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FOREWORD

The papers presented in this RECORD examine social, economic, and behavioral practices as they relate to transportation planning. Inasmuch as local and economic issues have been in the forefront of the planning process recently, these papers are timely and should be of value to planners.

Gurin studied the travel behavior and mode preferences of 50 male students. Trip logs, budgets, and other information were collected during weekly panel discussions designed to investigate traveler characteristics, needs, and problems. Panelists were 15 to 18 years old, lived in three working-class Boston suburbs, and had varying degrees of access to public transit and automobiles. Gurin concludes that automobiles and walking were preferred modes even where good transit was available, possibly because of the boys' need for informal, off-peak, and unchaperoned travel. Finally, expanded programs to improve pedestrian facilities and ease access to automobile travel are suggested for satisfying the travel requirements of the teenage subgroup.

Levinson and Gersten performed a transit attitude survey for the East Central Florida Regional Planning Council and the Florida Department of Transportation. The primary purpose of the survey was to provide input to a modal-split model designed to determine patronage of a future regional mass transit system. Indirectly, criteria for long-range planning of the regional transit systems were determined from potential users' attitudes. The survey suggested that community interaction accomplishes two objectives: publicizes the potential of public transportation in an automobile-oriented community and provides researchers with an initial measure of the market for captive and free-choice transit. The community attitude survey served to confirm the basic assumptions of the disutility model that was adopted and provided the captive rider endpoints, thus making the model more realistic for application to the Orlando urban area.

Epps and Stafford examined interchange development along the Interstate Highway System in South Carolina with the intent of identifying information that can be used to develop a model for the development of commercial establishments at an interchange. The model can be used to provide a basis for coordinated planning on the remainder of the Interstate System in South Carolina and in other states with similar demographic and economic characteristics. Also, the data can be used to project the amount of economic development at existing interchanges along non-Interstate highways that have been constructed to Interstate standards. The results of the study will provide a method of planning interchanges that have not yet been fully developed and those that are being planned for future construction.

Gamble, Sauerlender, and Langley examined four residential communities adjacent to Interstate highways to determine the effects of regional accessibility and highway-generated disturbances on property values. Disturbances measured within each community included noise, carbon monoxide, nitrogen dioxide, hydrocarbons, and particulates. Data were collected on traffic mix, volume, and speed. Residents were interviewed to determine their perceptions of highway disturbance and other pertinent information. Noise pollution level (NPL) contour lines and CO isopleths were plotted for each community. The NPL regression coefficient was significant in explaining variation in property values in all communities and showed an average loss of $2,050 per property abutting a highway. Although there is a high degree of multicollinearity between the NPL and CO variable in the regression model, the NPL coefficient reflects more than just property value losses due to noise.

Burco discusses environmental constraints of regional transportation planning in the Lake Tahoe Basin of California and Nevada. The conflicts between technical planning methodology and environmental policy considerations are discussed, and recommendations are made for institutional changes that would allow broader policy considerations and systems alternatives to be evaluated in the planning process. Certain aspects of the planning strategies and conceptual solutions are generalized to regional transportation planning efforts elsewhere.

Ohrn and Podolske examine the need to provide bicycle facilities. The authors discuss four basic questions that assist in planning urban bicycle facilities on a more organized basis: How much money should be invested in bicycle facilities; what types of and how many trips are candidates for bicycling; what types of facilities should be provided; and where should bicycle facilities be placed? They conclude that planning and engineering bicycle facilities are in a shakedown period in which many good and bad ideas will be tested before the best solutions surface and become the norm.

Judge examines problems in interurban road investment appraisal. This study is a report on work in progress on the Lancashire-Yorkshire (M62) Motorway. The main questions of this study are (a) whether there are indirect benefits of road investment that should be incorporated in appraisals, (b) what account should be taken of regional effects, and (c) the nature of and what allowance should be made for generated traffic that is included only on an ad hoc basis. A cross-sectional analysis of the relationship between transport costs and subregional employment growth has been carried out. Interim results suggest that the M62 will cause marginal employment growth in Yorkshire and Lancashire. New traffic generation on the 27-mile trans-Pennine section is lower than expected.

