inside and increasing the diameter of the spiral.

Awanhee Avenue

This pedestrian overpass, located in a single-family-unit residential area, has been billed by state officials as a showcase of the implementation of new draft state standards. (The draft standards were adopted in August 1977.) The facility was completed in early 1977. The structure is fenced and approached by switchback ramps.

In general, the survey team was impressed favorably by this facility. Team members concluded that the facility came close to meeting the needs of disabled groups Relatively level rest areas were provided to the side of the travelway on the switchback approaches, and easy-to-grasp handrails were provided on both sides of the length of the facility. However, the diameter of handrails was slightly larger than state specifications. Also, the slope of the approaches was measured as 1:11 instead of the minimum standard of 1:12 and expansion joints on the structure were much wider than those normally encountered in sidewalks. Crossing the expansion joints caused major jolts for wheelchair users.

The overpasses present one major problem, particularly for wheelchair and walker users and the blind. Maze-like barriers had been installed at the bottom of each ramp sometime after the structure was built. The purpose of these barriers is to discourage speeding bicyclists and skateboarders. Clearances through the barriers made wheelchair meneuvering extremely difficult. More importantly, the barriers were on 1:11 slopes, which made it difficult for people in wheelchairs to avoid crashing into the barriers when coming downhill or making tight turns necessary to maneuver through the barriers. In addition, barriers cause confusion for blind persons. Maze-like barriers at the ends of approach ramps are not expected and it is difficult for blind persons to maneuver through them without repeatedly bumping into the sides of a maze.

A major positive feature for the blind was plastic screening attached to sections of fence at structure-ramp transition areas. The screening was attached to protect the privacy of residences immediately adjacent to the structure. For the blind, the screening reduced noise levels from the freeway below and made it easier to detect direction and potential conflicts.

CONCLUSIONS

Findings from background research and the three example on-site evaluations that have been discussed suggest some general conclusions:

1. The disabled are a heterogeneous group who have varied mobility limitations and needs;
2. A combination of treatments is needed to make a facility truly accessible;
3. Motor vehicle-pedestrian overpasses where there are high-speed ramps are generally hostile environments for the disabled. Additions of curb cuts may not be enough to create an environment perceived to be barrier-free; and
4. Spiral ramps may have continued usefulness in areas where limited land is available. However, careful design is necessary to ensure accessibility.

The method of using disabled panelists to conduct on-site evaluations may be a useful technique, which local and state officials can use to plan retrofit treatments or new construction. This technique should be used to complement facility warrants and design manuals. In areas where retrofits are planned, local groups of disabled members could visit the sites and provide advice on how best to make corrections. When new construction is planned, disabled advisors could visit similarly built structures and provide on-site critiques to designers. Disabled panels would be particularly useful for areas that have general warranting procedures or standards.

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Model Pedestrian Safety Program: An Overview

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The model pedestrian safety program was the final project in a series of pedestrian studies sponsored by the Federal Highway Administration. The objectives of this project were (a) to consolidate the results of the earlier studies with pedestrian safety data from numerous other sources into a usable format and from that (b) to develop guidelines for communities interested in initiating or augmenting a pedestrian safety program. This paper gives an overview of the entire project. The literature review resulted in classification of 450 documents into a 71-item subject matrix for easy reference by anyone interested in pedestrian safety. During the review of operational experience, contacts were made with 19 American communities to gather data on the day-to-day operations of ongoing pedestrian safety efforts. Finally, a six-point users' manual was developed. These guidelines detail (a) identification of the extent of the pedestrian safety problem, (b) identification of alternative countermeasure solutions, (c) selection of the best alternative, (d) implementation of the alternative chosen, (e) evaluation of its effectiveness once initiated, and (f) maintenance of the safety program.

The objectives of the model pedestrian safety program were to consolidate pedestrian safety data from numerous sources and to develop programmatic safety guidelines based on these data. Collection of these data consisted of a massive literature review and a survey of 19 American communities that had successful, ongoing pedestrian safety programs. The Users' Manual (1) developed from the data offers guidance in program planning and presents design strategies based on empirical research results and operational experience.

REVIEW OF THE LITERATURE AND OPERATIONAL EXPERIENCE

Numerous innovative ideas about pedestrian safety have been developed during the past several years. Many of these have been evaluated and discussed in various documents and research studies. Unfortunately, a large number of these documents are distributed on a limited basis and their contents are never considered for incorporation into pedestrian safety programs. Other innovative ideas have been developed by local safety officials and incorporated into their community safety programs. Unfortunately, the results of these efforts are frequently never communicated beyond the cognizant jurisdiction.

The initial efforts of the model pedestrian safety program were twofold:

1. To identify all documents relevant to the development of a model pedestrian safety program and to assemble these documents into a useful format for reference by anyone interested in pedestrian-related literature, and
2. To survey several American communities that have successful, ongoing safety programs to obtain data on the real world of pedestrian safety efforts.

Literature Review

The screening and review of literature on pedestrians resulted in a bibliography of 450 documents. The information in each was reviewed and classified into a 71-item literature review subject matrix. A sample portion of the matrix is shown in Figure 1.

The data from the documents were grouped into five major topic areas:

1. Facilities—engineering and physical countermeasures designed to aid pedestrians in crossing the street or to prevent them from entering the street at particular locations; subcategories identify different types of facilities and behavioral-attitudinal responses to, problems associated with, design of, and warrants for installation of these facilities.
2. Accidents—system failures that involve a pedestrian; subcategories identify population groups, locational and environmental factors, and accident types (preaccident behaviors).
3. Behavior—the ways pedestrians act, patterns of actions, tendencies to respond in particular manners, and reasons for reacting; subcategories identify subpopulations (age groups, the handicapped, drivers), locational and environmental factors, and behavior types.
4. Safety programs—potential and existing efforts toward pedestrian safety, types of safety programs, and responses to these efforts.
5. Type of document—the general class of document (research report, bibliography, or discussion).

Dots along a row in the matrix indicate topics discussed in that document. Conversely, documents about a particular subject can be identified by reading down the relevant column and cross-checking documents in that row. Matrix subject, subfactor definitions, and the complete matrix and bibliography appear in Volume 1 of the project interim report (2).

Review of Operational Experience

The final objective was to develop methodological guidelines that localities of all sizes can use to initiate or augment pedestrian-oriented safety efforts. The findings and ideas from the literature must be considered within the context of the operational experience of already-established safety programs. Localities that have successful pedestrian safety efforts had much to offer to the development of the users' manual. Therefore, a survey was made of the operational experience of 19 regionally and socioeconomically varied American cities with successful ongoing pedestrian safety programs.

The American Automobile Association (AAA) 1976 pedestrian safety inventory program collected data on local and state safety programs. It was used as a data base to identify cities making efforts to maintain pedestrian safety. During December of each year, survey forms are distributed to participating localities by the local automobile clubs. Small towns, large cities, counties, and states participate voluntarily by filling out a two-page survey. Safety program performance ratings are made based on an evaluation of activities in eight basic areas:

1. Pedestrian deaths and injuries,
2. Accident records,
3. Legislation,

Figure 1. Sample page of literature review subject matrix.

	Facilities																Accidents		
	Safety Islands	Signing	Signalization	Crosswalks, Pavement Mkgs.	Barriers	Sidewalks	Crossing Guards	Grade Separation	Ped. Environment Urban	Ped. Environment Residential	Other	Impact	Attitudes Toward	Problems	Design	Warrants	Children	Adults	Elderly, Handicapped
RTKL, 1976b								•	•	•		•		•	•				
Rubenstein, 1972						•		•			•				•				
Rudofsky, 1969						•		•	•		•	•	•	•	•				
Rumar, 1966											•			•					
Russam, 1975				•							•	•			•		•		
Safety Through...,n.d.																	•		•
Salvatore, 1973																			
San Diego, 1971		•	•	•			•	•							•	•			
San Jose (1), 1972			•	•			•									•	•	•	•
San Jose (2), 1972a				•			•				•				•				
San Jose (3), 1972b							•												

4. Enforcement,
5. Traffic engineering,
6. School traffic safety,
7. Public information and education, and
8. Safety program coordination.

From over 2400 cities in the AAA data base, 19 were selected and contacted for further information. These 19 cities covered a wide range of socioeconomic factors (determined from 1970 census records), spanned a large range of population categories (the smallest city has 14 000 inhabitants; the largest has 800 000), and were regionally representative of other cities in their population category.

Each of the cities selected was contacted to obtain more detailed data about its pedestrian safety program. Sixteen of the cities were visited for 1 d to observe the safety efforts in operation. Discussions with city personnel generally centered around the following subject areas:

1. Safety program coordination—the organization (governmental, citizen group, business, local) responsible for the total pedestrian safety effort;
2. Traffic engineering—physical and engineering facilities designed to create a safer environment for pedestrians;
3. School and child safety—specific programs aimed at young pedestrians;
4. Provisions for the elderly and handicapped—specific safety efforts aimed at older and disabled pedestrians;
5. Public information and education—media and teaching efforts on safety problems and regulations;
6. Enforcement of pedestrian-related laws;
7. Accident analysis—types of data collected and how they are used; and
8. Safety program recommendations—general underlying philosophy of pedestrian safety.

Detailed discussions on the AAA pedestrian safety inventory, the city selection process, and most important, the results of these contacts (both individual and in summary) are available in the interim report, Volume 2 (3).

USERS' MANUAL

The users' manual is based on the literature and the operational data obtained during the early stages of the project. The manual is designed to be both a guide and a resource for individuals and organizations interested in planning and in creating safer environments for pedestrians. It identifies steps to follow to set up a pedestrian safety program and provides information to help in choosing solutions. It lists numerous possible solutions to safety problems and provides lists of additional references. The manual is written for both those individuals with minimal safety program experience and those already involved in a program. The guide presents methods and techniques useful in developing a complete and effective pedestrian safety program and is a source of additional ideas, which can be incorporated into an ongoing program.

The model pedestrian safety program users' manual provides the what and how of creating an effective safety program. In combination with the motivation, involvement, and long-term interest of local individuals, the manual can help create safer pedestrian environments.

The guidelines are presented in a six-step process:

Step 1—Determine the extent of the pedestrian safety problem,
Step 2—Identify alternative solutions,
Step 3—Select the best alternative (benefit-cost analysis),
Step 4—Implement selected alternatives,
Step 5—Evaluate the effectiveness of the implemented alternatives, and
Step 6—Maintain the pedestrian safety program.

Step 1: Extent of the Pedestrian Safety Problem

The goal of every pedestrian safety program should be to reduce fatalities, injuries, and material losses from pedestrian accidents. The initial effort should be to determine the extent of the pedestrian safety problem by identifying hazardous locations and unsafe pedestrian behaviors. Step 1 describes three procedures useful for determining where pedestrian accidents and unsafe behaviors are occurring, the data important for choosing rational solutions, and how the relevant data can be collected.

Complaints from local citizens are discussed as on-scene sources identifying existing hazardous conditions and potential accident sites. It is impossible for transportation engineers, planners, and other government officials to locate every possible hazardous site. Individuals who live in a neighborhood, cross certain streets, or pass through the same intersection on a daily basis are much more familiar with the long-term problems of those locations. Data from these users can focus attention on a problem that might not have been noticed otherwise.

Pedestrian accidents are the result of a sequence of events that, if not interrupted, will produce a pedestrian-vehicle collision. Investigating accidents as sequences of events provides the opportunity to identify one or more points at which to break the collision chain. Understanding what contributes and leads to accidents and injuries must precede rational selection of countermeasures. The emphasis in step 1 is, therefore, on the use of accident reconstruction as a basis for determining behavioral causes of accidents.

This type of approach leads to the identification of

1. Major aspects of the pedestrian accident process,
2. Methods of grouping these different aspects into a behavioral accident typology in order to understand accidents with common causal patterns, and
3. Ways in which these patterns may be reversed and the identification of possible countermeasures.

This section of step 1 addresses the necessity of collecting behavioral, rather than just violation, accident data. Techniques for recording the appropriate data necessary for classifying accidents into a behavioral typology are described.

Each type of accident is distinguished by the presence or absence of critical descriptors; however, not all pedestrians exhibiting such actions are involved in accidents. The frequency of an accident-producing event sequence not leading to a collision is much higher than of it resulting in an accident. Therefore, collection of data on the frequencies of accident-producing behavior in noncollision situations should be done.

Techniques of activity sampling, the collection of nonaccident behavioral data, are also described in step 1. These are usually used as shorter term methods to determine the level of hazard of a site and to evaluate the effectiveness or noneffectiveness of an installed countermeasure.

Step 2: Alternative Solutions

Step 2 details numerous countermeasures known to be effective in solving pedestrian safety problems. The solutions are grouped into four major areas. Three of these reflect the three Es of pedestrian safety (engineering, education, and enforcement), and the fourth deals with the special problems of young pedestrians.

Engineering and physical facilities countermeasures can be designed to promote the safety of pedestrians while crossing the street or to prevent pedestrians and vehicles from coming into contact with each other. Individual subsections deal with barriers, bus stop relocation, crosswalks, grade separation, facilities for the handicapped, lighting, one-way streets and diagonal parking, retroreflective materials, safety islands, sidewalks, signalization, signs and markings, and urban pedestrian environments. Educational programs can be developed for instructing children, the general public, and the elderly about pedestrian safety and the hazards associated with interacting with vehicles. Sample instructional programs are discussed. Enforcement programs can be enacted to develop compliance with pedestrian-related laws. Child protection countermeasures can be undertaken specifically oriented toward the protection of young pedestrians. Included are subsections on preschool and child safety countermeasures, safe route to school program, school bus routing and patrols, crossing guards, play streets, other countermeasures for school children, and general considerations for child protection.

Within each of these four major sections, each countermeasure is treated as thoroughly as possible under the following headings: (a) definition, (b) associated behavioral and accident data, (c) varieties, (d) disadvantages, (e) target people, (f) target locations, (g) implementation considerations, and (h) pertinent references. In addition, tables relating each countermeasure to the type of accident it is designed to mitigate are provided.

Step 3: The Best Alternative

Step 3 describes a method for selection of the alternative having the highest anticipated benefits for the lowest anticipated costs and meeting the desired goals and necessary constraints. To combat some of the problems of other types of cost-effectiveness procedures, particularly those that attempt to apply monetary values to nonquantitative benefits and costs, the procedure outlined converts all benefit and cost variables to value ratings. The methodology of the value rating technique is described. All benefit and cost variables for each of the applicable alternatives are computed and converted to the neutral value rating score. The individual benefit and cost ratings are then summed and compared as a ratio:

$$\rho = \text{benefit/cost} \tag{1}$$

The alternative with the highest ratio that also meets the constraints (such as total funds available or severity of the problem to be solved) is selected for implementation.

In step 3, problems associated with the subjective nature of all cost-effectiveness techniques are discussed. Procedures for working within these constraints are described.

Step 4: Implementation

Once a countermeasure has been selected, the next step is to implement it. Step 4 has five requisite substeps in order for an alternative to be successfully realized in the environment.

The specific goals and objectives of pedestrian programs will vary from one jurisdiction to another. Common to all of them, however, should be

1. Reduction of the frequency of pedestrian accidents and
2. Reduction of the severity of pedestrian accidents.

It is vital that these goals be written in a policy statement from the highest level of government. Formulation of such a statement is a means of communicating the desired safety program to those who will implement it. Local priorities and safety objectives should be stated plainly in this document.

One of the major problem areas of pedestrian safety is the multitude of agencies sharing the responsibility for pedestrian affairs. This is true at all levels of government. Having many agencies involved can lead to duplication of effort or to inaction. Long-term, successful pedestrian safety programs occur only when one group or individual has the desire and authority to see that the efforts are made. Several organizational suggestions for pedestrian safety coordination at the local level are made.

The single most important criteria for successful implementation is probably the citizens' perceived value of the project. Without acceptance at the most local level—the implementation site—it is doubtful that any safety program countermeasure will be effective. A successful total safety program requires the support of all involved governmental agencies, media, schools, and businessmen, as well as the public at large. This necessity for total public support is discussed.

Many options are available for funding individual pedestrian projects. The options will vary depending on the project scope and target subjects. Possible funding sources are identified.

Time is a critical factor after a problem area has been identified. To prevent a problem from increasing in magnitude, the appropriate safety countermeasure should be implemented as soon as possible. Numerous pedestrian and other traffic projects can exist simultaneously. The limited funds available must be split between several problem areas. This section discusses a method for setting priorities on pedestrian safety projects among themselves and within the total transportation system.

"Hazard prioritization" is a technique for evaluating the degree of hazard associated with a particular problem area. Three elements are used to rate each location:

1. Severity—the degree of the problem if left unattended.
2. Probability—the likelihood of an accident if no solution is implemented.
3. Cost—the cost of the implemented solution.

Priorities based on the severity-probability-cost of a problem location can establish a sequence for addressing pedestrian and other safety problems. Figure 2 illustrates a sample design for a hazard analysis identification and prioritization card.

Figure 2. Example of hazard analysis card.

HAZARD ANALYSIS CARD

Date: ______

Hazard Description: ____________________

____

____

Severity	*Probability*	*Cost*	*Action*
• Nuisance	• Unlikely	• Prohibitive	• Defer
• Minimal	• Probable	• Extreme	• Analysis
• Critical	• Considerable	• Significant	• Immediate
• Catastrophic	• Imminent	• Nominal	
		Completion Date: ______	

Step 5: Effectiveness

It is imperative to know whether or not an alternative was successful in creating a safer situation for pedestrians. Step 5 discusses how to (a) develop an evaluation plan, (b) conduct the evaluation, and (c) analyze the data.

Two major types of evaluations are addressed in this step:

1. Programmatic evaluation of the operation and management of the pedestrian safety program and
2. Effectiveness evaluation of the behavioral changes induced by particular facility installations.

Programmatic evaluation deals with the determination of whether or not the overall pedestrian safety program is meeting its stated policy goals and objectives. This section discusses the management of programs designed around these goals in terms of program activities.

The most difficult to obtain, but most useful evaluation data, concern the effectiveness of an implemented countermeasure at an installation site. These data are the basis for the expansion, contraction, redirection, or modification of specific elements of the program. Three substeps are discussed as parts of this type of evaluation. These deal with

1. Developing the evaluation plan—establish countermeasure goals and objectives, select what measures will show its effects, and select appropriate statistical analyses to analyze the data;
2. Conducting the evaluation—discuss logistical and operational problems of data collection and give illustrations of sample data collection forms; and
3. Analyzing and interpreting the data—describe the statistical aspects of evaluation, the various types of data that can be collected, and the mathematical procedures for data analysis.

Step 6: Maintenance

A successful pedestrian safety program requires a continual watch on the safety environment. Step 6 is not so much a definite step as a feedback movement returning to step 1. The traffic situation can be viewed as a pressure cooker—without a lid, the pot would quickly boil over; a tight lid keeps the contents under control. If the contents of the pot are thought of as the interactions between pedestrians and vehicles, without constant watch of the situation (the lid) these interactions become too intense and boil over into accidents, injuries, and fatalities. A complete program reduces the frequency and severity of accidents. The complete model pedestrian safety program begins with a return to step 1 and a recycling through the total program again and again. Quick identification of problems and timely selection and implementation of solutions is a must for a long-term safe environment for pedestrians.

ACKNOWLEDGMENT

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Some Characteristics of Bicycle Travel and Accidents in Towns

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Findings of bicycle field surveys are presented, including 685 interviews with riders in six Israeli towns that have very different levels of bicycle use. Data are analyzed on bicycle accidents and on mode of travel to work and school in 29 towns. Estimates are made of the number of bicycles in use, the number of riders, and annual travel by age and sex of rider for major trip purposes. It is concluded that bicycle travel represents an overall addition of 12 percent to urban travel at present levels of use in Israel and, on this basis, accident risk per kilometer of bicycle travel is approximately the same or even lower than that for passenger automobiles. Furthermore, bicycles are not only an extremely important means of transport for the 10- to 19-year age group, but in towns where bicycle use is high (20 percent of total trips) all ages of males and females use the mode actively for shopping, recreation, and work. Trip lengths are rarely above 5 km and vary according to age, sex, and trip purpose. In general, trip length characteristics are similar to those found in Europe. For towns with flat topography and populations of 100 000 or less, multiple regression analysis indicated that six factors accounted for 59 percent of the variance in bicycle use in the 24 towns studied: population, radius, density, number of persons per household, percent welfare expenditure, and percent working out of town. It was further found that in very small and poor towns, walking was an alternative to bicycling. In other towns, industry-provided transportation appeared to be an alternative mode to bicycling.

Conventional transportation planning has been concerned with predicting travel demand, primarily for automobiles. Today planners are turning their attention from prediction of trends to intervention in the distribution of the modal split. This change has come about in developed, motorized countries because of the need to ease the problems of traffic congestion and the fear of further environmental degradation associated with ever increasing use of automobiles. In underdeveloped, less motorized countries, the promotion of modes of transport less costly than the automobile is considered essential.

There is clearly little possibility of expanding the recently rediscovered use of bicycles without a more thorough description of the basic travel characteristics of the mode—trip lengths, frequency, purpose, generators, attractors, and other basic elements. Furthermore, in the case of bicycles, unlike proposed innovative rail modes, the problem of safety in an expanded system looms as an unknown and serious problem.

The field work reported in this paper was carried out while attempting to answer elementary questions basic to establishing policy for national bicycle planning. Data from the survey support what the casual observer of the Israeli countryside knows well, namely, that in certain towns bicycles are an important part of the existing transport system. The findings are based on four stages of data gathering and analysis: a survey of bicycles in use, interviews with bicycle riders, analysis of accident data, and an analysis of national travel data.

Every Israeli municipality requires that bicycle owners purchase an annual permit at a minimal fee and display a metal registration plate. The number of licensed bicycles is very low because neither party to the transaction is especially concerned about its implementation. To estimate the number of bicycles in use, a survey was made of all towns over 5000 population (40 towns) to establish how many licenses had been issued. Observations were then made of the proportion of bicycles displaying licenses in 7 towns and the data were combined to estimate the actual number of bicycles in use.

METHOD

Interviews were conducted with 685 riders on main streets of six towns at locations on the periphery of the central business districts (CBDs). The six towns had very different levels of bicycle use.

Town	Population	Level of Use	Number Interviewed
Kiryat Haim	24 000	High	192
Nahariya	25 000	High	197
Hadera	32 000	Medium	102
Herzlia	45 000	Low	65
Givatayim	50 000	Low	50
Tel Aviv	400 000	Special	79
Total			685

Age and sex of the population interviewed were predetermined by all-day counts of bicycle riders in each town. The overall distribution of age and sex of riders was 52 percent children (11.5 percent girls, 40.5 percent boys) and 48 percent adults (10.5 percent women, 37.5 percent men). The children interviewed were 10 through 19 years old. The riders interviewed in Tel Aviv were young males and adult men who use their bicycles in the CBD, mostly in connection with their work. The interview form included questions on trip purpose, trip length, origin and destination, and frequency of bicycle use.

The accident data considered covers personal injury accidents where a bicycle was involved, as reported each year by the Israel Central Bureau of Statistics. Some of the basic data derived from the bicycle rider interviews, particularly the amount of bicycle kilometers traveled, were analyzed for rates of accident occurrence.

As part of the 1972 census of population and housing, interviews were conducted in 29 cities that had populations of 20 000 or more. Working persons and students over the age of 14 were asked the mode of travel used to go to work or school. Separate results have been made available for families with and without motor vehicles at their disposal. In light of the wide differences in bicycle use found among the towns, the census data and other relevant information were analyzed to obtain a better understanding of some of the factors that influence the extent of use of bicycles.

NUMBER OF BICYCLES AND RIDERS

Information on the number of bicycles registered in 1971, 1972, and 1973 in 40 towns with a population of at least 5000 was obtained by a mail survey of local authorities made under the auspices of the Ministry of Transport. The results of the survey were

1971—33 095 licensed bicycles
1972—30 786 licensed bicycles
1973—28 809 licensed bicycles

Data for 10 years, obtained from Kiryat Ata, Hadera, and Tel Aviv indicate a similar declining trend. The street counts made of the proportion of licensed bicycles in 7 towns averaged 16 percent. Based on this percentage, the number of licensed bicycles, the population of the 40 surveyed towns, and the population of very small towns and agricultural settlements, the following estimate was made of bicycles in use in 1973:

Size of Town	Number of Bicycles
Over 5000 population	222 000
Under 5000 population	54 000
Total	276 000

Thus, the estimated number of bicycles in use in 1973 was 85.5/1000 persons.

Number of Bicycle Riders

The number of bicycle riders was estimated from replies received to the interview questions, Do other persons share the use of this bicycle with you, and if so how many? Answers to the 685 interviews, when analyzed by age and sex of rider and town, showed an average of 1.85 riders/bicycle. There was some indication of increased sharing by women and girl riders and in towns that had high bicycle usage.

The resulting estimate of bicycle riders in 1973 is 500 000, including 400 000 in urban areas and 100 000 in small towns and agricultural settlements.

The composition of the bicycle riding population by age and sex was determined through all-day counts in five towns. The riders were not questioned but simply categorized by age group: to 9, 10 to 19, and 20+ (see Table 1).

A pattern of ridership emerged in which the association to overall bicycle usage in a town is clear: Where bicycles are used a great deal, they are used by all age persons of both sexes; where used less, children predominate. (Note: children under 10 years appeared in less than 3 percent in the street counts; they also account for under 5 percent of the injured riders in bicycle accidents).

Comparison of Bicycle Use

Very few countries have published estimates of the number of bicycles in use, and most estimates available are based on data from bicycle manufacturers and sales organizations. Table 2 shows that the estimate of bicycles/1000 persons in this study places Israel low on the international scale; however, estimates for individual Israeli cities, where bicycles are used seriously, compare well to other high-use places. In England the number of riders per bicycle is estimated to be 1.5 (1).

TRAVEL CHARACTERISTICS OF BICYCLE USERS

The primary source of information on travel characteristics reported in this section is the 685 bicycle-rider interviews. The interview data made it possible to summarize patterns of travel, such as trip frequency and length, for different groups of riders in terms of trip purpose. In addition, it was possible to extrapolate estimates of annual bicycle travel.

A secondary source of information on travel characteristics of bicycle riders was inferred from accident data. Table 3 gives the percent of bicycle trips to work by adults and the percent of all bicycle accidents to all accidents in 29 towns. These two sets of data have a rank order correlation of 0.77 (Spearman). [Other researchers, particularly Smith (2), have demonstrated the utility of inferring travel information from accident data, and without the benefit of empirical information on the relation between the two, such as that noted above.] While only a limited number of the travel characteristics reported in this section have actually been inferred from accident data, it is considered significant that those derived from the interviews are also confirmed by reference to the available accident data.

The frequency of four types of bicycle trip was investigated: work trips for adults, school trips for children, and buying and social trips for all riders. Table 4 gives the average number of days per year for which the given type of trip is made by those interviewees who use their bicycles for that purpose. Thus, for example, 50 percent of the boy riders interviewed use their bicycles to go to school and do so for an average of 205 days during the year.

Clear patterns of use indicate, for instance, that adult men who ride bicycles use them to travel to work daily (71 percent), but adult women use them primarily for shopping (92 percent) and social purposes; about half of the boys and girls who use bicycles do so in order to get to school, although girls use their bicycles less frequently; children (ages 10 to 19) depend on their bicycles for almost daily social transportation.

The data for trip frequency were analyzed for each town separately and no significant trends were isolated.

On the basis of information given by the interviewees about the length of their current trip, tabulations were made of one-directional trip lengths by purpose, age, and sex of rider. (Approximately 20 percent of the replies were plotted on large-scale maps in order to check the reasonableness of trip length estimates as given by the interviewees.) Two sets of graphs show the results—the first by trip purpose and the second by age and sex of rider.

Without differentiation as to age or sex, 90 percent of all work or school trips were 5.5 km or less (50 percent were less than 2.0 km). On the other hand, 90 percent of all social and shopping trips were less than 3.0 km (50 percent were less than 1.0 km). The only category of trip to be 6 km and over of any significance was male work trips. Ten percent of such trips were in this category (Figures 1 through 4). In general, it was found that 90 percent of the trips of adult males were 5 km or less, boys traveled 4 km or less, women traveled 3 km, and girls traveled 2 km (Figures 5 through 8).

The following travel characteristics relating rider age, time of day, day of week, and season of year were inferred from accident data:

1. Rush hours, 7:00 to 9:00 a.m. and 5:00 to 7:00 p.m., account for 30 percent of travel,
2. Older persons ride more during nonrush hours than do younger persons,
3. Weekday bicycle use is approximately twice that on the Sabbath,
4. Younger persons ride more on the Sabbath than do older persons, and
5. Older persons ride more during winter and younger persons ride more during summer.

The relation of Sabbath travel for the two ages remains the same throughout the year, thus substantiating the importance of the bicycle for social use by youth.

Table 1. Distribution of bicycle riders by age and sex.

Riders	Bicycle Riders (%) High Use: Nahariya,[a] Kiryat Haim	Medium Use: Hadera	Low Use: Givatayim, Herzlia
Children 10-19			
Boys	26.2	34.3	55.8
Girls	11.9	3.9	7.0
Total	38.1	38.2	62.8
Adults 20+			
Male	45.6	61.8	36.2
Female	16.2	0.0	0.9
Total	61.8	61.8	37.1

[a] In Nahariya, 69.4 percent of all riders were adults.

Table 2. Comparison of international bicycle use.

Place	Estimated Bicycles in Use (000s)	Bicycles/1000 Population
Holland	10 000	833
Sweden	4 800	560
Denmark	1 500	300
England	12 000	220
Israel	276	85
Nahariya	10.4	435
Kiryat Haim	9.5	387
Hadera	4.0	123
Tel Aviv	23.5	65
United States		
Davis, CA	20.0	740
Fullerton, CA	26.5	308

Annual Travel

Estimates were made of annual travel distances by bicycle riders based on trip frequency and trip length information generated by the interviews (see Table 5). Some differences were found in annual travel when analyzed by town, probably due to geographic differences and where industry or schools are located in reference to residential areas. Despite these differences, it was clear that the mode itself set the limits of annual travel and was, in turn, primarily influenced by the rider's age and sex.

Based on the average annual travel for the interviewed riders and an estimated 15 percent use by those sharing a bicycle, the following estimate was made of total urban bicycle travel:

$$\begin{aligned} 222\ 000 \text{ bicycles} \times 1873 \text{ km/year} &= 415 \times 10^6 \text{ km} \\ 188\ 000 \text{ other riders} \times 280 \text{ km/year} &= \underline{52 \times 10^6 \text{ km}} \\ & 467 \times 10^6 \text{ km} \end{aligned}$$

Table 3. Percent of work trips and school trips made by bicycle and percent of bicycle accidents in 29 towns.

Town	Work Trips by Bicycle (%) Family Has No Motor Vehicle	Family Has Motor Vehicle	School Trips by Bicycle for All Families (%)	Bicycle Accidents/ All Accidents (%)
Jerusalem	0.2	0.1	0.5	1.6
Tel Aviv	4.0	0.4	8.4	6.5
Haifa	2.0	0.6	11.0	3.2
Ramat Gan	1.4	0.1	6.7	4.6
Petah-Tikva	5.1	0.8	14.6	10.8
Holon	4.2	0.3	12.3	9.8
Beersheba	4.2	0.1	6.8	8.9
Bnei Brak	2.1	0.4	4.6	4.0
Netanya	10.3	1.9	17.6	14.6
Bat Yam	1.4	0.2	1.7	5.3
Rishon L'zion	3.9	0.8	10.2	-
Ashdod	2.9	0.3	5.5	14.2
Hadera	5.9	1.3	16.2	11.5
Givatayim	2.2	0.1	12.8	5.6
Ashkelon	4.4	0.5	4.3	9.8
Lod	6.1	1.7	8.0	10.0
Herzliya	3.8	0.7	10.3	2.5
Rehoboth	10.7	1.8	34.6	14.5
Acre	8.9	7.7	8.3	25.0
Nazereth	-	-	-	-
Ramleh	6.3	3.9	18.1	16.2
Dimona	8.2	1.2	6.0	30.6
Tiberias	-	-	0.5	-
Kfar Saba	5.6	0.3	9.7	14.0
Nahariya	25.1	10.4	55.3	24.3
Kiryat Ata	4.6	0.6	14.0	6.7
Kiryat Gat	21.9	8.2	53.8	15.5
Kiryat Yam	4.7	2.4	19.7	14.0
Ramat Hasharon	1.4	0.3	15.9	11.6

Table 4. Annual trip frequency by trip purpose, age, and sex of bicycle rider.

Riders	Trip Purpose: School or Work Riders (%)	School or Work No. Days/ Year	Shopping Riders (%)	Shopping No. Days/ Year	Social Riders (%)	Social No. Days/ Year
Children 10-19						
Boys	50	205	85	204	79	212
Girls	58	172	74	193	80	192
Adults 20+						
Male	71	263	72	198	74	142
Female	33	230	92	242	68	184

The average annual travel per bicycle is therefore 2100 km/bicycle, which compares reasonably with other vehicles: automobiles, 20 800 km; motorcycles and scooters, 9900 km; and bicycles with auxiliary engines, 5900 km. All urban motor travel in Israel in 1972 totaled 3842 × 10^6 km. Bicycle travel, therefore, represents a 12 percent addition to total urban travel.

Comparison of Travel Characteristics

English data for the length of work trips and mixed purpose trips made by cycle are shown in Figure 9 (3). Ninety percent of the work trips in Stevenage are less than 4.5 km and those in London are 6.0 km (in Israel the distance was 5.5 km). In both places, 50 percent of these trips are less than 2.5 km (Israel 2.0 km). Ninety percent of the mixed purpose trips in Leamington Spa were less than 2.5 km (Israel 3.0 km), and 50 percent were less than 1.2 km (Israel 1.0 km). Work trips in Lambeth by cycle were found to average 8 km and some were as long as 13 km (4). In Petersborough the percentage of work trips of greater than 5.0 km were found to be negligible. School trips were investigated and it was found that for trips less than 1.0 km and more than 4.0 km bicycle use fell off sharply. In Israel 60 percent of the school trips by girls were between 1 and 2 km and 50 percent of boy's school trips were between 1 and 4 km.

In Bedford home-based bicycle trips to work were 48 percent (Israel 47 percent), shopping trips were 14 percent (Israel 22 percent), and social trips 20 percent (Israel 31 percent) (5). In a discussion of trip lengths to transit stations for St. Paul, Minnesota, by bicycle, Ohrn states that up to 3.2 km is an ideal distance (6). In Uppsala, Sweden, 21 percent of work trips were made by bicycle in 1971; however, social and recreational use was not found to be outstanding (7).

Annual kilometers of travel by bicycle have been divided into two groups in Denmark—high-use bicycle owners, who average 1000 km/year and low-use riders, who average 500 km/year (8). British use can be estimated by dividing the Transport Ministry's estimate of total annual bicycle kilometers (9) by the British Cycling Bureau's estimate of the number of cycles in use (1). This calculation indicates an average annual bicycle use of 400 km. Heasman (4) of the London Borough of Wandsworth expresses doubts about the ministry's annual bicycle kilometer estimate. One estimate of bicycle travel in the United States arrived at through cyclometers mounted on 500 bicycles indicated that children in Raleigh, North Carolina, whose average age was 8½ years, rode 500 km/year (10).

Figure 1. Cumulative length distribution of all trips.

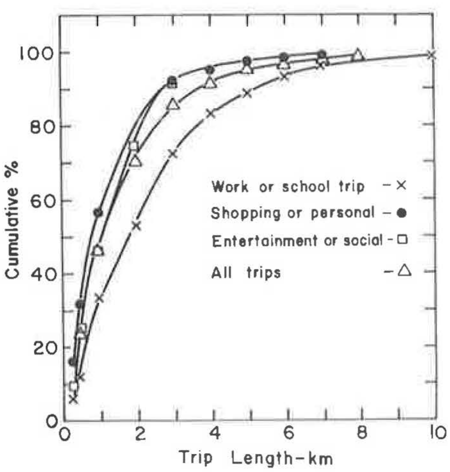


Figure 2. Cumulative length distribution of work trips by age and sex of rider.

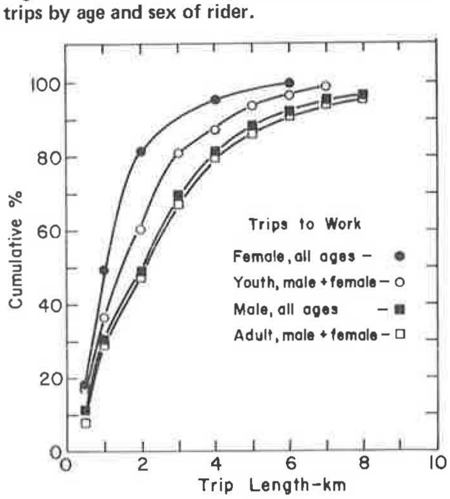


Figure 3. Cumulative length distribution of purchase and personal trips by age and sex of rider.

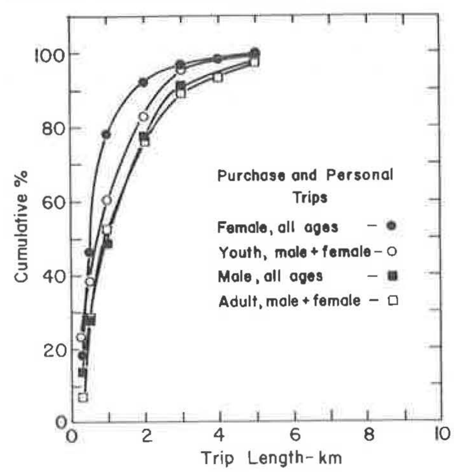
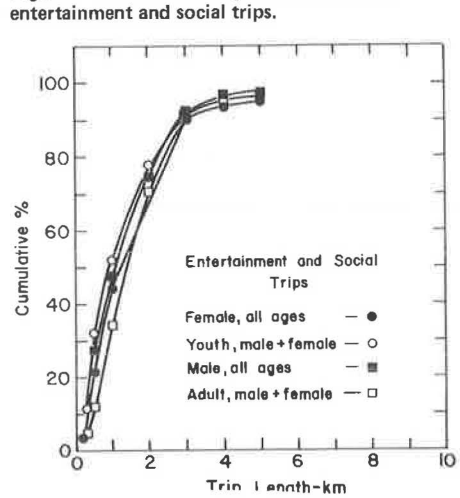


Figure 4. Cumulative length distribution of entertainment and social trips.