Hammer discusses the role of the new "growth management" framework being built at the local level and its effect on land use and transportation planning. Fiscal and environmental considerations are basic to the position of local leaders that advocate managing or controlling growth along some rational lines. The key elements of growth management, according to Hammer, include tight controls over capital expenditures for water and sewer facilities and for transportation (both highway and transit); innovative revisions of zoning and subdivision regulations; coordinated administration of open space and park development programs; and initiation of new public mechanisms for joint public-private efforts in land development.

Mulder discusses the development of criteria used in the determination of highway improvement programs for three corridors through the Upper Great Lakes region of Michigan, Minnesota, and Wisconsin, to foster economic growth. The overall study had the further objective that the findings be applicable to future planning and development of comparable highway corridors in the region. The criteria and output included definition of operating speed relationship between traffic function and ambient scenery; development of new design-hour and service-level criteria for planning highway improvements in rural recreation regions; and development of a method to identify and evaluate scenic values in the planning and design of scenic routes. The route selection procedure is outlined in a flow chart indicating the elements of scenic inventory and evaluation plus the other considerations normally used in highway planning.

TRAVEL PATTERNS OF SUBURBAN HIGH SCHOOL MALES AND PROGRAMS TO INCREASE THEIR MOBILITY

Douglas Brian Gurin, Department of City and Regional Planning, Harvard University

A study of the travel behavior and mode preferences of 50 male teenagers documents their lack of dependence on public transit. They prefer private or personal transportation modes such as walking and automobile travel. Trip logs, budgets, and other information were collected during weekly panel discussions designed to investigate traveler characteristics, needs, and problems. Panelists were 15 to 18 years old, lived in three working-class Boston suburbs, and had varying degrees of access to public transit and automobiles. Similar conclusions about travel patterns were drawn in each town. Automobiles and walking were preferred modes even where good transit was available. Teenagers' responses to available transportation and their expenditures to achieve mobility reflected their degree of interest in travel. That is, currently mobile teenagers travel more than less travel-oriented, but otherwise similar, youth if transportation is provided. Maturing working-class travelers felt compelled to secure their own transportation, even at high cost, because their parents and communities seemed unwilling to provide transportation that permits informal, off-peak, and unchaperoned travel. Bus and rail transit service, dial-a-bus systems, and other forms of public transportation seem unable to accommodate teenagers' needs for short-range, fast, and spontaneous tripmaking. Expanded programs to improve pedestrian facilities and ease access to automobile travel would most likely satisfy the travel requirements of the teenage subgroup.

•THE LACK of general travel theory to guide planners creates problems for those who must develop and evaluate new transportation systems or improve existing operations. Proposed highways, rail transit, and other systems could be costly to users and non-users alike. The political and social impacts of making mistakes in location and design are apt to be great. An understanding of travel behavior and the variables affecting travel decisions is vital to the accurate prediction of the effectiveness of proposed transportation programs.

Many serious shortcomings in concepts of mobility and travel were dramatically revealed in the failure of the transportation-poverty programs of the late 1960s to attract and retain new transit riders. Planners attempted unsuccessfully to apply long-range planning methods to short-term transportation improvements required by the urban poor. These failures pointed to the need for disaggregating the population into homogeneous segments and considering each group's travel desires and requirements. The need for improved methods to plan and research short-run or innovative transportation improvements also became apparent. It seemed that the quality of research could be improved by focusing individually and in depth on each pilot subgroup rather than by conducting superficial, simultaneous examination of every group.

Teenagers were selected as the initial population segment for research for many reasons: They make up a large percentage of the population (about 13 percent) and

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account for a substantial proportion of public transportation users. Teenagers had received little previous attention from transportation planners and policy-makers. Teenagers are counted among the potentially curious and interested consumers of new public transportation systems, even though their dependence on current public transit versus other modes has not been proved. Finally, the immobility of youth might limit their personality development and cause social problems.

THE TEENAGER MOBILITY STUDY

The teenager mobility study (TMS) was conducted to examine teenagers' travel behavior by using a subgroup approach. Its principal objectives were to describe the travel patterns, attitudes, decisions, and problems of teenagers; to predict the short-run responses of teenagers to alternative transportation improvements, especially public transit; and to develop and evaluate exploratory methods to collect, measure, and analyze data on travel patterns and attitudes.

This paper summarizes the substantive results of the first two objectives. Some comments on methodology appear later and are detailed in the complete technical report (14). After the conceptual approach is outlined and the techniques of data collection are briefly introduced, the principal findings and conclusions on teenager travel behavior are presented. These generate recommendations for transportation planning and policy based on teenagers' mobility needs and desires.

The Organizing Concept

The demand-by-analogy concept, used to organize the TMS, estimates the effects of increased access to transportation by examining the differences in the travel patterns of similar populations with and without access. These differences approximate the volume and form of short-term travel behavior that might be expected if the constrained "immobiles" are given the same transportation access as the unconstrained "mobiles". The approach requires the identification of mobile and immobile populations, inventories of movement behavior of each group, and examination of the travel differences between the groups.

We concentrated on a mobile teenager population that had good public transportation or automobile access and a contrasting immobile population that lacked one or the other. To ensure that the travel desires of the two populations were similar, we chose a teenage population with similar demographic and economic characteristics.

Study Locations

Three communities in the Boston region were selected for TMS data collection: Cambridge, an inner-city suburb; Arlington, a 1920s single-center suburb; and Burlington, a 1950s sprawl suburb. The towns have different development histories and land use patterns, but planners, school officials, and local residents agree that these towns represent blue-collar, middle-American communities. Only about 40 percent of each town's public high school graduates go to college or vocational schools. The towns vary in transportation facilities and services: Cambridge has networks of sidewalks and frequent, inexpensive bus and rail transit service that few communities in the United States can match and few suburbs can expect to provide; Arlington has some sidewalks and good bus service, mostly along one main road; and Burlington has few sidewalks and little public transportation except school buses.

Data Collection Methods

Our principal means of collecting travel information was a series of local weekly panel discussions with teenagers; these meetings were held for several months. This method had been recommended by several studies (5, 11). This approach combined the advantages of classroom survey research and in-depth interviews by permitting easy, efficient collection of personal, survey-like data. It created a social and physical environment that facilitated open-ended discussions and questions about a range of mobility topics. Weekly sessions permitted us to explore travel resources and trip-making over time.

Written records were kept of panelists' social, economic, and personality characteristics and their past and current travel activities and attitudes. Trip frequency estimates were obtained, detailed trip logs were kept for 4 days during one autumn week, and budget data were collected.

Sample Population Characteristics

We selected a small sample of paid volunteers rather than randomly chosen individuals. We assumed that a study of volunteers would include a higher proportion of both knowledgeable teenage travelers and teenagers with travel problems. Also, we felt that, because we wanted to study travel behavior over time, uninterested participants could not be compelled to produce complete and honest information for the duration of the study. A small but relatively homogeneous sample was desired to ease data collection administration. This nonrandom, small sample prevented statistical generalizations to the total teenage population in our study communities but allowed considerable refinement of the basic descriptive categories of teenagers and their behavior, which should be used in future, large-scale survey research on subgroup travel.

Our study population, recruited from public and parochial high schools in each study town, consisted of 50 white males. This demographic group seemed most likely to include the highly mobile population needed to implement the demand-by-analogy approach. Most panelists were 16 or 17 years old, although some 15- and 18-year-olds were also included. About half the sample had some kind of job. Median personal weekly cash income was about $25. Based on several studies (2, 10, 11), the 26 panelists who expressed no expectation of continuing their education after high school were considered working class; college- or vocational school-bound students were considered lower middle class. Other household data reinforced our impression that the sample included youth from blue-collar families.