BICYCLE SAFETY

There are two basic changes that will take place and should therefore be studied with respect to their possible effect on risk.

1. The growth in the proportion of bicycle riding that will take place on special pathways: The safety benefits of completely separate bicycle pathways have been sufficiently established and, in any event, are self-evident. The problem with these pathways is the difficulty in providing them where needed (and where they will be used). The open question in bicycle facility design today is the extent to which bicyclists feel comfortable and are attracted to the various types of semi-separated bicycle lanes and the associated question of safety and risk for this type of facility.
2. The increase in the proportion of bicycles to motor vehicles in the conventional traffic stream: We can assume that not all of the increased riding will take place on separate bicycle facilities and that parts of the ordinary road system will be subjected to an increase in bicycle traffic flow. Risk to riders under this changed condition should also be investigated.

At the present time there is very little information available on bicycle risk for different types of facilities or for different populations of users. This is due to the almost total absence of elementary exposure data, the number of bicycles in use, and the amount of bicycle travel. In the discussion that follows, basic accident data collected annually by the Israeli police and the Central Bureau of Statistics and information on exposure generated by the bicycle survey interviews will be used to analyze risk for different populations of bicycle riders. The resulting risk rates and accident patterns will reflect the conditions existing in Israeli towns today, where urban riders mix with motor vehicles without benefit of special bicycle facilities.

Based on the estimate of 222 000 bicycles in use in towns over 5000 population, there were 5.2 bicycles involved in accidents/1000 bicycles in 1972 (1136 bicycle accident involvements) (11). Compared to other road vehicles, this rate of involvement is very low:

Mode	Accident Rate (involvements/ 1000 vehicles)
Automobile	57.6
Motorcycle, scooter	61.5
Bus	398.5
Bicycle	5.2

Figure 5. Cumulative length distribution of cycle trips by adult males.

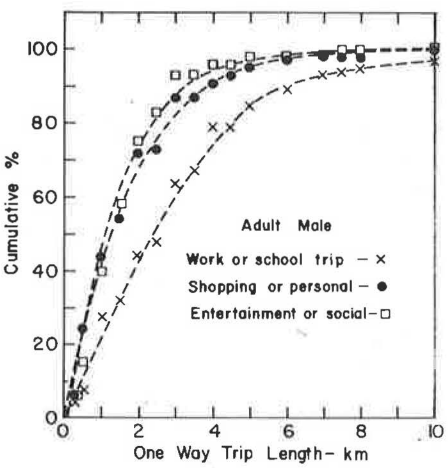


Figure 6. Cumulative length distribution of cycle trips by adult females.

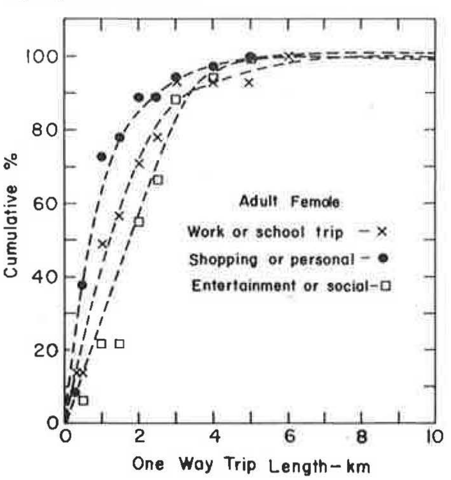


Figure 7. Cumulative length distribution of cycle trips by young females.

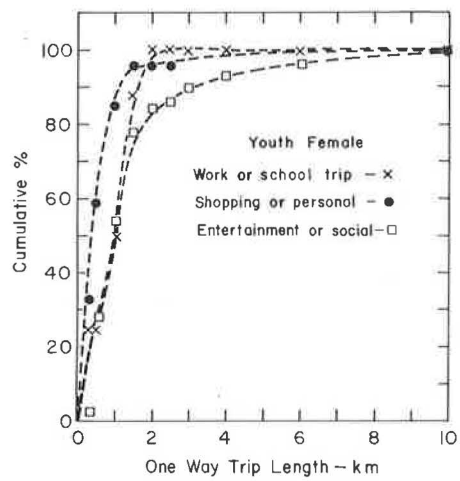


Figure 8. Cumulative length distribution of cycle trips by young males.

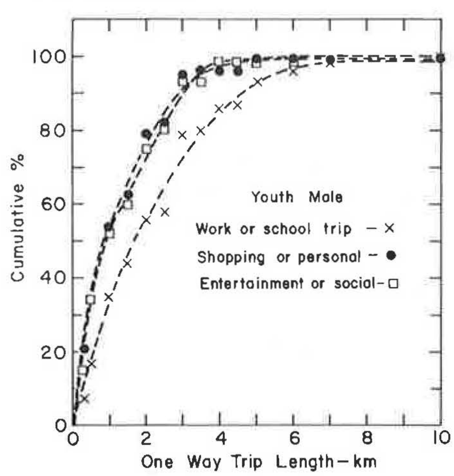
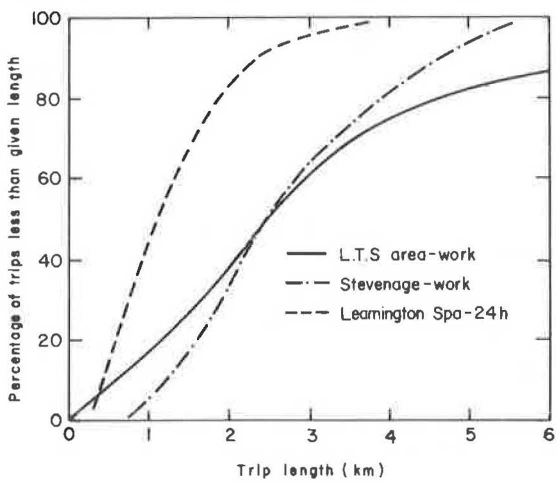


Table 5. Average annual bicycle travel by age, sex, and trip purpose.

Rider Group	Trip Purpose (km) Work or School	Shopping	Social	Total
Children 10-19				
Boys	640	453	826	1919
Girls	398	266	556	1220
Adults 20+				
Male	1330	586	360	2276
Female	688	706	317	1711
Weighted average[a]	883	415	575	1873
Percent	47	22	31	100

[a]Entire interview population.

Figure 9. Cumulative length distribution of bicycle trips, English towns.



The total amount of urban bicycle travel was estimated as 467×10^6 km/year. Of the total 1136 bicycles involved in accidents in 1972, approximately 88 percent were in urban areas (i.e., 1000 involvements). The number of bicycles involved in urban accidents per kilometer of urban travel is therefore 2.14 involvements/ 1 million km of travel. The involvement rates for other types of vehicles on urban and interurban roads combined are

Mode	Accident Rate (involvements/ 10 million km)
Automobile	2.77
Motorcycle, scooter	6.29
Bus	4.23

If urban automobile travel is estimated to be 56 percent of total automobile travel (12), it appears that approximately 8000 automobile involvements occur in 2240×10^6 km of travel. This yields a rate of 3.6 automobile involvements/10^6 km compared to 2.14 for bicycles (1.0 to 1.7).

In a study of four residential neighborhoods in Haifa, relative involvement rates were calculated for different types of vehicles on the basis of observations of the proportion of vehicles in the traffic stream to their proportion in accident involvement. [The original report combined all two-wheel data, separated in Table 6 into two-wheel motorized and bicycles (13).]

While this study does not confirm the 1:1.7 ratio of accident involvement in favor of bicycles noted previously, it confirms that they are less involved than for any other passenger vehicle considered. (Ahuza and Shaanan are extremely hilly, have low bicycle use, and had no bicycle accidents in the period.)

Differences for Changing Ratios of Bicycle and Vehicle Travel

It has been found that "... pedal cycle (accident) rates tend to rise when pedal cycles form a relatively smaller part of the traffic" (14). This tendency is in fact very marked and as automobile use has increased, the risk to bicyclists increases, and the perception of this has undoubtedly led to decreased use of bicycles, which in turn has raised the risk yet again.

The table below supports the above-mentioned British finding but alternatively suggests a positive interpretation—when a community uses bicycles a great deal more than it uses automobiles, then the risk of riding a bicycle is relatively low. Apparently, the more bicycles in the traffic stream, the lower the accident risk for bicycle riders.

Town	Bicycles/1000 Population	Injuries/1000 Bicycles
Tel Aviv	62	43.7
Holon	65	19.0
Givatayim	65	14.6
Rehoboth	109	20.5
Hadera	123	7.6
Kiryat Gat	254	5.5
Nahariya	438	5.2

The bicycle accident problem in towns and urban areas resembles their pedestrian problem. The distribution of bicycle casualties between intersections and road sections, however, resembles the pattern of motor vehicle casualties (Table 7) (11).

Notwithstanding the high use of bicycles by children and the expectation that cycle accidents would be essentially confined to residential neighborhoods, it appears that their location is similar to that of other accident types. In Givatayim, a town with low bicycle usage and therefore basically child use, the bicycle accident pattern is very similar to that for all accident types (Table 8). Sixty percent of the bicycle accidents occur on six main streets whose length is 13.8 percent of the total length of all streets in town. In Nahariya, a high-use bicycle town, over 50 percent of the bicycle accidents also occurred on main streets. (This distribution has not been compared to the location of other accident types.)

Age of Injured Bicycle Riders and Relative Risk

The age of those injured in bicycle accidents is influenced markedly by the composition of the population who use bicycles. Where bicycles are not an accepted mode of transportation, the use and injury pattern is dominated by the young rider between the ages of 10 to 19. Table 9 gives the percent injured in main age categories for all of Israel in 1971 and 1972 and for four towns having different patterns of bicycle use: Nahariya and Rehoboth are high bicycle-use towns, and Jerusalem and Givatayim are very low use towns. It is clear that increased use of the bicycle brings all ages into the injured rider group.

The age of specific involvement of bicycle riders has been calculated by various researchers. Typical fatality rates of bicycle riders per million population are as follows (14):

Age	Male	Female
5 to 9	10	2
15 to 19	45	7
25 to 29	15	5
60 to 69	45	3

The high representation of young adults (15 to 19) and male riders over 60 years of age appears in the Israeli data as well. However, when risk is examined in respect to bicycle use for the different towns studied, the strong influence of exposure is clear. In Table 10, population distribution, accidents, and estimated exposure percentages indicate that the high involvement rate of the 10 to 19 age group may be related to frequency of use rather than ability to cope with traffic or carelessness. (Table 10 was calculated on the basis of information provided in Tables 1, 5, and 9. Bicycle exposure is expressed in percent trips and percent kilometers.)

Table 6. Relative accident involvement of different types of vehicles in four Haifa neighborhoods adjusted for their proportion in traffic.

Vehicle	Ahuza	Shaanan	Yam	Eliezer
Bus	1.70	2.22	3.11	1.56
Taxi	1.13	0.93	1.24	1.79
Truck	0.95	1.22	0.44	0.67
Two-wheel motorized	4.14	5.22	3.94	5.91
Automobile	1.00	1.00	1.00	1.00
Bicycle	0.0	0.0	1.06	0.56

Table 7. Location of accident casualties on the road network.

	Bicycle		Pedestrian		Four-Wheel Motor Vehicle	
Location	Number	Percent	Number	Percent	Number	Percent
Urban (interurban)	88	12	89	11	55	45
Urban intersection (urban road)	53	47	26	74	58	42
Interurban intersection (interurban road)	25	75	22	78	21	79

Table 8. Distribution of bicycle and other accidents on the main streets and secondary streets (Givatayim 1967-1971).

Street	Length of All Streets (%)	Bicycle Accidents Number	Bicycle Accidents Percent	Other Accidents Number	Other Accidents Percent
Katzenelson	3.8	26	29	181	28
Weizman	2.5	14	15	90	13
Sirkin	1.2	2	2	21	3
Sheinkin	2.3	1	1	34	5
Hamaavak	1.9	5	6	57	8
Lamed Heh	1.6	6	7	12	3
Total	13.8	54	60	395	60
Other streets	86.2	35	40	253	40
Total	100.0	89	100	648	100

FACTORS ASSOCIATED WITH THE EXTENT OF BICYCLE USE IN TOWNS

In a previous section of this paper it was noted that bicycle use and characteristics varied according to the age and sex of the rider, but they were not influenced by differences between towns. On the other hand, very large differences in the extent of bicycle use for work and school trips have been found among the 29 Israeli towns included in the 1972 census and travel survey (15). In many of these towns bicycle trips accounted for less than 1 percent of all trips, but in others, as high as 25 percent of the work trips and 55 percent of the school trips were made by bicycle (see Table 3).

Among the possible factors explaining such large differences in the pattern of bicycle use could be (a) those directly related to the existing transport system such as level of automobile ownership, availability of public transport, and level of bicycle facilities; (b) those related to the primary determinants of travel need such as size and structure of a town; (c) environmental factors such as topography and weather; and (d) socioeconomic and psychological factors, such as income, status, and tradition.

The towns of Haifa, Jerusalem, Tiberias, and Nazereth are extremely hilly. The latter two are entirely situated on hillsides where there are no flat areas and bicycling is almost nonexistent. Jerusalem and Haifa are largely hilly and have bicycle-use percentages far under the average of the 29 towns. The cities of Haifa, Tel Aviv, and Jerusalem have populations of over 300 000 and motor vehicle traffic volumes approach those of European cities of similar size. The extent of bicycling in those three large cities is extremely low. All other cities in the list of 29 have populations of 100 000 or less. (The inner ring of towns included in the Tel Aviv metropolitan area, despite having certain activity centers of their own, follow the low bicycle-use pattern of Tel Aviv itself.)

Smallness and a flat topography appear to be necessary conditions for any use of bicycles, at least where no special bicycle facilities are provided. Therefore,

Table 9. Percent of bicycle casualties by age group in four towns having different bicycle use and for all Israel (1971-1972).

Age Group	Jerusalem	Givatayim	Rehoboth	Nahariya	All Israel
0 to 9	2.5	9.0	4.0	3.5	4.5
10 to 19	79.5	66.5	41.0	29.0	42.5
20 to 59	5.0	10.0	35.5	43.0	36.0
60+	13.0	14.5	19.5	24.5	17.0

Table 10. Bicycle accident involvement in high- and low-use towns by age of rider and estimated age-specific exposure.

Age	High-Use Towns Trips (%)	High-Use Towns Accidents (%)	Low-Use Towns Trips (%)	Low-Use Towns Accidents (%)	All Israel Accidents (%)	Population (%)
0 to 9	4	4	4	6	4	21
10 to 19	36	35	60	72	43	19
Total youth	40	39	64	78	47	40
20 to 59	-	39	-	8	36	48
60+	-	22	-	14	17	12
Total adult	60	61	36	22	53	60

Tel Aviv and the four hilly cities of Jerusalem, Haifa, Nazereth, and Tiberias, have been excluded from further analysis.

No towns have planned networks of bicycle paths, bicycle lanes, underpasses, or special signs. A high bicycle-use town such as Nahariya has one path making it possible for cyclists from a particular suburb to approach the CBD. The central area itself has no separate bicycle facilities. The only significant facility existing in the towns where bicycle use is heavy are parking racks outside of major buildings. It is extremely doubtful that facilities as such account for any of the differential use of bicycles noted among the 29 towns.

As would be expected, the use of bicycles by adults for work trips by families not owning a motor vehicle is significantly higher than for families with motor vehicles. The average use for families owning motor vehicles was 1.9 percent and for families without motor vehicles, 6.5 percent.

Fifty percent more bicycle trips to school were made by children from families that own motor vehicles than by children from families that do not own motor vehicles. This reversed situation is undoubtedly related to the economic ability to purchase a bicycle. (Table 3 does not show separate figures for bicycle trips made by children from families with and without motor vehicles. This information is included in the 1972 census but is not published here.)

An attempt was made to identify some socioeconomic factors by treating the percentage of bicycle trips to work (for families with and without motor vehicles) and trips to school as the dependent variables in three separate step regression analyses (see Table 3). Initially, 10 independent variables were examined:

1. Total population,
2. Radius,
3. Population density,
4. Length of paved roads,
5. Persons per room,
6. Percent welfare expenditure,
7. Income per person,
8. City taxes per person,
9. Percent of persons with high school education, and
10. Percent of population who immigrated from Asian and African countries.

As some of these variables were found to be highly intercorrelated, a selection was made based on order of entrance of the variables into the regression equation. The final tables for the three regression equations included the same five explanatory variables: (a) population, (b) radius, (c) density, (d) persons per room, and (e) percent welfare expenditure.

These five variables explained 44 percent of the variance in respect to bicycling to school. An extra variable was added to the two regression equations pertaining to trips to work: percent working out of town (15). This variable was found to have a high negative correlation with bicycle use (i.e., the higher the percentage of population working out of town, the lower the percentage of persons bicycling to work). The six variables accounted for 59 percent of the variance associated with bicycling to work for the sample of families with motor vehicles, and 56 percent for families without motor vehicles. Population had a significant effect on bicycle use in all three cases—the smaller the town, the greater the use of the bicycle.

With smallness of population as a prior condition, large radii are associated with increased bicycling to work. For school trips, small radii are associated with high bicycle use (given small population). High percentages of persons bicycling to work are associated with high rates of welfare and a high number of persons per room, indicating the lower economic level of towns where bicycles are used. For school trips, this was reversed and few persons per room contributed 12 percent to the explanation of the variance.

The 1972 census (15) provides information on the other modes of travel used for the work and school trip in each of the 29 towns. From these data it is possible to further refine the analysis of factors influencing bicycle use:

1. Walking and bicycling are moderately correlated ($r = +0.5$); often, therefore, where bicycle use is high, walking trips are also frequent, and either bus travel or automobile travel (or both) are low (since the sum of all modal trips must be 100 percent). The significance of these relations is illustrated by the example of the town of Dimona, which is small in population and high in percentage of welfare recipients, yet relatively low in bicycle use. The modal split information shows, however, that 40 percent of the adults and 85 percent of the children walked to work and school (radius of Dimona = 1.1 km). This alternative possibility of walking has apparently contributed to a lower use of bicycles in towns with very small radii and very low economic status. [In Nairobi, Kenya, a flat city amenable to bicycling, workers preferred to walk above average distances to work, apparently out of economic considerations of bicycle cost, and bicycle use remained as in a highly motorized city, 2.6 percent (16).]
2. Transportation provided by employers proved to be an alternative mode of transport, which reduced bicycle use in certain towns. Thus, Hadera, Ashkelon, and Acco might have been sites of higher bicycle use according to factors mentioned previously if such special transportation were not provided. (It accounted for approximately 15 percent of all work trips in the three towns mentioned above.) Hadera, for example, has a bicycle path system that leads to its industrial zone, but it has been abandoned since the large manufacturing enterprises instituted their own travel arrangements.

The above findings simply confirm the logic of how availability of alternative forms of transport act to influence the modal split, including the extent of use of bicycles.

SUMMARY AND CONCLUSIONS

Various counts of bicycle traffic, in addition to interviews with 685 bicycle riders, were conducted to ascertain basic information on the use of bicycles in Israeli towns. The information desired was of the sort generally considered necessary for understanding any transportation system—age and sex of those using the mode; the type of trips made; their frequency, length, and purpose; annual travel by the mode; level of vehicle ownership; and number of riders. For motor vehicles, some of this information is available from official vehicle registration and driver files, and the balance is obtained through surveys. For bicycles, none of the above information is available from any standard file, a situation common to almost every country in the world.

The research approach used was to sample bicycle ownership and travel habits in towns having very different levels of bicycle use. Prior information on the extent of use was mostly speculative, although some hard data were available from traffic studies. Because of this lack of information and other inherent difficulties in establishing a representative sample, the extrapolations made to the entire population of bicycle users must be regarded as preliminary. After the field studies were complete, however, results from a national travel census, which described the use of bicycles for work and school trips in 29 towns, became available. From this census information it was possible to establish that the sampling program followed was sufficiently valid to permit interpretation with reasonable confidence of the survey data acquired.

The findings indicate a modest level of bicycle ownership, 85/1000 persons, compared to 800 in Holland and 200 in England. On the other hand, the average rider traveled 1800 km/year, and because bicycles are shared, each bicycle was estimated to travel 2100 km/year. This is higher than most estimates elsewhere in the world, but reasonable when compared to bicycles with auxiliary engines in Israel that travel 5900 km/year.

On the basis of 222 000 bicycles, it appears that their annual travel adds about 12 percent to total urban travel. It is important to interpret this finding correctly: in Tel Aviv bicycle ownership is estimated at 65/1000 persons and in Jerusalem even less; in Nahariya, on the other hand, there are 435 bicycles/1000 persons and in Kiryat Haim, 387. In other words, the additional 12 percent urban travel by bicycle is not distributed in the same way as motor vehicle travel but appears to be a part of the total transport system where it is most needed, where it is possible (topography and distance), and where, for elusive sociocultural reasons, it is desired.

This interpretation is supported by the results of the regression analysis made to identify the factors contributing to the wide differences in bicycle use among 29 Israeli towns. The results showed that bicycles are most used in small towns that are economically backward. In cities over 100 000 or in any town that is hilly, bicycles are not used in Israel for purposeful trips (except to school to a limited extent). Where bicycling was less in use than might be expected, it was often attributable to the available alternative of walking (in the smallest and poorest towns) and to the existence of industry-subsidized transportation to work.

Bicycle owners appear to depend on their vehicle in a manner resembling the behavior of automobile owners. In the towns where bicycles are popular, they are used by males and females of all ages, and trip frequency is almost daily for purposes that fit the life cycle of the rider. The length of trips made was found to be very similar to that in European countries, apparently reflecting universal limitations imposed by human capability and inclination to expend energy. Some workers traveled 10 km/d, but school children restricted their trips to from 1 to 4 km and most other trips were within the framework of 3 to 4 km.

Finally, the calculations of bicycle kilometers of travel and the estimate of how this travel is apportioned among different age groups and different towns, made possible a rough evaluation of travel risk for bicyclists. The results are contrary to those generally accepted in that they indicate the risk of bicycle travel to be the same as or lower than that for automobiles. To integrate this finding into a general pattern it appears necessary to accept the premise that bicycle riders do their best to ride where it is safest. This premise is supported by the finding that riding does not take place in large, traffic-oriented cities, but is restricted to smaller towns. An additional finding was that involvement rates are lowest in towns having many bicycles.

In conclusion, it appears that bicycle travel is both needed and wanted by many segments of the urban population. For towns in developing countries, striving to keep transport costs low, and for other municipal authorities desirous of protecting environmental quality, it appears that at least some parts of the urban structure should be planned to meet this need and encourage it further.

It should not be forgotten that the findings of this study have as their source an environment entirely hostile to bicycle riding, and in spite of this, the use of the mode persists and serves substantial numbers of citizens. The lack of bicycle facilities appears to be an unjustified misappropriation of transportation infrastructure funds.

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Cyclist Behavior at Signalized Intersections

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This study seeks to determine cyclist behavior patterns at signalized intersection approaches. These behavior patterns indicate which types of bicycle traffic regulators are most likely to reduce bicycle-motor vehicle conflicts. Cyclist behavior was recorded during February 1977 in Tempe, Arizona, at nine intersections, which were selected for their various bicycle facilities. Three approaches are classified according to the type of push-button traffic signal available and the existence of a bike lane. The rate of use of the three types of push buttons—standard, cyclist, and cyclist-pedestrian—are compared. The effect on push button use by the presence of motor vehicles is analyzed by type of intersection. Cyclist queuing patterns at the intersections, the use of pedestrian crosswalks by cyclists, and cyclist delay caused by vehicles turning right at the intersection were also studied. Cyclist push buttons are used most frequently and induce the majority of the cyclists to stop in the most suitable queue area. Painted bike lanes have no effect on the rate of use of push buttons or the use of the safest queue area. Cyclists are willing to use the crosswalk provided it is not too far from their route of travel.

Bicycles are more popular in the United States today than ever before. Bicycle transportation provides the cyclist with the benefits of comparatively low acquisition and usage cost and a means of vigorous exercise. For society, it reduces air and noise pollution, energy consumption, and traffic congestion. As a consequence, bicycles are recognized by a large number of Americans as an alternative mode of transportation for going to school, work, shopping, and recreation. Bicycle sales in the United States increased from 3.7 million in 1960 to 6.9 million in 1970 and reached a peak of 15 million by 1973 (1). Arizona's climate allows cycling as a year-round activity in the state's most populous areas.

Two major problems brought by the bicycle boom that concern the traffic engineer and the police are the increased number of bicycle accidents and the ambiguous status of the bicycle in traffic law. The number of bicycle accidents in Arizona increased from 383 in 1967 to 1124 in 1975. More than 90 percent of these accidents occurred in urban areas (2). Furthermore, bicycle-motor vehicle accidents occurred most frequently at intersections. For example, a report on bicycle accidents in North Carolina shows that almost one-half (48.7 percent) of all bicycle accidents took place at intersections. The next two most common locations of bicycle accidents were two-way roads (27.8 percent) and driveways (11.3 percent) (3). Since bicycles traverse sidewalks and pedestrian crossings as well as roadways, it is difficult to pinpoint which traffic laws are applicable to cyclists.

Even though the trend today is to separate bicycle and motor vehicle traffic, if possible, a high accident potential still exists when bike routes, lanes, or paths cross major streets and highways at grade. Pedestrians, bicycles, and motor vehicles competing for space during a limited time interval create a constant problem. The larger number of bicycles adds new emphasis to the evaluation of the old problem. Grade separation is a desirable solution to the problem, but the construction of such facilities involves large amounts of money; therefore, the reduction of bicycle-motor vehicle conflicts in at-grade intersections still challenges the traffic engineer.

THE PROBLEM

In the city of Tempe, many traffic control devices, such as curb cuts, painted bike lanes, and traffic-light push buttons have been installed to improve the safety and performance of bicycle traffic at intersections. In order to make decisions about future use, the city traffic engineer needs statistical comparisons of cyclist behavioral patterns at improved and unimproved intersections. An improved intersection is an intersection that has, in addition to a standard push button to activate traffic signals, a cyclist push button or cyclist-pedestrian (bifunctional) push button and bike lane. An unimproved intersection is an intersection that has only a standard push button and no bike lane.

The city traffic engineer is interested in knowing the extent to which the cyclist push buttons and cyclist-pedestrian push buttons affect bicyclist behavior. In addition, the following questions should be answered in order to better regulate bicycle traffic at intersections:

1. Do cyclists rely on motor vehicles to activate the traffic signal?
2. What are the patterns of queueing series of cyclists?
3. Do cyclists use pedestrian crosswalks, and if so, do they walk or ride their bicycles?
4. Do cyclists yield to automobiles making right turns?

The purpose of this research is to

1. Compare the proportions of cyclists using different types of push buttons,
2. Determine whether or not the actions of cyclists using push buttons are independent of the presence of motor vehicles,
3. Compare the patterns of cyclist queueing series at intersections under various conditions,
4. Compare the percentages of cyclists using pedestrian crosswalks at different types of intersections, and
5. Compare the percentages of cyclists delayed by motor vehicles making right turns at different types of intersections.

Definitions for the following terms are necessary for an understanding of the problems and the results of this research:

1. Bike lane—A portion of the roadway set aside exclusively for bicycle use. It is defined by painted line, curb, or other separation.
2. Stop—A stop for a bicyclist means a complete stop, with at least one foot touching the ground.
3. Cyclist push button—A traffic-signal push button designated for bicycle rider use only, usually located on or near the curb line, so that a cyclist can reach it while on a bicycle in the street. It is also known as curb-mounted push button (see Figure 1).
4. Cyclist-pedestrian (C/P) push button—A bifunctional push button designated for both cyclist and pedes-

trian use, usually located on the corner area of sidewalk.

5. Standard push button—Pedestrian push button mounted on signal standard or individual post. This device is not suitable for cyclist use.

6. First cyclist—The cyclist who reaches the intersection first and stops because of a yellow or red light.

7. Following cyclist—Any cyclist who stops at the intersection after the first cyclist has already done so.

8. Delay—A delay occurs the moment a motor vehicle turns right and a bicycle drives forward after the signal light has changed from red to green. In this situation either the motorist or the cyclist must stop in order to avoid a collision.

REVIEW OF THE LITERATURE

What do bicyclists want while they are using bicycles as a mode of transportation? According to a 1971 survey by the Metropolitan Washington Council of Governments, "Somebody must provide a place to store his bike at the destination, and there must be provided for the cyclists a right-of-way or other means of recognizing a bikeway for his use (4)." Kaplan mentioned two important characteristics that a bikeway designer should always keep in mind: (a) the rider's urge to maintain momentum and (b) the cyclist's tendency to select the most direct route whether or not it is designated as a bicycle facility (5).

In the discussion of why cyclists were involved in intersection accidents, the Institute of Transportation and Traffic Engineering concluded that in the vicinity of intersections the cyclist often is involved in accidents because he or she cannot clearly perceive dangers. In general, one assumes that only the cyclist who makes a left turn is in danger; however, the cyclist who is traveling straight or makes a right turn is much more endangered because he or she is confident that the right side of the street is safe and does not suspect possible danger.

Also, Germano listed the following frequent causes of cyclist fatalities and injuries (7):

1. Making improper turns;
2. Disregarding traffic signs, signals, and markers;
3. Riding double;
4. Running into an open door of a parked vehicle; and
5. Failing to yield right-of-way.

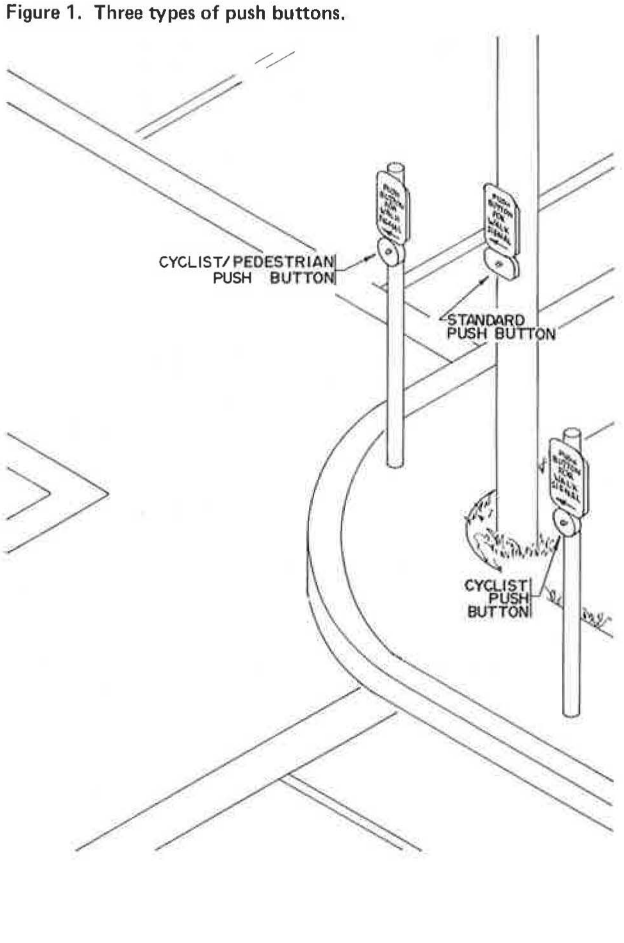
One thing is clear. A cyclist psychologically sees himself or herself as both a vehicle driver and a pedestrian, depending on the situation. For example, if the automobile volume is not large, the bicyclist will share the roadway with automobiles. On the other hand, if the traffic is heavily congested he or she will shift the bicycle from the roadway and compete with the pedestrians for the use of sidewalks.

The Institute of Traffic Engineers states that at unchannelized at-grade intersections a bicyclist can follow a wide variety of paths to cross or turn at the intersection; thus the potential for bicycle-motor vehicle-pedestrian conflict is increased. Channelization for bicycles is strongly recommended (8).

In Germany and the Netherlands the conflict between nearside turning motor vehicles and the through bicycle movements is reduced by offsetting the bikeway crossing 5 to 10 m (16 to 33 ft) from the intersection (6).

Intersections that have relatively large bicycle traffic volumes have a greater potential for conflicts. Unless the traffic volume is low, a bikeway crossing is suggested. If traffic volume is low, a vehicular-type left turn is acceptable. The bikeway crossing should be offset from the intersection.

Figure 1. Three types of push buttons.



INTERSECTIONS STUDIED

Nine intersections within the city limits of Tempe, Arizona, were studied. All of these intersections have four approaches. There are various types of bicycle facilities and devices at each intersection approach. For example, the west approach of Terrace and Rural is equipped with a bike lane and a cyclist push button, but the east approach is equipped with only a cyclist push button. Therefore, each approach was studied as an individual unit. Specifically, this research concerns only intersection approaches, not the intersection as a whole.

The intersection approaches are classified into types A, B, and C for the convenience of the study. The three types of approaches are defined below:

Type A—Approach installed with cyclist push button or C/P push button and bike lane.

Type B—Approach installed with cyclist push button or C/P push button but no bike lane.

Type C—Approach installed with only standard push button and no bike lane.

Table 1 shows all the intersection approaches studied, their types, major trip generators, and major age groups of cyclists. The largest trip generators are the university or other schools. Because 58 percent of the bicyclists ride to schools, these generators offer a steady and large daily traffic volume on school days. Fixed class schedules generate a large number of cyclists passing through the intersections within a short time. This provided a chance to record the behavior of cyclists in large groups as compared to the behavior of a single cyclist or those in small groups. In addition, the prob-

Table 1. Site information.

Site No.	Location	Approach Type	Push-Button Type	Major Trip Purpose	Age Group
1	Terrace/Rural West side	A	Cyclist	University	18 to 26
2	College/Apache South side	A	Cyclist	University	18 to 26
3	College/Broadway North side	A	C/P	University	18 to 26
4	Terrace/ Rural East side	B	Cyclist	University	18 to 26
5	Mill/Broadway South side	B	C/P	High school	12 to 18
6	Terrace/Southern North side	B	C/P	Elementary school and community center	All ages
7	10th St./Mill East side	C	Standard	University	18 to 26
8	McAllister/Apache South side	C	Standard	University	18 to 26
9	College/Curry North side	C	Standard	Park	All ages

Figure 2. Queue zones for type A intersection.

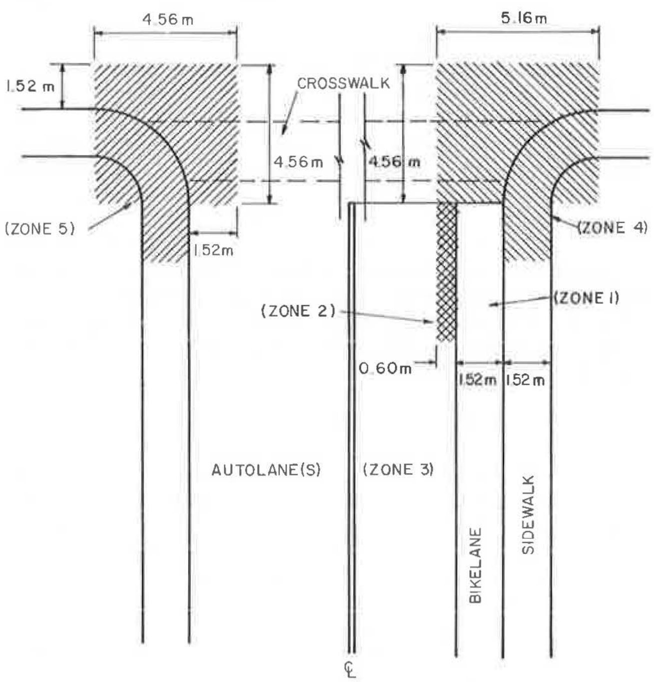
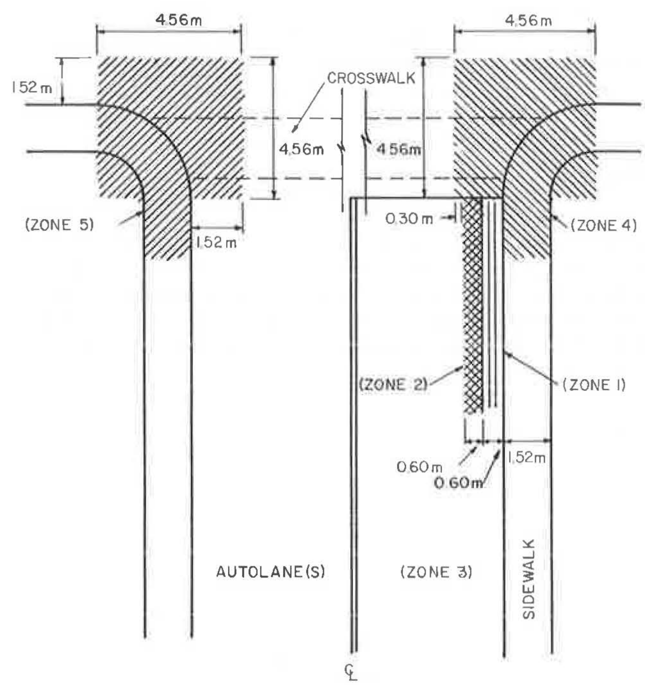


Figure 3. Queue zones for types B and C intersections.



lem of identifying ages of cyclists can be minimized if the observations are conducted at the proper time.

Most observations were conducted on weekdays, except at sites 6 and 8. Site 6 is near an elementary school and a community center. The school serves as a playground for neighborhood children and the community center is used for many activities during the weekend. Site 8 is the entrance of Papago Park, which attracts a majority of users during weekends and holidays.

The observation period was from February 1 through February 28, 1977. Two observations were conducted at each site. The day of observation for each site was selected at random, but carefully avoided a Monday-Wednesday-Friday series or a Tuesday-Thursday series. That is, if the observation of one site was made on Monday, Wednesday, or Friday, the next observation for this site was on Tuesday or Thursday.

To obtain the best results, all the observations were made within the peak periods, except those observations made on weekends and holidays. For those sites for which the trip generator was the university, the peak period was 7:30 to 9:30 a.m. and 3:00 to 5:00 p.m. The peak periods were determined by two 11-h (7:00 a.m. to 6:00 p.m.) continuous observations at the intersections of Terrace/Rural and College/Apache. Peak-periods for site 5 were 7:00 to 8:00 a.m. and 2:30 to 3:30 p.m., determined after interviewing the staff of the school adjacent to this intersection.