Estimated annual family earnings were $10,000 to $15,000 and were produced by several workers in each household. The average family size was almost six people. Home living conditions were described as crowded and noisy. Most families had lived in the same town for more than 10 years and had relatives living nearby. Median parent education level was high school, and most fathers and mothers worked in craft, service, or lower management occupations.

We inventoried each teenager's access to transportation; comparisons of travel-pattern differences reflected access differences and provided clues about the travel patterns that would result from improved transportation access. Forty of our 50 panelists lived within a 10-minute walk of a transit stop. Only one teenager's family did not own a car. An average of 2.4 drivers in each household shared 2.0 automobiles. Parental chauffeuring was more available to college-bound, middle-class youth than to working-class teenagers. Twenty-six of 34 panelists old enough to have licenses had already obtained them, and 13 panelists above and below the minimum driving age of 16½ had driving permits. Only three teenagers reported having neither automobile access nor friends who could provide car rides.

Automobile access among licensed drivers varied. Ideally, this access would have been measured for each specific trip reported on the trip logs, inasmuch as access fluctuated for some teenagers on an hourly, daily, or weekly basis. An alternative measure might have estimated the degree of automobile availability per week as a continuous function, e.g., the percentage of trips for which a car was available. Since cars per household or drivers per household car seemed to be unsatisfactory personal access measures, we evolved a four-category measure of household car access among our sample: Eleven panelists owned cars; 10 had restricted use of family cars; five had unrestricted use of family cars; and 24 were unlicensed or had permits but had no access to cars for individual travel.

FINDINGS AND CONCLUSIONS

This section summarizes some of the principal conclusions about panelists' travel behavior, focusing on mode choice and design considerations for improved teenager transportation systems. We reinforced the reliability and validity of our observations about working-class teenaged boys and their travel by repeating measures of behavior, using several measures and questions, and comparing our data with data from other studies of youth and youth travel (1-3, 5-9, 11-13).

Trip Generation

Panelists were active travelers, regardless of their access to transportation or the definition used to count trips. They made an average of 9.6 trips per day including walking and vehicle trips on 2 midweek school days, a Friday, and a Saturday. This figure varied from a high of 11.2 among car owners to a low of 8.4 among unlicensed travelers. Licensed teenagers generally made about 20 percent more trips per day than both young or old unlicensed panelists. Average trip levels were lower weekdays than on Fridays or Saturdays, but car owners and restricted car users still typically made more than nine trips on weekdays. Our data showed no relation between transit access and trip generation.

We also calculated a daily trip generation rate, which discounted walking trips, to compare our data with those of other studies, which typically neglected pedestrian travel. The vehicle trip generation rate was 5.6, higher than rates in other youth travel studies (5, 11, 13). This trip generation rate may be a more valid indicator of trip generation of older teenaged boys; other studies included female travelers with lower trip generation rates, made few attempts to obtain complete and honest trip generation rates, made few attempts to obtain complete and honest trip reports, and neglected teenagers' increased travel activity on weekends.

Panelists indicated that the quality of their relationships with their families greatly influenced their trip-making and, indirectly, the degree of automobile access. Daily trip generation appeared to be highest among panelists who had the greatest problems with their families, and, presumably, many of their trips were made to avoid conflicts at home. This same group tended to be car owners, have restricted access to family cars, and have action-seeking adolescent behavior. Panelists who reported good family relations also reported making many trips because of parental encouragement, unrestricted family-car access, and more frequent chauffeured rides. These teenagers were well-behaved and adult-like in their activities and attitudes. Teenagers having neither strong negative nor strong positive relations with parents had relatively low trip generation rates and only moderate access to household cars.

Travel Expenditures

The study teenagers spent approximately $5.70 per week on transportation, which amounted to approximately 20 percent of their weekly budgets. These averages conceal wide variations among drivers and nondrivers: Car owners spent $15.40 per week or 47 percent of their budgets on transportation; family-car borrowers spent roughly $4.00 or 16 percent of their budgets; unlicensed youth spent $2.00 or 10 percent of their budgets. Budget percentages seemed to be better indicators of trip generation than absolute expenditure levels: Frequent trip-makers spent a high percentage of their budgets on travel, and infrequent travelers spent only a small share. Almost all drivers considered automobile expenses as top-priority budget items, whereas only one-third of the panelists who used transit most often considered transit expenses as important budget items.

Trip Distances

Our teenagers generally made short trips. Median trip length by all transportation modes was 1.2 miles and 5 minutes. The average trip distance for drivers was 2.7 miles at an average trip speed of 19 mph. This contrasts with the comparative figures for unlicensed panelists, 1.8 miles at 9 mph. Average trip times in all four automobile access categories were under 10 minutes, suggesting widespread preferences to keep trip times short.

Trip Purposes

Trip purpose breakdowns showed differences among licensed and unlicensed older panelists (Table 1). When we examined the possible effects of age on trip purposes of

Table 1. Percentages of trip purposes.

Trip Purpose	Trip Share	Trip-Maker Age and Licensing: Younger Than 16½ Unlicensed	Older Than 16½ Unlicensed	Older Than 16½ Licensed	Apparent Effects of Age on Trip Purpose
Home	23.5	24.8	24.2	22.7	No change
Social-recreation	22.0	23.1	27.4	20.6	No clear pattern
Personal business	15.2	12.9	15.1	16.3	Increase with age
Change mode	13.6	18.8	10.6	11.8	Decrease with age
Education	9.8	12.7	10.0	8.4	Decrease with age
Serve passenger	9.8	2.2	4.5	14.2	Increase with age
Work	5.2	3.7	7.3	5.7	Increase with age
Overall	100.0	28.0	10.7	61.3	
N	1,658	464	179	1,015	

Note: Column percentages may not add to 100 percent because 13 "other" trip purposes are not shown.

teenagers, homebound trips accounted for about one-fourth of all trips; trip shares for personal business, serving passengers, and work increased; trip shares for education and changing modes fell, and social-recreation travel shares showed no clear pattern.

The most frequent trip purposes were home, social-recreation, and personal business; fewer trips were made to change mode, for education, to serve passengers, and for work. Licensed drivers reported relatively more serve passenger, family chauffeuring, and errand trips and fewer social-recreation trips than their older, unlicensed peers. Generally, maturation led to more complex school, job, and social-recreation trips than the routine, local trips of early adolescence. Transportation was desired that could meet the most stringent travel requirements of later adolescence, such as those associated with dating or the fast, after-school-to-work trips of the student in vocational training programs.

Mode Choices

Panelists' mode preferences were examined by looking at mode use collectively and among panelists with differing mode access. Either way, the teenagers were not dependent on public transit; the basic mode choices were walking and automobiles. Transit accounted for 8 percent of all trips, 11 percent of the trips by unlicensed young panelists, and 18 percent of the trips by unlicensed older panelists (Table 2). Walking accounted for 40 percent of all trips and 63 percent of trips by younger unlicensed panelists; even licensed youth made more than one-fourth of their trips on foot. Panelists used automobiles on 51 percent of their trips as drivers, passengers, or hitchhikers.

Table 2. Percentages of mode use.

Mode	Trip-Maker Age and Licensing: Younger Than 16½ Unlicensed	Older Than 16½ Unlicensed	Older Than 16½ Licensed	Mode Share
Walk	62.5	47.0	27.8	39.9
Transit	11.4	17.8	4.8	8.1
Automobile	24.4	35.2	64.3	51.0
Driver	2.6[a]	16.8[a]	46.9	31.2
Passenger	17.5	18.4	17.4	17.6
Hitchhiker	4.3	0.0	0.0	2.2
Overall	28.0	10.7	61.3	100.0[b]
N	464	179	1,015	1,658[b]

[a]Most of these trips were made by panelists with driving permits or under a parent's supervision.
[b]Twenty-three bicycle trips are included in column total percentages and total counts.