Two different data collection sheets were used in this research. Form A was used to register the bicyclists' reaction to the push buttons and the surrounding condition of the intersection during recording intervals. Form B was used to register bicyclists' queueing series, delays of both bicycles and right-turning motor vehicles, and the manner in which the cyclists crossed the intersection. Due to the heavy bicycle traffic at one intersection during the peak periods, it was impossible to record bicyclists' behavior on both forms A and B simultaneously. Therefore, 1-h observations were conducted on 4 successive days at the same time of day, using form

A the first 2 d and form B the last 2 d. However, for the intersections that did not experience heavy traffic, even during the peak periods, it was possible to record on both forms A and B at the same time.

Regarding the bicyclist queueing series, five zones were created and the numbers of cyclists stopped at each zone were counted. The definitions of the zones used in the intersection approach types vary with type.

For type A approaches (see Figure 2):

Zone 1—The area within the bike lane did not exceed the crosswalk lines.

Zone 2—The narrow strip just outside the bike lane in which one bicycle can travel.

Zone 3—Carlane, except zone 2.

Zone 4—All area encompassing sidewalk, crosswalk, and the right corner of an intersection.

Zone 5—All area at the left side of the road.

For type B and C approaches (see Figure 3):

Zone 1—Roadside area just adjacent to the curb wide enough for one bicycle.

Zone 2—The narrow strip bordering zone 1, to the right of zone 3, where the outside bicycle of two bicycles abreast would be.

Zones 3, 4, and 5—Same as in type A approaches.

In many cases, especially at roadways without painted bike lanes, it was difficult to determine exactly what zones the cyclists were in. Therefore, the zone that the cyclists were in was determined solely by the observer's own judgment. For instance, if three cyclists stopped abreast at the roadside, the one nearest the curbline was considered to be in zone 1, the next in zone 2, and the outside cyclist was considered to be in zone 3.

DATA REDUCTION AND ANALYSIS

The data consist of push button use, records of the presence of motor vehicles and the use of push button by the first cyclist, the queueing series patterns, the number of conflicts, and the use of crosswalks. The majority of the cyclists were college students and there was no attempt to differentiate the sex of the cyclists.

Table 2 contains the number of the first cyclists and the following cyclists who used the push button at type A, B, and C intersection approaches.

It is obvious that the cyclists at type A approaches have the highest rate of push button use (46 percent) and the cyclists at type C approaches have the lowest use rate (14 percent). A test of hypotheses regarding the difference between the two proportions shows that the use rate of push button at type B approaches is equal to the use rate at type A approaches at a 0.05 level of significance (95 percent confidence level). The same proportions test shows that the use rate at type B (and thus also type A) approaches is greater than the use rate at type C approaches at the 0.05 level of significance.

However, when the data were tabulated according to the types of push button, and not by the type of intersec-

Table 2. Push button use by intersection approach.

Approach Type	Pushed	Not Pushed	Total
A			
First cyclist	137	93	230
Following cyclist	22	96	118
Percent	45.7	54.3	100
B			
First cyclist	54	52	106
Following cyclist	22	65	87
Percent	39.4	60.6	100
C			
First cyclist	21	102	123
Following cyclist	6	69	75
Percent	13.6	86.4	100

Table 3. Use of push button by type.

Push-Button Type	Pushed	Not Pushed	Total
Cyclist			
First cyclist	145	108	253
Following cyclist	37	89	126
Percent	48.0	52.0	100
Cyclist/pedestrian			
First cyclist	46	37	83
Following cyclist	7	72	79
Percent	32.7	67.3	100
Standard			
First cyclist	21	102	123
Following cyclist	6	69	75
Percent	13.6	86.4	100

Table 4. Push button use rates of first cyclist by presence of motor vehicle.

	Pushed		Not Pushed		
Approach Type	No.	Percent	No.	Percent	Total
A					
Motor vehicle present	107	59.4	73	40.6	180
No motor vehicle present	30	60.0	20	40.0	50
B					
Motor vehicle present	39	52.7	35	47.3	74
No motor vehicle present	15	46.9	17	53.1	32
C					
Motor vehicle present	12	15.4	66	84.6	78
No motor vehicle present	9	20.0	36	80.0	45

Table 5. Distribution of cyclists in queue zones.

		Zones										
		1		2		3		4		5		Total
Approach Type	Site No.	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.
A	1	92	54.1[a]	9	5.3	0	0	63	37.0	6	3.6	170
	2	137	66.2	26	12.6	2	1.0	39	18.8	3	1.4	207
	3	11	12.9	3	3.5	0	0	66	77.7	5	5.9	85
B	4	200	58.7	33	9.7	6	1.7	97	28.4	5	1.5	341
	5	17	9.0	3	1.7	0	0	39	20.7	129	68.6	188
	6	1	4.5	1	4.5	0	0	20	91.0	0	0	22
C	7	26	29.9	8	9.2	3	3.4	39	44.8	11	12.7	87
	8	23	17.8	1	0.8	0	0	26	20.2	79	61.2	129
	9	0	0	0	0	0	0	33	80.5	8	19.5	41

[a]The underlined numbers indicate the largest percentages.

Table 6. Site delays.

Site	Total Signal Cycles Observed	No. of Cycles in Which Delayed Occurred	Rate[a] (%)	Bicycle Delays	Automobile Delays
1	86	11	12.8	2	9
2	90	15	16.7	4	11
3	52	3	5.8	0	3
4	80	23	28.8	5	18
5	42	2	4.8	0	2
6	14	2	14.2	1	1
7	50	2	4.0	0	2
8	48	4	8.3	0	4
9	22	2	9.1	0	2

[a]Rate = cycles delay occurred/total cycles.

Table 7. Crosswalk use rate by cyclists.

Site	Total Number of Cyclists	Crosswalk Nonusers		Crosswalk Users			
		No.	Percent	No.	Percent	Rode	Walked
1	170	19	11.1	151	88.9	148	3
2	207	183	88.4	24	11.6	23	1
3	85	27	31.8	58	68.2	56	2
4	341	88	25.8	253	74.2	252	1
5	188	180	95.7	8	4.3	5	3
6	22	9	40.9	13	59.1	13	0
7	87	67	77.0	20	23.0	17	3
8	129	119	92.2	10	7.8	9	1
9	41	9	22.0	32	78.0	27	5

Table 8. Crosswalk use rate by cyclists (zone 5 excluded).

Site	Total Number of Cyclists	Crosswalk Nonusers		Crosswalk Users			
		No.	Percent	No.	Percent	Rode	Walked
1	164	13	7.9	151	92.1	148	3
2	204	180	88.2	24	11.8	23	1
3	80	22	27.5	58	72.5	56	2
4	336	83	24.7	253	75.3	252	1
5	59	51	86.4	8	13.6	5	3
6	22	9	40.9	13	59.1	13	0
7	76	56	73.7	20	26.3	17	3
8	50	40	80.0	10	20.0	9	1
9	33	1	3.0	32	97.0	27	5

tion approach (Table 3), the tests of proportions show that the use rate of cyclist push buttons is greater than the use rate of C/P push buttons. In addition, the use rate of C/P push buttons is greater than that of standard push buttons at a 0.05 level of significance.

Regarding the push button use rate of the first cyclist and the following cyclist, it was found that among the observed 459 first cyclists, 212 of them (46.2 percent) used the push button, and only 50 out of 280 of the following cyclists (17.9 percent) were push button users. The explanation of the difference in use rate between the two groups of cyclists is that the majority of the following cyclists saw a first cyclist push the button or at least assumed that he or she had done so.

The use rate of the following cyclists in Table 2 is 29.4 percent for cyclist push buttons, which is much higher than the C/P push button rate (8.9 percent).

Presence of Motor Vehicles and Push Button Use Rate

Do cyclists rely on the motor vehicle to activate the signal? To answer this question, button-pushing action of the first cyclists and the presence of motor vehicles were both recorded. The results are given in Table 4.

Chi-square tests of independence showed that, at all three types of intersection approaches, the action of a cyclist pushing the button is independent of the presence of motor vehicles at a 0.01 level of significance.

The Queueing Series

Five queueing zones were created in dealing with the cyclist queueing series. Queueing series distributions at each site were tested using the data in Table 5.

A chi-square test of independence among the three types of approaches and the five zones shows that the types of approaches and zones where cyclists stayed were dependent. By comparing the expected and observed frequencies, one can see that type A approaches attracted considerably more cyclists than would be expected in zone 1: type C approaches attracted nearly twice as many cyclists as would be expected in zones 4 and 5.

A further analysis revealed the following interesting features. The sites that were equipped with cyclist push buttons (sites 1, 2, and 4) had the greatest number of cyclists in zone 1. Sites 3 and 6, which were equipped with C/P push buttons, had the majority of the cyclists in zone 4. Most of the cyclists at sites 5 and 8 were in zone 5 because those two sites experienced a heavy left-turning bicycle traffic volume. At site 9, where a widened sidewalk was designated for cyclist use, most of the cyclists stopped in the sidewalk area, which was defined as part of zone 4.

Through observation, it was found that most cyclists who were in zones 4 and 5 stopped their bicycles within the crosswalks and by the corner areas of the intersection. This would consequently obstruct the right-of-way of pedestrians and vehicles making right turns.

Delays Between Through Bicycle and Right-Turning Vehicle

When a group of cyclists occupied the corner area of an intersection (zone 4), a delay would not occur at the moment the signal turned green, because the automobile drivers making right turns were forced to wait until all the cyclists had crossed the street. Table 6 shows the total number of signal cycles observed and the number of times that delays occurred. After analyzing the data in Table 6, the results can be summarized as follows:

1. The approaches equipped with cyclist push buttons had a higher possibility of delay occurence, because those approaches had fewer cyclists stopped in corner areas (zone 4). As already mentioned above, a large group of cyclists stopped in zone 4 will decrease the possibility of delay occurrence.
2. Bike lanes had no effect on delay occurrence.
3. The low delay rate of type C intersection ap-

proaches was due to the light motor vehicle traffic at those intersections.

4. The majority of delay actions occurred to automobiles.

5. Site 4 had the highest delay rate among all observed sites primarily due to the heavy right-turning motor vehicle traffic.

The Use of Crosswalks

Table 7 shows the rate of cyclists using the crosswalk. The data in Table 7 were divided into two groups, the high-use rate group and the low-use rate group. The use rate of the former group was not less than 59.1 percent, while the use rate of the latter group was not more than 23.0 percent.

Table 7 shows the number of cyclists in all zones who used the crosswalk and those who did not. It is quite obvious that cyclists in zone 5 (left side of the road) will not use the crosswalk on the right side of the road. Therefore, Table 8 was constructed to show only the number of cyclists in zones 1, 2, 3, and 4 who used the crosswalk to see if there was any significant change in the results from Table 7.

By comparing the two tables, except for sites 5, 8, and 9, one will find that the change in use rate is very small. For those three sites, even though the changes in use rate were relatively large, the changes did not affect the group to which they belonged. For example, at site 5, the use rate increased from 4.3 percent to 13.6 percent but it is still in the low-use rate group.

Through observation it was noted that the major factor affecting the rate of cyclists using the crosswalk was that if a crosswalk was offset from the intersection there would be a tendency for fewer cyclists to use it. It was found that if a crosswalk was close enough to a cyclist's route of travel, the cyclist was likely to use the crosswalk, even though it was not directly in his or her course.

CONCLUSIONS AND RECOMMENDATIONS

1. Cyclist push buttons have the highest usage rate by bicyclists (48.0 percent), C/P push buttons have the next highest (32.7 percent), and standard push buttons have the lowest (13.6 percent).

2. There is no significant difference in the push button usage rates at type A and type B intersection approaches; the installation of painted bike lanes has no effect on the usage rate of push buttons.

3. The presence of motor vehicles at intersection approaches from either direction does not affect the action of the cyclists pushing the buttons.

4. Painted bike lanes have no effect on cyclists stopping withing the safer queue area (zone 1).

5. Cyclist push buttons induce the majority of the cyclists to stop in zone 1, the most suitable queue area for cyclists.

6. C/P push buttons and standard push buttons cause more cyclists to stop in zone 4, the area that has the greatest potential of accident occurrence.

7. When stopped at a red light, a large number of cyclists making a left turn shift to the left side of the road.

8. Evidence shows that the C/P push button is not a desirable design for it does not have a high usage rate by cyclists and it causes a large number of cyclists to stop their bicycles in an undesirable queue area.

9. Intersection approaches equipped with cyclist push buttons have a higher rate of delay than the approaches equipped with other types of push buttons.

10. More than 80 percent of motor vehicles turning right yielded the right-of-way to the cyclists.

11. Cyclists are willing to use the crosswalk while they cross the intersection provided that the crosswalk is not too far from their route of travel.

12. Only a very low percentage of the cyclists who use crosswalks walk their bicycles while crossing the street.

Future installations of push buttons should be cyclist push buttons in order to achieve the maximum utilization. If possible, replace C/P push buttons with cyclist push buttons at busy intersections. Channel bicycle traffic at intersections by providing cyclists with bicycle crossings or painted queue areas to avoid motor vehicle-bicycle conflicts. Unless this channelization at intersections is done, the effect of separating the bicycle from the normal traffic flow by bike lanes is of little use. Encourage cyclists to follow the pedestrian walking signals by either stating a bicycle safety rule that cyclist should follow the pedestrian signals or by posting signs such as: BIKE RIDERS CROSS ON WALK SIGNAL.

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Evaluation by Experienced Riders of a New Bicycle Lane in an Established Bikeway System

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The attitudes of cyclists toward a newly established on-street bicycle lane and its effect on their route selection were analyzed by pre- and post-bicycle lane mapping and interview studies and by pre- and post-bicycle lane traffic counts. Cyclists rated the street as a much improved bicycle route, and both the mapping interview studies and the traffic counts demonstrated that many of them shifted their route selection to take advantage of the bicycle lanes. These ratings and route selection shifts occurred because cyclists believed that the bicycle lanes made riding safer and more convenient by giving bicycles their own area on the street. The degree to which bicycle lanes were considered an improvement and the likelihood of a route shift to take advantage of them were strongly related to the age of the cyclist. Cyclists 25 and older perceived the greatest degree of improvement and were most strongly influenced in their route selection. College-age (18 to 24) cyclists perceived the smallest degree of improvement and were least influenced in their route selection by the installation of the lanes.

One of the most salient and sensible questions about bikeways is, "Do riders really like them, and will they use them?" There are many reports of an increase in bicycle traffic following installations of bicycle paths or lanes, but the interpretation of these results is confounded by the possibility of increased bicycle traffic with or without lanes. Moreover, in a community where riders had no bicycle facilities there is a strong novelty effect that might tend to obscure negative attitudes that would develop with more experience. At present few communities have bicycles facilities well enough established to serve a large and sophisticated riding population. Therefore, the opportunity to study the response to installation of a new set of bicycle lanes in Davis, California, which has many riders and an 8-year history of bicycle facilities, was especially welcome.

In the initial design of the city of Davis bicycle lane system, a general travel grid for bicycles was laid over the existing street grid. Provisions for bicycles were made with on-street bicycle lanes on some of the streets and no facilities were provided on others. One arterial for which bicycle facilities had originally been considered was Anderson Road; however, bicycle lanes were not built in the original development. An argument against the lanes was that parallel bicycle lanes on arterials 0.40 km (0.25 mile) in either direction from Anderson Road would attract the bicycle traffic to them, making lanes on Anderson Road unnecessary.

This hypothesis seemed to be contradicted by experience. In 1974, Anderson Road still carried a very high volume of bicycle traffic. The city then put bicycle lanes on Anderson Road, altering its original configuration of 195 m (64 ft) of four traffic lanes and on-street parking to two traffic lanes, two-way left turn lane, 4-m (1.4-ft) bicycle lane, and on-street parking, as indicated in Figure 1a and b.

The high volume of traffic on Anderson Road led to the alternative hypothesis that the bicycle lanes on the alternate routes were not attracting a significant part of the riders. The establishment of new bicycle lanes provides an opportunity to get a more precise evaluation of both these hypotheses.

This new facility also provides an opportunity to examine two hypotheses about bicycle lanes that have been advanced by their critics. Critics generally argue that lanes are imposed on resisting cyclists. The generally acknowledged enthusiasm for the lanes by Davis cyclists has been interpreted by Scott (1) as revealing that the Davis population is composed of two sorts of cyclists: voluntary and involuntary. Involuntary cyclists are those without enough money to drive an automobile or enough status to get an acceptable parking place. They are the young and the poor. Since students are frequently both, they constitute a large group of involuntary cyclists. The Scott hypothesis asserts that only such unwilling cyclists want bicycle lanes. Cylists who freely choose bicycles over readily available alternatives reject the lanes. Since the new bicycle facility serves an area housing people falling into both of Scott's categories, their reaction to it provides an opportunity to examine his hypotheses.

Another hypothesis critical of bicycle lanes is Forester's (2) contention that bicycle lanes are redundant on streets that have wide traffic lanes. Since the original configuration of Anderson Road included a very wide curbside lane of 6 m (20 ft) including parking, the installation of bicycle lanes provides an opportunity to learn whether or not the cyclists regard the lanes as redundant.

The basic methodology is a comparison of the route choice of the bicycle riders in the general area served by Anderson Road before and after the installation of the bicycle lanes. The comparison was accomplished in two ways: (a) through the comparison of route maps obtained in interviews conducted before and after the bicycle lanes were established, and (b) by a comparison of the bicycle traffic on Anderson Road before and after the installation of the on-street lanes.

PREVIOUS STUDIES

The approach used in this study differs from approaches used in previous studies. Route choice usually involves motorized transportation modes. Further, in the case of transportation studies using standard planning packages, the focus is on a system of alternative transportation links (3). Alternatively, studies that focus on route choice in the context of disaggregate behavioral travel demand models (4, 5) attempt to capture the essentials of individual decision processes, which are hypothesized to involve both individual characteristics and the characteristics of the routes under consideration.

Both the systems and disaggregate approaches to route choice attempt to describe alternative routes in an abstract manner. That is, the attempt is to specify a small number of variables that describe alternative routes with respect to the route choice decision. At the extreme is the common practice in the route assignment routines in the standard planning packages. Here routes are often characterized by a single factor, travel

Figure 1. Anderson Road: (a) before modification and (b) after modification.

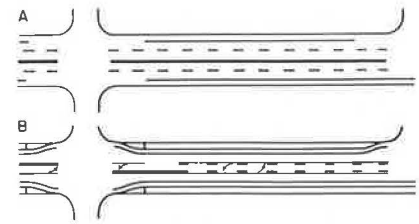
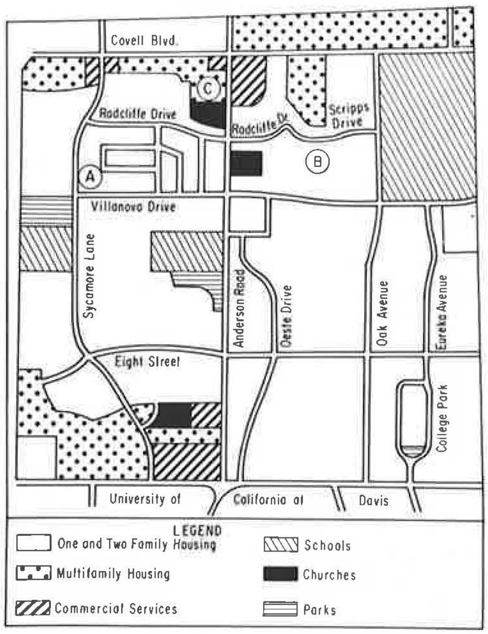


Figure 2. Commuting routes and land use patterns in relation to mapping-interview sites.



time, and trips are assigned to the route with the minimum travel time. Similarly, in disaggregate studies, routes are usually characterized by trip costs and times and the decision maker is assumed to choose that route with the most satisfactory time and cost combination. Further, the data used to develop such models are collected at one point in time—a cross-sectional approach.