Young unlicensed panelists rode automobiles twice as much as transit. Overall trip levels remained about the same for older and younger unlicensed teenagers, but both transit and automobile trip shares increased with age. Inasmuch as transit was equally available to young and old panelists, its increased use by older nondrivers suggests increased vehicle travel caused by changes in behavior due to maturation. (The easing of parental travel restrictions, less fear of strangers, and the availability of more spending money also enabled older teenagers to increase their use of transit.) With licensing, driving substituted for both walking and transit trips. The data in Table 2 suggest that hitchhiking and bicycle use were extremely low among the panelists.

Mode choice patterns of the study group differed from commonly held conceptions of teenager travel. Transit, motorcycles, hitchhiking, and bicycles were used by only a small fraction of the teenagers, whereas walking and automobiles were used daily by almost everyone. Transit use was not high even among youth living within a 3-minute walk of a transit stop (although the nonhome orientation of many teenager trips may invalidate access distance as a measure of teenager transit availability). Diversion rates away from transit were not equal among all older youth; they seemed greater for adolescent action-seekers than for well-behaved, adult-like teenagers. Perhaps the most surprising fact about panelists' mode availability and choice was the high reliance placed on car rides provided by friends rather than parents. Young panelists made only 27 percent of their car trips as passengers with family adults. Family chauffeuring increased slightly with age among unlicensed panelists, as needs for vehicular travel increased; but, even among this group, friends provided more than twice as many car passenger rides as parents did. Overall, chauffeured travel accounted for just 13 percent of panelists' automobile trips and 6.5 percent of their total travel.

Other data lend support to the teenagers' nondependence on public transit for mobility. Trip generation rates, the percentages of weekly budgets spent on transportation, and the popularity of automobiles and walking were all very similar among panelists, in spite of the varying availability of transit service. Trip generation was reported to be highest in the evenings, on weekends, and during summers, when transit service was least available. Transit was used primarily for the most routine and familiar trip purposes of going to school and home, whereas walking and car travel were used for all trip purposes. Panelists traveled with other people on 60 percent of their trips in groups that averaged 2.4 people and often involved three or more friends; transit, unlike walking or cars, has many features, such as individual fares and crowds, that discourage peer group trips. Furthermore, fears of unwanted interactions with strangers inhibited panelists' use of transit for individual trip-making; when panelists traveled alone, they used transit for 7 percent of their trips, walking for 51 percent, and car driving for 38 percent.

Transportation Availability as a Dependent Variable

Generally, teenagers considered transit service, walking facilities, and hitchhiking rides as independent, exogenously determined variables of transportation supply. Bicycles and almost all forms of car access, on the other hand, were within at least partial control of individual teenagers, especially those in car-owning households. Many exogenous factors affecting transportation supply were not absolute in restraining teenager travel, however. Given personal motivation to travel, teenagers appeared to be resourceful in expanding their transportation options to overcome these constraints.

The degree of travel motivation and the general importance that teenagers place on mobility were indicated in economic, educational, and social behavior patterns. People who worked to earn money for transportation expenses or who spent high percentages of their incomes on travel or vehicles seemed to value mobility more than their nonworking, transportation-cost-sensitive peers. Teenagers who cultivated positive social relations among people from whom they might have received transportation assistance (in the form of information, rides, or gifts) seemed more concerned with travel possibilities than those who made few such efforts.

Perhaps the clearest indicators of mobility importance were those relating to automobile operation and access. Possession of a driver's license clearly involved an active role for teenagers, who had to decide whether the learning efforts and financial costs would be worthwhile. Teenagers were responsible, to some extent, for deciding how early they learned to drive and how early they secured their licenses. Presumably driving was more important to drivers than to nondrivers at any age level.