In contrast, the present study focuses on a single bicycle route. The attempt is to examine whether the installation of bicycle lanes on this particular route influences bicyclists' responses to the route. The methodology is to gather data on bicyclists' route choices before and after the installation of the bicycle lane. Since variables such as trip times and costs did not change appreciably after the installation of the bicycle lane, it is possible to focus on the single attribute of bicycle lane installation without considering the effects of other factors.

The present study also differs from previous studies of bicycle transportation. Much research has been devoted to either the physical design of bicycle facilities or the discussion of the public planning processes involved in the location of bicycle facilities (6, 7), but little research has focused on the actual behavioral response to such facilities. The research that has focused on the behavior of bicyclists has usually not considered explicitly the influence of bicycle facilities on that behavior (8, 9).

Therefore, this study is an attempt to consider the effects of a particular bicycle facility on bicycle route choice. The study involves the use of a case study of a particular route to identify the effects of the facility on route selection. Since some of the other factors considered in route choice studies (e.g., trip times and costs) are not systematically considered in this study, it is recognized that a complete planning approach is not being developed. Rather, this paper uses a case study approach of a particularly interesting city to illustrate the possible influences of bicycle lanes in route choice. Such an approach is useful in furnishing insights into bicycle facilities planning in other cases and would also complement a more standard approach to route choice, which would be an interesting subject for future research.

DAVIS ROUTE CHOICE STUDY

There were two mapping interview studies. The first was conducted during the third and fourth weeks of May, prior to the striping of the bicycle lanes, which occurred during the first week in June. The goal was to determine the usual route choice of the people in the service area prior to the installation of bicycle lanes. Therefore, the subjects selected were people living north of Villanova Drive and on or within two blocks of Anderson Road (see Figure 2). Three housing groups chosen to provide extensive samples of each of the three demographic and geographic subpopulations served by this corridor were interviewed. A total of 254 subjects were contacted in their homes by a 25-year-old male, who presented them with a printed map of the city streets and asked them to identify their usual route to downtown or campus. An attempt was made to contact each household in the survey areas, and every cyclist in each contacted household was interviewed.

Housing group A included 25 subjects living in duplexes or single-family homes west of Anderson Road and north of Villanova Drive. They reported high use of Anderson Road (92 percent) with the remainder (8 percent) using Sycamore Lane. Housing group B included 42 subjects living in duplexes or single-family homes east of Anderson Road and north of Villanova Drive. Anderson Road was the usual route for only 33 percent of these cyclists; the remainder used Oak Avenue (43 percent), College Park Drive (12 percent), and Oeste Drive (12 percent). Housing group C was 176 cyclists interviewed in apartments located near the southwest corner of Anderson Road and Covell Boulevard. Eighty-nine percent of these subjects told us they customarily used Anderson Road as their route to downtown or the university. Figure 2 shows the relationship between housing group and usual route chosen.

The results from housing areas A and C tend to support the notion that bicycle traffic route choice is governed primarily by convenience rather than the availability of bicycle facilities. Nearly all riders chose a direct route. The results from housing area B are less clear cut. There was a split in route choice between Anderson Road and Oak Avenue. Our interview technique did not provide any basis for evaluating the reasons for route choice.

As a means of focusing more sharply on the question of the role of bicycle lanes in route choice, we conducted a somewhat different mapping-interview study during the second week of August, 2 months after the striping of the lanes. This allowed time for opinion to jell and habit patterns to alter.

The housing area in the second survey was bounded by Villanova Drive on the south and Radcliffe Drive on the north (see Figure 2). Forty-four cyclists lived east of Anderson Road and west of Oak Avenue. Sixty-four cyclists lived west of Anderson Road and east of Sycamore Lane. These boundaries were extended east to Oak Avenue and west to Sycamore Lane from the first survey to include more cyclists for whom Sycamore Lane and Oak Avenue were more feasible alternatives than were included in the first survey. A 100 percent sample was attempted in this survey also, producing some overlap with the first survey. Since the student apartment dwellers used the Anderson Road route before the installation of the bicycle lane, route shift was considered too unlikely to justify inclusion of these subjects in the second survey.

The interviews were conducted by the same young man who had conducted the previous mapping interviews. The questionnaire was designed to gather a certain amount of demographic information that seemed likely to be relevant to bicycle route choice in the study population.

Nearly every home had one or more cyclists, and interviews were secured with 54 male and 56 female riders. Most (57 percent) were 25 years old or older. The educational level of the sample, excluding minors under 18 years of age, was 15.5 years of schooling completed by female cyclists and 18.4 years by male cyclists.

Minors made up 29 percent of the sample; adult male and female cyclists each represented 35.5 percent. One-third of the adult women were housewives, 28 percent attended the university, and 38 percent were employed full- or part-time, most as elementary or secondary school teachers. Thirty-one percent of the adult male cyclists were University of California, Davis, students, 28 percent were faculty, 36 percent had nonfaculty employment of various types, and 5 percent were retired.

These subjects were asked two questions about route choice. First, they indicated on a printed map their usual routes to downtown or campus. When question 1 had been answered, question 2 was asked: "Have you changed your route lately?" Two subjects, one male and one female, each 25, had moved to Davis after lane installation and so were excluded from the remaining analysis.

For analysis we divided the sample into two residential areas. For the 44 cyclists living east of Anderson Road, use of the new bicycle lanes meant traveling an additional block or two on each end of a 1.6- to 3.2-km (1- to 2-mile) trip. In contrast, the 64 cyclists living west of Anderson Road were provided a more direct bicycle lane route to the university campus or to downtown Davis through the university bicycle path network.

Overall patterns of use of Anderson Road were similar for each residential area. Roughly half the cyclists used Anderson Road before bicycle lanes were provided. After the paths were installed, nearly half of the remaining cyclists changed their route to travel on Anderson Road. These changes are reported in detail in Table 1.

Among the cyclists living east of Anderson Road there were striking changes among the 25 years or older age group in the choice of Anderson Road. Male use increased from 40 to 80 percent and female riders increased use from 36 to 64 percent. All of the cyclists under age 17 said they already used the Anderson Road route, but five children said they had previously ridden on the sidewalk along the street.

The pattern of change was different west of Anderson Road. Nearly two-thirds of the men age 25 and over were already using Anderson Road so the increase in mature males from 63 to 84 percent was less dramatic. Female cyclists over 25 years old increased use of the Anderson Road route from 39 to 64 percent. Considerable increase took place in the elementary, high school, and college groups as well. No one who had ridden on Anderson Road before the bicycle lane was established switched to another route, but 45 percent of those using other routes before the bicycle lane was established switched to Anderson Road afterward.

To this point, of course, we are reporting only the verbal behavior of the subjects. Very positive or negative attitudes toward lanes or their use could distort the accuracy of these statements. The basic question asked in this study is whether there was more peak-hour bicycle traffic on Anderson Road after the installation of the bicycle lanes than there was before. In order to answer that question, of course, it was necessary to count the traffic before and after. By itself, however, such data would remain ambiguous. Many things affect traffic counts on any given day, so the really meaningful figures have to be comparative, and the question has to be asked in the form, "Did relatively more people ride on Anderson Road before or after the bicycle lanes compared to the number riding the parallel streets where the bicycle lanes had already been established?"

The needed counts were done simultaneously by three observers on all three streets on two consecutive days some weeks before the establishment of the paths, and on two consecutive days 1 week after their establishment. All bicycle traffic was manually counted from 7:30 to 8:30 a.m. on each of the four mornings and from 3:30 to 5:30 p.m. on each of the four afternoons. Bicycle traffic was counted within 30.5 m (100 ft) north of the intersection of Oak Avenue, Anderson Road, and Sycamore Lane with Russell Boulevard, the east-west arterial adjacent to the campus.

Previous studies suggested that all bicycle riders might not be equally influenced in their route choice by the existence of bicycle lanes. Therefore, we categorized the bicycle riders into age and sex classes

Table 1. Selection of Anderson Road as a travel route before and after bicycle-lane installation.

	Age and Sex Class										
	0 to 11		12 to 17		18 to 24		25 and up		Total		
Route Selection	M	F	M	F	M	F	M	F	M	F	All
Residence east of Anderson											
Using other route before	2	-	-	-	3	1	7	10	12	11	21
Using Anderson before	1	3	3	5	1	1	4	5	9	14	23
Using Anderson after	1	3	3	5	1	2	8	9	13	19	32
Change from other route to Anderson	-	-	-	-	-	+1	+4	+4	+4	+5	9 of 21 (43%)
Residence west of Anderson											
Using other route before	2	6	3	1	3	1	7	11	15	19	34
Using Anderson before	1	2	3	-	2	3	12	7	18	12	30
Using Anderson after	1	4	6	-	3	4	16	12	26	20	46
Change from other route to Anderson	-	+2	+3	-	+1	+1	+4	+5	+8	+8	16 of 34 (47%)

while recording the traffic to permit later analysis of possible differential responses of these age and sex classes to the existence of the bicycle path. Age was estimated by the observer. Different patterns of use among cyclist age-sex groups emerged as the three routes were compared during the peak hours of morning commuting (7:30 to 8:30 a.m.), after-school travel (3:30 to 4:30 p.m.), and evening commuting (4:30 to 5:30 p.m.). Each of the three routes increased its ridership by similar numbers—Anderson Road and Sycamore Lane each added 103 riders and Oak Avenue drew 95 additional riders. However, the observed composition of cyclists by age-sex groups shifted considerably. These data are reported in Table 2.

It is clear from this table that Anderson Road after its new bicycle lanes did not show greater increase in riding than the other streets, but there was a marked increase in riding by cyclists 25 years and older. This subpopulation increased on all three travel routes, but the most marked increase was on Anderson Road. The table below abstracts the data on this age group.

Alternate Route	Before	After
Sycamore Lane	134	145
Anderson Road	255	477
Oak Avenue	240	364

The table reveals that the use of Anderson Road by this age group was both absolutely and proportionately much greater than on Oak Avenue and Sycamore Lane, whether the streets are considered separately or together. It is difficult to know just what model is appropriate to evaluate the statistical reliability of this outcome. Since the same riders are apt to appear both before and after the lane was established, the assumption of statistical independence required for χ^2 contingency tables may be violated, and the degree of statistical reliability of observed differences is underestimated. This is because the model assumes that their choice of route after the lane was established was not influenced by the previous route. To the extent, if any, that established habit patterns lead to choice of the former route, the attractiveness of the bicycle lanes as a route feature is underestimated. This is the most conservative treatment of the data and, therefore, was followed. When the differences are compared this way, the increase in traffic by this group is statistically reliable compared to the increase on the other two streets combined ($\chi^2 = 9.20$, df = 1, $p < 0.01$). The increase on Sycamore Lane alone is reliably less than that on Anderson Road ($\chi^2 = 14.3$, df = 1, $p < 0.001$), and the increase on Oak Avenue alone is also reliably less than that on Anderson Road ($\chi^2 = 3.20$, df = 1, $p = 0.08$). Thus, riders in this age group increased more both relatively and absolutely on Anderson than on either of the alternative routes. There were fewer college-age riders, especially males, on all routes in the afternoon. This count was made during the last week of the quarter, during a period of increased participant sports activity on the campus. Perhaps these factors led to a later homewardbound schedule. There were many more children in the early morning traffic during the June count. The geographical relations between housing and schools in that area suggest that they were relatively long 2.4- to 3.2-km (1.5- to 2-mile) school trips. Probably the total increase in these younger riders and those over 25 is due to the improved riding weather in June.

Table 2. Cyclists' choice of three alternate routes before and after restriping of Anderson Road for bicycle lanes.

	Age and Sex Class							
	0 to 11		12 to 17		18 to 24		25 and up	
Alternative Route	M	F	M	F	M	F	M	F
Sycamore Lane								
Before	82	13	28	14	526	389	118	16
After	98	33	26	31	552	443	130	15
Anderson Road								
Before	6	3	29	14	617	550	223	32
After	2	5	33	8	488	564	395	82
Oak Avenue								
Before	2	1	27	18	277	139	206	34
After	5	1	24	16	232	157	284	80

In any case these data tend to support the self reports of the second mapping study: The existence of the bicycle lanes strongly influenced the route choice of the cyclists age 25 and over. The cyclists' reasons for changing their route to incorporate the new facilities on Anderson Road were revealed by their responses to questions in the second mapping-interview study.

Our best evidence on the reasons for this route shift was in answer to the question asked in the second mapping study: "Please rate Anderson Road for bicycle use before and after striping of lanes." A rating of 1 was used for very good conditions and a rating of 7 for very bad ones. A comment section was provided and drew many explanations for the rating given.

A strong consensus thought that Anderson Road was greatly improved for cyclists by the restriping. The average rating for Anderson Road after the bicycle lanes were striped was 3.7 points lower (better), which was more than half the scale. No subject thought it was worse and only two thought there was no change. Anderson Road before bicycle lanes was given a mean rating of 5.5 by the 97 cyclists answering the question. Adults over 25 rated it 1.3 points worse on the scale than did college-age riders. Female riders gave it a slightly worse rating than males of the same age group in these cases. Ratings by riders under age 17 were intermediate and did not differ by sex.

Anderson Road after the bicycle lanes were completed received a mean rating of 1.97 with close agreement among age groups. Variations in the amount of perceived improvement stemmed from the fact that riders over age 25 perceived the original street conditions as being worse than did any of the other age groups.

In this age group our studies had already revealed the greatest extent of route shift to take advantage of the bicycle lanes. This correlation suggests that the probability of shifting to a new route is influenced by the degree of improvement perceived. To provide some additional evidence bearing on this hypothesis we studied the relationship between the degree of improvement perceived by the individuals and the incidence of changing routes.

We took as our study group those people interviewed in the second mapping study who had not been riding on Anderson Road before the bicycle lanes were built. Since some of them shifted routes to use the bicycle lanes and others did not, we were able to compare each person's evaluation of the degree of improvement in bicycle accommodations on Anderson Road to the probability of changing routes to ride on Anderson Road. Since the occurrence of route shift was a dichotomous category (yes or no), it was useful for statistical evaluation to create dichotomous categories of degree of facility improvement. This was done by determining the mean shift in route evaluation and categorizing the difference between each individual's pre- and post-bicycle lane ratings as larger or smaller than the average difference for the group. These same individuals were also categorized according to whether or not they switched routes to Anderson Road. The respondents living east of Anderson Road are considered separately from those living west of Anderson Road. Separate improvement means were calculated for each group and each individual in that group was categorized as recording a rating improvement above or below that group mean. Five subjects (four living east of Anderson Road and one living west of it) declined to rate the degree of change and so are excluded from this analysis.

Degree of Improvement Perceived	Changed to Anderson Road	No Change
Above the mean	6	0
Below the mean	3	7

The above table reveals that those living east of Anderson Road whose evaluation of the improvement of bicycle accomodations was above the mean were more likely to shift routes than those who perceived less improvement than did the average subject. This difference is statistically reliable ($p = 0.025$ one-tailed, Fisher's exact probability test).

The difference is of considerable interest since those living east of Anderson Road shifted to a route that leads less directly to most work or shopping destinations than did formerly used routes. Consequently, their shift is apparently a function of their conviction that the superiority of currently available facilities outweighs convenience in their route choice. For those living west of Anderson Road, it is a more convenient route than was formerly available with bicycle lanes:

Degree of Improvement Perceived	Changed to Anderson Road	No Change
Above the mean	8	7
Below the mean	7	6

In their case the average improvement recorded was slightly less (3.7 compared to 4.3 for those living east of Anderson Road) and, as shown above, there was no relationship between the perceived degree of improvement and the probability of making a route shift.

Cyclists' comments about the effect of striping give some insight into the reasons for these ratings and route shifts. Primarily they talked of being safer because of a separation of modes of traffic. Fifty-three of the 100 comments mentioned separation or the importance of having your own area on the street.

We also asked those 78 cyclists who were licensed drivers to rate Anderson Road for automobile use before and after restriping on the same seven-point scale. Among the 71 drivers who responded, the mean degree of improvement was 2.0 points, from 4.6 before to 2.6 after.

SUMMARY AND CONCLUSIONS

A new bicycle lane may gain increased ridership from a variety of factors. Increased bicycle ownership and the relatively small number of desirable cycling facilities often confuse the picture when attempts are made to evaluate the use of a new bikeway.

In these studies it was possible to minimize these factors. Bicycling in the city of Davis is so widely accepted as a mode of transportation that the number of newly purchased bicycles is a small influence in the overall number of riders. The existence of long-established bicycle lanes on two alternative routes to the same destination avoids the problem of novelty effect, which may occur if people come from adjacent areas to enjoy a new bikeway. Comparative before and after data of the three routes measured the amount of change in use by various age-sex subgroups. Interviews, route maps, and observation yielded consistent results, each helping to verify the other data.

So it is clear from these studies that bicycle facilities can act as a significant attraction in route choice. Bicycle lanes are regarded as an improvement in riding conditions by about 99 percent of riders who have previously experienced riding on the same facility without lanes. Since Anderson Road in its original configuration had a very wide outside lane, this demonstrates that cyclists do not believe that a wide lane shared with motor vehicles is as satisfactory as a bicycle lane.

The greater the degree of improvement perceived by the individual rider, the more likely it is that that individual will change his route to use the bicycle lane. Not all subpopulations of riders and not all choices by a given subpopulation are equally affected. If a bicycle lane route is markedly less convenient than a route without one, convenience generally determines the choice. College-age riders are substantially less influenced by the availability of bicycle lanes than are older riders. This bears directly on the Scott prediction of the response of voluntary versus involuntary cyclists. Whatever the true viability of this conceptual scheme, it is clear that it would classify more riders 18 to 24 years old than those 25 years and older as involuntary cyclists. If this age variable is used as a surrogate for the voluntary versus involuntary status variable, then the data are not consistent with Scott's hypothesis.

This information can be useful in offering insights into planning bicycle facilities in other areas. Further, the characteristics of individuals that appear to be important in this study could also be incorporated into future studies that attempt to consider the joint contribution of bicycle lane designation and such variables as convenience of travel on route selection. Such studies, which might use the procedures used in route-choice studies for motorized modes, would complement this study in furnishing information for the planning and evaluation of bicycle facilities.

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Discussion

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The authors recommend that cycling transportation engineering and planning should be guided by their findings that a significant proportion of Davis cyclists over 25 years of age (incorrectly described as experienced riders) changed their routes to use a newly bike-laned street because they believed that the bike lane made the street significantly safer. Innocuous and conservative as that recommendation appears to be, it raises critical issues of public policy and professional ethics. The bikeway controversy is between scientific knowledge and superstitious support of bikeways.

There are three ways, in general use, of following the authors' recommendations: (a) Install bike lanes because people believe that bike lanes reduce cycling accidents significantly, (b) install bike lanes in order to persuade more people to use cycling as a mode of transportation in the belief that cycling has been made sufficiently safe for use, and (c) install bike lanes to persuade cyclists to change their route in the belief that the new route is safer.