The preceding suggests that access levels to private transportation significantly reflect individual travel demand and cannot always be considered as independent variables in travel analysis. Rather, high individual access to transportation modes other than transit may be an indication that personal mobility is important to the traveler.

If we relax the assumption of homogeneous travel demand among TMS teenagers, we conclude that improved access to transportation may not increase teenagers' total trip levels or distances significantly. Likewise, it may not change most of their trip purposes or mode choices. The travel patterns of the mobile TMS teenagers probably represent the upper bounds on the magnitudes or proportions of trips that will be generated by improved access to transportation. Older teenagers who have poor transportation access already make essential trips to school and to home. They may just have less interest in self-initiated travel than teenagers who take steps to obtain good transportation. Young motivated teenagers with improved transportation will still tend to make local trips, although they may make slightly more trips and travel slightly further and faster than young, unmotivated travelers.

PROGRAMS TO IMPROVE TEENAGER MOBILITY

Mobility programs involving transit, para-transit such as taxis or dial-a-bus, walking, and automobiles were evaluated primarily from the viewpoint of the TMS panelists, although the attitudes and resources of their parents, community residents, and transportation planners received some consideration. Short-run teenager responses to various programs reflected their expressed travel and expenditure behavior and attitudes. TMS forecasts assumed that planners are unlikely to provide activities that would divert teenagers from the unstructured informal activities that currently generate most of their trips.

An Ideal System for Teenagers

Program evaluation in the TMS relates proposed transportation improvements to the attributes of a transportation system that panelists suggested would be ideally suited to their travel, social, and psychological needs and those of other teenagers. This ideal system would fulfill travel requirements for all trip purposes and be available at all times, especially late at night, on weekends, and in the summer. It must be readily accessible with no preplanning, allow occasional intersuburban and long-distance recreation travel, and minimize stress during exploratory travel and travel in dangerous neighborhoods. It would enable routing and speed control by the traveler and provide operating challenges for certain optional but enjoyable movements.

Some form of personal transportation seemed important to maturing working-class panelists in particular. They felt compelled to secure their own transportation, even at high cost, because their parents and communities appeared reluctant or unwilling (legally and morally) to provide family or public transportation for their trip purposes such as dating. Working-class panelists reported negative outlooks on future marriage and full-time work and felt pressure to have travel adventures and the excitement of vehicle ownership and control while they were still single. The ideal system would also provide what families, schools, public transportation, and other societal institutions cannot or will not provide: feelings of freedom, adulthood, equality, masculinity, physical or emotional security, and, in some cases, status; a means of nonverbal self-expression; and an ability to help other people.

Transit

Evaluation of housing and other social services of a caretaking nature suggests that the provision of new services valued by middle-class planners does not change the values and behavior of those working-class and lower class people who are offered the services. This finding supports our observation that the provision of increased transit is unlikely to generate much response from working-class youth who do not place a high value on public transportation.

The TMS found low transit use among its participating teenagers, regardless of the quality of public transportation. It has identified many basic technical and conceptual problems of transit that discourage its use by teenagers, especially for recreation and courtship travel. Most problems that discourage use, however, are a function of the basic concept of public transportation as adult-driven, -supervised vehicles for adolescents whose behavior is incompatible with adult norms. Transportation is still seen by planners only as a means to an end; passengers' desires for independence, privacy, and spontaneity are not considered in transit system design, which must cluster together unrelated groups of strangers. The inconvenience and impersonality of transit are particularly annoying to teenagers who are struggling to strengthen and develop social relationships among their friends, families, classmates, and others. Transit use is also lowered by complex information requirements for nonroutine travel, stresses due to unfamiliarity with system operations, and feared interactions with vehicle drivers or passengers. Major changes in service will be required, then, before transit service will be competitive with automobile transportation.