All of these actions appeal to the public superstition that bike lanes make cycling much safer. However, there is no objective evidence that painting the normal bike-lane stripe modifies either cyclist's or motorist's behavior in such a way as to reduce accidents. On the contrary, the evidence available at this time is that if the desired modifications were totally achieved, the reduction in cyclist accidents would be about 0.3 percent [2 percent of urban daylight automobile-bicycle collisions (10) times 17 percent of all cyclist accidents (11, 12)], and that the modifications actually produced are to increase some types of behavior that already produce significant proportions of automobile-bicycle collisions. The Lotts claim that bike lanes have reduced automobile-bicycle collisions in Davis (13), but their data are swamped by uncontrolled variables such as width of street and presence of traffic controls, their non-validated computational method shows internal inconsistencies, and their claimed reductions greatly exceed the number of automobile-bicycle collisions that are amenable to the bike-lane treatment (14). The controversy still rages because of the emotions involved, but if bike lanes had the qualities attributed to them by bikeway advocates, the evidence in their favor would now be overwhelming. In fact, bikeway advocates repudiate the best studies in the field (10, 11) and adopt unproved statistical computations and incorrect comparisons in attempts to detect an effect that, if present, has been too small to detect by normal methods.

If this analysis is correct, then responding to the public demand for bike lanes in any of the ways described above is detrimental because it diverts resources (financial, intellectual, and public support) away from the real means of improving cyclists' safety and convenience. In my opinion there is also ample evidence that bikeways are detrimental to cyclists, but this is a more controversial issue. Insofar as bike lanes are advocated as a means of changing the public's travel patterns by mode or by route, by persons who do not have adequate scientific evidence that bike lanes reduce cyclist casualties, this is a process of manipulating the public by misrepresenting the safety improvement produced by bike lanes.

Given this disparity between opinions, it is reasonable to investigate how the authors' recommendations came about. I find two deficiencies in their paper: (a) Cyclists are incorrectly described as experienced on the basis of age and residence in Davis, and (b) the actual hazards of the roadway are not described and assessed.

The authors assume, both herein and in other contexts, that riding for a few years in Davis makes one an experienced cyclist. This does not match the dictionary definition of the word, which is one who is wise and skillful through experience. The action of riding in Davis is insufficient to develop skill or wisdom. Davis is a small city (population 34 000), isolated from others and with only internally generated traffic. Contrary to the Lotts' claim that it is a 4.83 × 11.3-km (3 × 7-mile) rectangle (13), its built-up area is 3.2 × 4.8 km (2 × 3 miles) and the maximum one-way commuting distance is about 5.6 km (3.5 miles) (15). The average student cyclocommuting distance is 2.6 km (1.6 miles) (16). Davis cyclocommuters average 19.3 km/h (12 mph). In contrast, employed adult cyclocommuters to the Sunnyvale aerospace complex about 160 km (100 miles) away average 25.7 km/h (16 mph) with an 85th percentile of 29.7 km/h (18.5 mph), and the slowest observed speed is equal to the Davis average. Their average one-way commuting distance exceeds 6.4 km (4 miles) and significant numbers travel over 16.1 km (10 miles). Their trip is largely through normal metropolitan area traffic. Davis cyclocommuters rarely ride elsewhere, and in Davis they do not need to travel efficiently through heavy traffic, so they do not learn how to do it.

The roadway in question is 19.5 m (64 ft) wide. It was divided into four 3.65-m (12-ft) traffic lanes and two 2.4-m (8-ft) parking lanes. In 1977 its two-way average daily traffic (ADT) was 8500, and its speed range was 40 to 56 km/h (25 to 35 mph). This is a good design and easy traffic load. From examination both before and after construction of bike lanes, I conclude that it presented no unusual facility or traffic hazards, except Davis motorists' nasty habit of turning right without first merging and the incompetence of Davis cyclists. I see no reason to believe that overtaking motorists constituted a greater than average hazard on that street. I know of no data showing that such streets are particularly hazardous in any way that might be ameliorated by bike lanes. If the street did not have an accident rate considerably above average before the bike lanes, it is practically impossible for the bike lanes to make a large reduction in automobile-bicycle collisions.

My recommendation is to take those actions that can be reasonably expected on scientific grounds to significantly reduce cyclist accidents or improve traffic flow in an equitable manner and to treat the psychological problems of cyclists, the cyclist inferiority complex that produces these peculiar opinions, by the appropriate measures for such problems. Acceding to the desires of the Davis cyclists would not even have the merit of protecting cyclists from their own errors, because it is generally agreed that bike lanes do not protect against the errors of motorists turning right, cyclists running stop signs, and cyclists turning left.

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Authors' Closure

The main purpose of our paper was to present information on the impact of a new bicycle facility on route choice. Such information may be useful in an assessment of the possible increase in ridership on a proposed bikeway facility. Changes in ridership should then be considered with other potential impacts, such as safety, in deciding whether to install a bikeway. Our recommendations deal with how to provide better information on the objective ridership impacts of bicycle lanes and on people's satisfaction with bikeways, not with the normative questions of whether bicycle lanes ought to be provided or whether people should be induced to use them.

Therefore, Forester's discussion seems to be peripheral to the main point of our paper. He has taken this occasion to renew his earlier criticism (14) of an earlier paper by Lott and Lott (13), which analyzed the enhancement of cyclist safety achieved by bicycle lanes, to attack bicycle lane safety in general. This has no relevance to the present paper, so on this issue we will confine ourselves to pointing out that the overwhelming preponderance of empirical data collected from objective sources demonstrates that bicycle lanes enhance cyclist safety very substantially. To take but one example, the Cross study (10) found that 37 percent of all fatal bicycle-automobile accidents in the absence of bicycle lanes were the result of automobiles overtaking cyclists. Even Forester agrees that bicycle lanes prevent that kind of accident.

The main issue that is both addressed by Forester and relevant to this paper is the issue of the experience of Davis cyclists and the credibility it gives them as evaluators of bicycle facilities. We believe that a typical 25-year-old Davis cyclist's experience in riding 1931 to 2414 km (1200 to 1500 miles) a year for 6 to 8 years (more total distance than San Francisco to New York and return) is a meaningful level of experience and can serve as the basis for informed judgment about bicycle facilities. Forester disagrees. As one line of evidence for his view he cites "bad riding" by Davis cyclists. This is surprising in view of his contention a few months ago (14) that the lowered accident rate in Davis bicycle lanes reported by Lott and Lott (13) was the result of improved riding by Davis cyclists rather than the lanes themselves.

Forester's second line of evidence concerning the alleged incompetence of Davis bicycle riders reveals an important aspect of his position. He compares the speed of Davis bicycle commuters to the speed of Sunnyvale commuters. In his view the lower speeds in Davis clearly reveal the cyclists to be incompetent. Although Forester equates fast cyclists with knowledgeable cyclists and vice versa, bicycling speed is determined by physical condition, not expertise. Riding a bicycle at 19.3 km/h (12 mph), the average Davis speed, takes about 37 W (0.05 horsepower), the highest sustainable output for an untrained individual (17). Riding at 25.7 km/h (16 mph), the average Sunnyvale speed, takes 74.6 W (0.10 horsepower), much more work than the untrained individual can sustain. The 85th percentile at Sunnyvale rides at 29.8 km/h (18.5 mph), which requires about 119.4 W (0.16 horsepower), a level of effort that only 1 or 2 percent of adults can sustain. These riders are well-trained and well-motivated athletes. That does not make them traffic or facility experts, but it does make them a cycling elite, which Forester believes should be the focus of public policy on bicycle facilities. He does not shrink from the fact that the needs of 98 percent of adults and 99 percent of children are neglected by the public policy advocates. Rather, he believes that cycling is inherently elitist, that many will aspire but few will achieve, and that it should and must be that way. He believes that now and always the rare sight of a doughty rider challenging taxis, trucks, and tornados on a featherweight 15-speed bicycle will inspire a murmured or silent, "There goes a real man," from every passerby. The truth is, experience has taught us that if we make cycling safer and more pleasant, a great many very ordinary people are able and eager to do it. In our judgment, wise public policy will be guided by the needs of the many rather than those of the few.

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North Carolina's Bicycling Highways

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The bicycle program of the North Carolina Department of Transportation has initiated a unique project called "bicycling highways" to develop a statewide bicycle route system on existing roads of the state's primary and secondary highway system. The purpose of the project is to provide some measure of safety for cyclists. Although no roadway where automobile and bicycle mix will ever be totally safe, many highways, unknown to the majority of people, are relatively safe for bicycling due to their low traffic volume and good roadway conditions. By linking these roads throughout the state and providing detailed route information, a safer environment is expected for all. This paper describes the methodology undertaken in the selection of highways, survey techniques, information gathering procedures, map drafting, and reproduction. The resulting maps and narrative provide a very usable and informative product, which requires only small amounts of money and resources.

The bicycle program of the North Carolina Department of Transportation initiated a unique project 3 years ago: the development of a statewide bicycle route system on existing roads of the extensive primary and secondary highway system. The idea for "bicycling highways," as the project is being called, evolved from three changes in the bicycle environment:

1. An increasing number of people, particularly adults, are bicycling. There are no bicycle traffic counts nor other sources to determine specific increases; however, evidence of this greater involvement has been observed at all levels of government. Requests to local and state agencies from across the state and nation ask the question, "Where can I safely ride my bicycle?" People are venturing out for 1- or 2-d bicycle trips, others are traveling much greater distances by bicycle, and still others wish to combine automobile-bicycle trips in the areas to which they travel.
2. The growth of the bicycling population has brought parallel increases in safety problems. Total transportation accidents and deaths in North Carolina are on the decline, but bicycle accidents and deaths are climbing. Moreover, the average age of those involved in accidents has increased significantly. There are many reasons for these accidents—unsafe bicycles, improper operation, or lack of respect from motorists, but a great many are due to the bicyclist's lack of knowledge of the safest roads on which to ride. Where traffic volumes are high and trucks are numerous, the potential for accidents is great unless special high-quality bikeway facilities are provided. In North Carolina, such facilities exist, on a limited basis, only in urban areas and are thus available to just a small segment of the population.
3. The seriousness of the safety problem has precipitated demands to improve the existing situation for both the bicyclist and the motorist. In 1974, the North Carolina Bicycle and Bikeway Act was passed, which mandated to the department of transportation the responsibility for developing a statewide bicycle network. The initial reaction was to provide extensive bikeways; however, such provisions are both impractical and impossible. To provide statewide bikeways for the needs and desires of North Carolina's bicyclists would require millions of dollars, amounts far beyond the most cost/beneficial expenditures required to provide a safe bicycling environment. The more feasible approach is to utilize what is already available to the bicycle—the 120 700 km (75 000 miles) of primary and secondary highways existing in the state. By selecting the roads determined to be safer for bicycling and providing the public with bicyclist-oriented maps and information, knowledge of alternatives to the high-volume roads presently being used by bicyclists would then be available.

The overall goal of the bicycling highways project is to locate those roads across the state that are safest for bicycling and link them into a network of routes to make a statewide bikeway system. This system will include four or five major routes and a series of regional loop routes, which will serve as local connectors to the major routes. Each route developed will be described in a route guide, which will include maps and narrative offering all information pertinent to the cyclist's safety and comfort. On completion, the bicyclist in North Carolina will have the most thorough bicycle-oriented road data available in any state.

North Carolina has much to offer the bicyclist. In the west lie the Great Smoky and Blue Ridge mountain ranges with 49 peaks over 1828 m (6000 ft)—a challenge to even the best riders. Weather conditions permit bicycling from May through October; fall is an especially spectacular season. This is a rugged and somewhat isolated region where recreation areas and scenic vistas abound. The region has several important historic sites and many points of interest.

Traveling east through the Piedmont area, the terrain changes to rolling countryside. Here, one occasionally encounters the remains of an ancient mountain. The climate is more temperate than in the mountains; bicycling weather is good from mid-March through mid-November. Spring and fall offer particularly pleasant warm days and cool evenings. Winter weather is often suitable for bicycling but is unpredictable; temperatures can vary from freezing to the upper sixties. The Piedmont is the most populated and industrialized area of North Carolina, and most of the major cities of the state are located here.

Stretching the final 161 km (100 miles) to the ocean, the Coastal Plain offers virtually flat land for easy pedaling. The days here are usually warmer than those in other sections of the state throughout the year. Spring and fall are generally the best times for riding because summer days are hot and humid. The Coastal Plain was the first section of North Carolina to be settled, thus the feeling of history is strong. Many historic sites and old plantation homes can be found throughout the area. Along the coast and on North Carolina's unique Outer Banks, a series of barrier islands off the coast, there are numerous recreation areas.

The bicycle program has completed the development of its first major long-distance bicycle route, the mountains-to-sea bicycle route, which traverses these three regions. This route runs from Murphy, deep within the Appalachian Mountains, to Manteo, on the Outer Banks—a total distance of 1146 km (712 miles). A route guide, which offers 16 segment maps and accompanying narrative, has been produced and is being distributed, free of charge, on request. Several thousand copies have been distributed since the guide first became available a year ago. Requests are still received every day from around the nation as bicycle touring grows in popularity.

Demand for such long-distance bicycle routes and bicycle-oriented road data is overwhelming; guidelines for development are virtually nonexistent. Therefore, step-by-step procedures used by the bicycle program in developing their system are offered below as a guide to the development of bicycling highways in other parts of the country.

Evolution of Project

1. Develop concept study,
2. Develop road selection criteria,
3. Conduct corridor study and selection,
4. Investigate information sources,
5. Select draft route,
6. Conduct field survey,
7. Design pamphlet format,
8. Produce pamphlet, and
9. Promote finished product.

CONCEPT

Prior to working out the details of actually developing the project, the general ideas had to be conceptualized. When firmly developed, a presentation of the concept was made to proper state officials, who offered their input and support for the project. Bicycling highways then had the important support it would need throughout its many phases.

Road Selection Criteria

To select a bicycle route from all the roads in a state would be an overwhelming task, unless some limiting factors were imposed. Therefore, a set of road selection criteria were developed to reflect what the ideal bicycling highway might offer. These include the following:

1. Traffic—The greatest hazard to the bicyclist is other traffic, particularly trucks. The most desirable road from this standpoint is, therefore, the one with the lowest volume of traffic. In terms of average daily traffic (ADT) counts, a road with a count of 1200 or less is most desirable. This means that at the peak travel hour, when it is estimated that 20 percent of the day's total traffic is on the road, 2 automobiles/min will pass in each direction. Traffic during the nonpeak hour would be significantly less frequent. A route with more than 25 percent commercial traffic is considered unsuitable.

2. Air pollution—A consequence of high volumes of traffic is a high level of air pollution. In such a situation, the bicyclist is forced to breathe air that contains excessive amounts of noxious gases; thus riding efficiency and alertness are directly affected.

3. Road surface—The road itself is an important consideration. The surface should be smoothly paved, preferably with high bituminous (plant mix) treatment. Some high-quality low bituminous (surface treatment) pavement is acceptable, however. Rough pavement increases the road resistence to the tire, thus increasing the effort a bicyclist must expend to propel himself or herself forward. Road shock cannot be absorbed by the bicycle on this type of surface and is transmitted to the cyclist. After a few hours of riding, the cyclist's hands become numb and other parts of the body feel great discomfort. Unpaved or gravel roads are unacceptable and should be avoided.

4. Roadway condition—The road selected should be in good repair, free from potholes, and have even, unbroken edges that are level with the shoulders. In the presence of potholes the cyclist is often required to swerve suddenly to avoid contact, thus endangering himself in the traffic flow. Uneven and broken road edges make it difficult for a cyclist to ride to the right to allow faster moving vehicles to pass. When the shoulders are low, a bicyclist who runs off the road might lose control and be thrown from the bicycle. Return to the road surface is also hazardous under such circumstances. These problems are not visible from the motorist's vantage point. The driver often cannot comprehend why a cyclist will not move to the right to allow a motor vehicle to pass. He or she may believe that the cyclist is stubbornly asserting a right to the road and thus become annoyed.

5. Roadway width—Wide lanes [over 3.66 m (12 ft)] and paved shoulders can sometimes compensate for otherwise undesirable features of a road. A somewhat higher volume of traffic, up to 2400/d, might be tolerated under these circumstances.

6. Grade and curvature—Steep grades should be avoided whenever possible, for obvious reasons. A 2 to 3 percent grade is the ideal maximum. Roads with many curves, where sight distances are short, should also be avoided.

7. Other—Other minor hazards should be avoided whenever possible. Railroad tracks that are not perpendicular to the road may catch a bicycle wheel and throw the rider. Narrow, one-lane bridges cause bicycle-motor vehicle conflicts. Roads that collect a lot of debris, whether natural or manmade, reduce riding efficiency and can cause bicycle maintenance problems, particularly flat tires. Strip development in cities and towns where there will be much entrance-exit activity on the road creates a prime accident area.

Corridor Study and Selection

To further limit the road selection process, it was determined that corridors 48 km (30 miles) in width would be defined; a 16-km (10-mile) leeway would be allowed on either side to compensate for the possibility that suitable roads might not be found within the primary corridor. The actual bicycle routes would be designated on roads within these corridors. Several factors were taken into consideration—existing corridors of bicycle travel, extent of present bicycling, state border points of frequent exit-entry, and frequent trip origin-destination points within the state. To determine the first three factors, information was solicited from individual bicyclists and bicycle clubs within the state. Correspondence with the bicycle program by both in-state and out-of-state cyclists requesting bicycle route information was reviewed for additional information. Maps detailing this information were prepared. To determine the fourth factor, maps were prepared showing population densities throughout the state; major points of interest, such as local, state, and national parks and recreation areas; historic sites; scenic areas; and places of cultural or educational significance. In order for any route to be useful, it must begin where cyclists are and end where they want to go.

Comparison and analysis of these maps and information defined several corridors within the state. It was found that one major east-west corridor, and three north-south corridors (one along the Blue Ridge Parkway, one along US-1, and one along the coast) were in regular use. It was further determined that the first route should be developed within the east-west corridor to serve as a backbone for the remainder of the system. Thus the mountains-to-sea bicycle route was initiated.

Information Resources

Once the corridor was selected an investigation of potential route information resources was undertaken. Much valuable data were collected from many state government agencies as well as from outside sources. This made the task of a route selection much easier. A thorough check was made of all maps available within the department of transportation and information was obtained on ADT counts, roadway widths, grades, and surfaces. Film footage of all primary highways made by the division of highways on the road provided an opportunity to make a preliminary review of some possible portions of the route before the actual field survey was conducted. The most important resource, however, was the experience and expertise of various central office and field personnel of the U.S. Department of Transportation.

Data on roads and road use were also solicited from local bicycle clubs, individual cyclists, and local and regional government contacts. A letter, which described the project and requested public input, was prepared and mailed to 250 individuals. Only 25 cyclists responded.

The reasons for this poor showing are unclear, but several speculations were made. Bicycling is a rather individual sport—perhaps the participants would rather bicycle than answer letters or attend meetings. Bicycling is a rather new sport—perhaps many cyclists do not feel qualified to respond. The bicycle program was, at that time, a new program—maybe it did not have sufficient contacts. It has since been learned by talking to many cyclists that all of these specifications were valid. Should we take this approach again today, the results would be more encouraging. Bicycling has continued to grow, and there are several good clubs in the state whose many experienced riders are willing to share their knowledge of safer roads.

Despite this poor showing, meetings were scheduled in eight cities across the state. At least 8 to 10 people attended each meeting. The success of these meetings varied. In one very urbanized area of the state, no useful route information was gained; in other areas, suitable 80-km (50-mile) segments were developed. The personal contact in all cases was extremely beneficial and served to develop a great deal of enthusiasm and support for the project.

Information was also collected on services and points of interest within the corridor. Some of this was accomplished during the preliminary field survey of the selected route, but as these attractions have a bearing on the actual route selected, some initial research was necessary. Within state government this information was obtained from the state parks and recreation division, the department of archives and history (including the state library, historic sites section, preservation section, and the state archaeologist), and from state travel and promotion, which handles all tourist information and has a wealth of pamphlets and brochures on points of interest throughout the state.

Additional information was gathered from local historical societies, newspapers and magazines, private foundations that have preserved various historic sites, and local chambers of commerce. National and regional government sources including the Blue Ridge Parkway administration of the U.S. Department of the Interior, the superintendent of national forests in North Carolina, and the Cape Hatteras national seashore administration were also contacted.

Selection of Draft Route

After this information was collected, corridor boundaries, road data, and preliminary information on services and points of interest were pinpointed on county highway maps [scale 2.54 cm = 3.2 km (1 in = 2 miles)], which show ADT counts for all state-maintained roads. In addition to this information, several other factors were taken into consideration in selection of the draft route.

Steps in Selecting Draft Route

1. Determine corridor,
2. Fix corridor boundaries on county maps,
3. Pinpoint known services and points of interest within corridor,
4. Select roads with low ADT counts,
5. Connect in linear fashion avoiding circuitous routing,
6. Provide access to cities and points of interest,
7. Keep any high-volume connector roads under 0.8 km (0.5 mile), and
8. Incorporate routes recommended by knowledgeable local cyclists.

Since the bicyclist's safety is the single most important consideration, a careful study was made of the low-volume (under 1200 ADT) roads within the corridor and an attempt was made to link these in a linear east-west fashion. Since a bicyclist will not follow a circuitous route, which will add an unreasonable distance to the overall trip, it became necessary, in some places, to route along short stretches of more heavily traveled roads to connect the desirable low-volume roads in a direct line. Generally, the distance of this connector was kept under 0.8 km. Where longer, it was designated as a hazardous area to be detailed in the final information offered to the bicyclist. Routes through large cities where traffic congestion would be high were avoided. The route should, however, come close enough to these centers of population to be useful to the cyclists living there and also to be a source of supplies and services for other cyclists using the route. In general, any area with a population over 5000 was skirted. Major points of interest such as state or national parks or important historic sites generate cyclist travel. Where safety considerations were equal, roads that provided closest access to these areas were selected. Wherever possible, the routes recommended by local cyclists were incorporated into the draft route.

FIELD SURVEY

When selection of the draft route was completed, a field survey was conducted. Although research of the route by bicycle would have been the ideal method, an automobile was used for the preliminary check since over 1609 km (1000 miles) of roadway had to be surveyed and the territory could be covered more quickly in this manner. Significant portions were covered by bicycle as a final check, however. Navigation and collection of data while driving presented the most serious problem in field survey data collection. Whenever possible, a driver was used while a second person navigated and took notes. A pocket cassette tape recorder recorded information. Freed from taking notes, it was possible to be constantly alert to road and terrain characteristics and to the exact location of all services. Numbers of the state secondary roads intersecting the route were used as reference for pinpointing all such information. The entire distance of the route was traveled in both directions. A turn that was easy to locate in one direction was sometimes confusing when traveling the other way and had to be noted for clarification on the final maps. Road signs were, on occasion, found to be incorrect or nonexistent; these locations were pinpointed for correction at a later date. Map portions that were confusing or difficult to follow were noted, to be clarified by enlargements on the final maps.

During the field survey, road selection criteria were applied to determine the suitability of the roads on the route and to locate areas where routing changes should be made. Notes were made about traffic conditions, type of terrain traversed, general description of the area (i.e., wooded, remote, or populated), and characteristics and conditions of the roadway and shoulder. Hazardous areas caused by heavy traffic, railroad tracks (those that cross roadway at an angle and would catch bicycle tires), bridges on blind curves, narrow bridges, poorly maintained roadways, broken roadway edges, and low shoulders were pinpointed. The method used to conduct the field survey is given below.

Conducting the Field Survey

1. Mark route on county road maps showing all state-maintained roads,
2. Use automobile to cover distance more quickly,
3. Have backup survey done by cyclists,
4. Use two surveyors (one to drive, one to navigate and take notes),
5. Use pocket cassette tape recorder to note information,
6. Use intersecting road numbers to reference information,
7. Travel entire route in both directions,
8. Check road signs carefully for errors,
9. Note any mistakes or confusing areas on base maps,
10. Note condition of roadway and shoulder,
11. Note traffic conditions,
12. Note type of terrain,
13. Note general character of area,
14. Note hazardous areas,
15. Note availability of services, and
16. Investigate points of interest.

Besides road data, availability of services essential to the cyclist were noted. All places directly on the route offering the basic services of food, water, and restrooms were pinpointed. No attempt was made to locate any such services away from the route, except in places where there was a scarcity of these basic service facilities directly on the route and no suitable alternative route was available. Those areas where the distance between basic service facilities exceeded 16 km (10 miles) were noted as remote areas. All cities and towns shown on each segment that offer full services including large grocery stores, motels, restaurants, hospitals, banks, laundromats, and drug stores were located. Bicycle shops where parts and service may be obtained were also located. Camping facilities on or within reasonable bicycling distance of the route were investigated and noted. All points of interest including recreation areas, historic sites, places of cultural or educational interest, and scenic areas were pinpointed and investigated to obtain firsthand information on what facilities each offers the bicyclist.

After the field survey was completed, the information was reviewed, with special attention given to the areas that did not meet the criteria. Once these were analyzed, alternative routes in those areas were selected and researched in the same manner as the draft route.

It is understood that with a long distance route it will be virtually impossible for all parts to meet the established criteria. About 85 percent of the mountains-to-sea route meets the ideal conditions outlined by these criteria. Since the remaining 15 percent is detailed to make the cyclist aware of all problems, these portions can, with caution, be navigated safely.

When the route was finalized, county maps marking the route were sent to the appropriate agencies and individuals for review. These included the department of transportation traffic engineering section, which conducted its own field survey; the trails coordinator of the parks and recreation section of the department of natural and economic resources; and selected avid cyclists who rode the route to give a cyclist's-eye view of any problems. This cyclist input is extremely important as some critical features of a road can only be detected on a bicycle. Those suggestions deemed appropriate to the goal of the project were incorporated into the final route.

DEVELOPMENT OF GUIDE DESIGN AND FORMAT

The few bicycle route brochures available from other parts of the country were studied for ideas on the best way to offer the information gathered. In-house production capabilities were investigated to determine what limitations would be imposed on the availability of supplies and machinery. Within these confines, the idea of offering a series of separate individual map segments evolved. Ironically, an almost identical format was being developed simultaneously by the East Coast Bicycle Congress for their East Coast bicycle trail, a route from Boston to Richmond.

Using this system of separate segments rather than a bound pamphlet, a bicyclist could lift out one or two segments for a short ride or use the entire packet for an extended ride. In the future when additional routes would be developed, it would be possible to combine segments of different routes in endless combinations to allow the cyclist to go almost anywhere in the state.

As the guide developed, each segment was named according to a geographic or historic feature found in the area. The segments were also numbered consecutively from west to east—the primary route from Murphy to Manteo—A-1 through A-16, and future routes would be numbered B, C, and D.

It was determined that the size of the package should be such that the map could fit into the map pocket of a handlebar pack. This 21.6 × 10.2-cm (8.5 × 4-in) size would also be convenient for a shirt or back pocket. The county road maps with a scale of 2.54 cm = 3.2 km were used as a base and reduced to 45 percent; each segment shows approximately 72 km (45 miles) of the route. This represents a day of riding for a novice bicycle tourist; more advanced cyclists might cover two or three segments in a day.

The package folder containing the maps offered general information pertinent to any route that might be developed. This information includes (a) laws pertaining to the operation of a bicycle in North Carolina, (b) helpful safety tips, (c) a brief sketch of the physiographic characteristics of the state, (d) instructions on using the maps, (e) average seasonal temperatures for the state's three regions, (f) direction of prevailing winds, (g) contacts for further information, (h) location of public transportation services, and (i) a disclaimer of responsibility for the safety of the route. The disclaimer was prepared by the department's legal staff and reads:

This guide is published by the Department of Transportation as an aid to bicyclists. The Department of Transportation in no manner warrants the safety of the highways indicated on these maps for use by bicyclists. The connecting routes and roads indicated on these maps are suggested only as more suitable than others for use by bicyclists as connecting routes. All roads suggested are regular roads of the highway system, used by automobiles and trucks, with no special lane provided for bicycles. As no separate lanes are provided for bicycles and therefore are dangerous for use by bicyclists, the bicyclist assumes the risk of his own safety when using the route indicated on the map.

To orient the cyclist, a foldout map included in the pamphlet package shows the major cities of the state, the routes, and the position and number of each map segment. This map also serves as a reference for selecting the map segments needed for a particular trip.

The segment map and narrative each cover half of a 21.6 × 20.3-cm (8.5 × 8-in) piece of paper, which is folded with one facing the other. The outside front of each piece shows the name and number of the segment, distance covered by the segment in miles and kilometers, and a highlight of the location of that segment in relation to the state. The outside back of each piece provides a complete legend (Figure 1), copyright information, and a space for notes.

The maps showing the route are the most important feature of the package. Since the route is not signed, accuracy of the information shown on the map is extremely important.

There are several reasons why these routes are not specially signed. First, with the length of roadway to sign, costs would be prohibitive. Second, the only available bicycle route sign that is currently permitted on the highway system is urban in orientation and, therefore, not suitable for the type of bicycle routes being developed in this project. The federal government is now studying the possible adoption of additional signs pertaining to bicycling. Finally, the scope of the project is such that three or four different routes might intersect in places. Using the one available sign would not clearly show the different routes and would greatly confuse the bicyclist.

It is important to include enough information on the maps so that the cyclist will be aware of his or her location at all times, without cluttering the maps with so much information that they are unreadable. This delicate balance was obtained by experimenting with degrees of information shown, varying from showing everything on the base county maps to showing only the route and the intersecting roads (Figure 2). However, since not all origins and destinations are directly on the route, adequate access information is needed so cyclists can reach any city or point of interest located in the segment. In this way, the maps can be useful to a greater number of people. Base information includes a network of major and minor roads pertinent to the route, the numbers of those roads, important creeks and rivers and their names, the name and location of major mountain ranges, cities and towns, railroad networks, airports, and county names.

Information necessary for the safety and comfort of the cyclist was then added to this base. The most important items are highlighted with a color overlay. These items include: the actual routes; an asterisk pinpointing hazardous areas; a star designating full-service cities or towns; a triangle pinpointing basic service locations; dots locating points of interest, restaurants, and campgrounds; the location and

Figure 1. Legend.

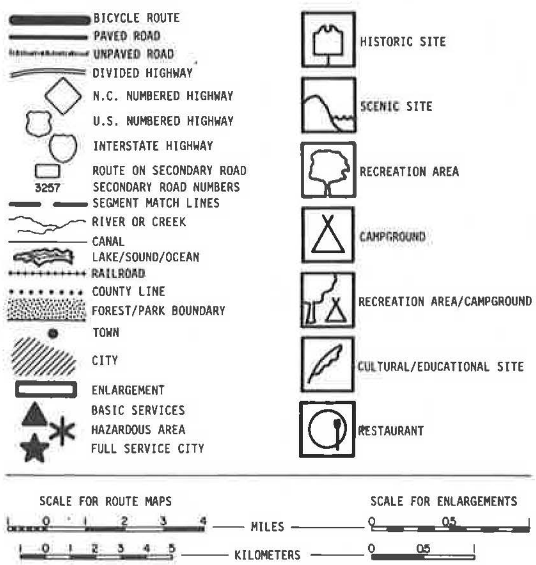
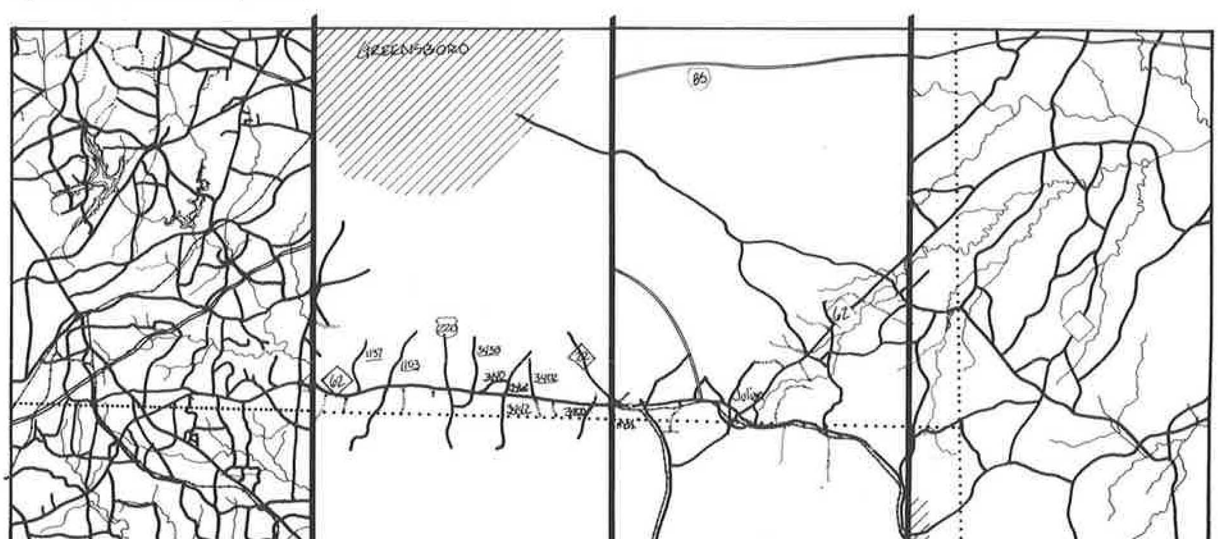


Figure 2. Evolution of map detail.



boundaries of the enlarged insets of confusing areas; and match lines. Care was taken not to overdo the use of color and thus destroy its highlighting effect.

Other additions to the face of the maps include enlarged insets of confusing areas; symbols denoting points of interest as recreational, historical, scenic, cultural, or educational; campground symbols; restaurant symbols; and a north directional arrow. The road number of all secondary roads that are a part of the route are enclosed in a rectangle to facilitate map reading.

Information offered in the narrative explains or expands the information symbolized on the face of the map. A general description of the physical features of the segment is given along with distance covered in miles and kilometers. Roadway conditions throughout the segment are briefly described with special regard to any areas that deviate from the established criteria. Hazardous areas are pinpointed and described completely, including an approximate duration of the problem. A discussion of available services includes information on the frequency of basic services (food, water, and restrooms) throughout the segment; the names of cities offering full services; the location of all bicycle shops in or near the segment; and the location of all overnight facilities, both indoor and outdoor. Finally, a description with background information on each point of interest is offered.

The entire package is copyrighted, primarily to protect the maps against reproduction for profit. The package is offered free of charge; the only requirement for obtaining a copyright is that a legal entity, in this case the department of transportation, must submit application for such.

A mockup pamphlet cover, foldout map, and map segment with accompanying narrative were prepared and sent out for review to several state and federal government agencies as well as to leading cyclists around the country. Suggested changes were incorporated in the final design.

Production

Actual production of the route guide pamphlet was time consuming, in part because no guidelines for development existed. Numerous decisions and minor details slowed the progress of the pamphlet. A general schedule can be offered, however. Preliminary research, including concept study, bicyclists' meetings, and selection of the draft route took 2 months. For the field survey, only 160 km/d (100 miles/d) could be covered thoroughly (allowing leeway for getting lost), and thus it required 2 weeks. Revisions in the draft route consumed another 2 weeks. Design decisions and production of a mockup pamphlet required a month. Individual map segments with color overlay required approximately 2.5 d apiece, or a total of 3 months of drafting time. Research and writing of the narrative accompanying each map segment and the text of the pamphlet cover took 2 months. Supervision of the reproduction of 1500 copies of the finished product, including shooting of photonegatives, 2-color offset printing, and folding and colating of the individual segments and the pamphlet cover, required another month.

Promotion

The promotion of the project and the final document began early in the planning process. With any project of this nature, especially those that involve new concepts, publicity is of ultimate importance. The idea must be sold to the public in order for the public to realize its value and accept the change from their normal methods of action—in this case, unplanned travel by bicycle; use of bad or unrelated information in bicycle trip planning; or simply not bicycling due to a lack of knowledge of existing roads.

To be able to determine the user, and his or her interests and needs, the bicycle program staff undertook the statewide campaign of information exchange. This exchange initiated the first publicity. Also, during this time the concept of bicycling highways was being transferred by word of mouth and through the regular channels of correspondence to bicyclists' inquiries.

After the basic data had been collected and the completion date was in sight, the major publicity was undertaken. The scope was state and national. A major news release was sent to all newspapers, radio stations, and television stations in the state. Details of the final product along with a location map of the total route were provided. Also, information on how to obtain copies of the maps was given. Special mailings with this same information went out to all bicycle clubs and other special interest groups (Sierra Clubs and local bicycle committees).

To ensure the proper national coverage, the major bicycle magazines were contacted along with major bicycle groups. These contacts resulted in a series of newsletter articles, magazine reports, and discussions at national conventions.

From the initial state and national publicity, secondary news sources were generated. Local or regional bicycle groups and related-interest publications picked up on the project and carried their own stories of the effort.

This publicity generated hundreds of letters of request and many inquiries on the methodology undertaken in the project. These letters came from throughout the state and nation, proving that the data we were offering were, as hoped, exactly what the bicycling public wanted and needed.

The only change suggested for the promotional effort would be to develop a coordinated publicity package with ads, slogans, and suggested distribution. This would cost more than the bicycle program had available but may have improved the salability to non-bicycle-related news resources. Nevertheless, the methods undertaken, even though more time consuming, did spread the word quite well.

A file was maintained of all requests. At completion, the first major mailing was to these requests. Bicycle shops and interested bicycle clubs were provided with copies. A supply was also given to the state travel agency for distribution to bicycling tourists as they inquire to that office for travel information.

A supply of maps will be readily available for all future inquiries to the bicycle program. Future routes will become a part of the package. The distribution of the mountain-to-sea route package included a mail-return request allowing the recipient to review the existing maps and material and notify the program of their desire for future mailings. Eventually the distribution process will be totally computerized for ease in the mailing of future route maps.

CONCLUSION

The bicycle program is now working on the selection of other major routes and the collection of information on roads, which will become regional loop routes. As expected, interest is being generated throughout the state. Local areas are developing their own shorter bicycling highways, which will be integrated into the statewide bicycle route system.

Much was learned in the development of the first route, which will make completion of future segments easier and more efficient. When the North Carolina bicycling highways project is finished, a bicycle trip of 8 to 8047 km (5 to 5000 miles), can be taken throughout all regions and reaching into all corners of the state. Most importantly, however, as bicycle-oriented maps and information become available, these trips may be accomplished with a degree of safety never before possible.

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