Several programs to encourage future suburban transit use seem likely to help only the upwardly mobile, ambitious teenagers—not the majority. Information about the region's transit system and how teenagers can use it could be introduced into high school or junior high school classrooms. Regulatory agencies should distribute current information about all bus lines in an area, so travelers can know how to make transfers and connections. Bus schedules and maps should be redesigned so that they are easy to use. Other information systems such as local phone directories, school and community newspapers, direct home mailings, and multiple listings in phone books (of transit company names, nicknames, and abbreviations) should all be evaluated from the perspective of shy teenagers who are reluctant to ask people (in person or on the telephone) for information.

Several improvements could be made by transit management. Suburban fare collection need not be structured to require exact fare, which irritates teenagers. Doing away with flat fares and instituting fares that vary with distance appeal to teenagers, whose trips tend to be short. From the teenagers' viewpoint, buses should run at least every 10 to 15 minutes during off-peak periods and late at night. They should maintain scheduled headways. Enough buses should be provided to avoid crowding. Simple shelters at bus stops would be appreciated in suburban areas where there are no nearby buildings in which to wait. Teenagers seemed to like new facilities and equipment because they were associated with functional performance, but, if old equipment and buildings were well-maintained and operated reliably, teenagers would not be discouraged from using them.

A few transit problems might be corrected by spending money for additional vehicles or services. These increased expenditures are unlikely to occur, however, if they must come from further taxation of working-class parents who have opposed educational innovations and other community services for teenagers. Unless parents show more concern about their children's social welfare, it is unlikely that transit companies will direct programs at young riders.

Para-Transit

Panelists' nonuse of taxis suggests that working-class male teenagers are unlikely to respond favorably to improved taxis or to new shared-ride para-transit systems such as dial-a-bus. Panelists' negative attitudes toward taxi-like modes must somehow be altered before they will take advantage of a personalized but prearranged service driven by adults or nonfriends. Because these systems usually do not meet privacy, late-night, and nonlocal requirements of dating and recreation trips, they seem unlikely to reduce older male teenager desires for personal car access. We suspect that the behavioral restrictions imposed by adults in the vehicle plus the inconvenience of the required telephone access and waiting time will outweigh the appeal of the door-to-door service of these systems.

If para-transit is to increase its market appeal among working-class teenagers, several features of the system must be modified or developed (4). Young, nonlocal, tolerant vehicle drivers on rotating shifts would increase rapport between teenage males and the driver and still preserve some anonymity for passengers. Service should be available until about 1 or 2 a.m. on Fridays and Saturdays. Free telephones and a posted system phone number should be located where teenagers might want to summon a vehicle. Rates per person or per group should be stated over the phone if exact destinations are known. A reasonable response time should be estimated over the phone and rides should be provided free or at a reduced rate if the pickup vehicle arrives late. Teenagers should have the option to pay extra money to choose their travel companions. The operating jurisdiction of a para-transit system should be broad enough to include nonlocal places where teenagers travel for commercial or social-recreation purposes, e.g., major shopping centers, sports fields, rock concert halls, and non-neighborhood movies. Vehicles should have plenty of leg room and should permit teenagers to sit beyond the driver's hearing range. Billing should be in cash, or credit could be offered to local teenagers who would be billed directly or through their high schools without parental interference. These basic bills would not have to contain all the timing and other trip data recorded for the trip; bills would only show the data a traveler might want to appear on his bill.

Walking

Male teenagers probably have the highest tolerance for walking of any population subgroup, and this willingness explains why walking is competitive with transit for teenagers. The most frequent complaints about walking were slow speed, exposure to inclement weather, visibility to people along the route, and lack of the excitement of vehicle acceleration and control. However, according to most panelists, walking provided a quicker, more predictable, and more convenient mode than the bus for many local, off-peak, and group trips.

Walking problems exist in moderate- and low-density suburbs where walking is a practical mode. The principal barriers to male teenage pedestrians result from the absence of pedestrian facilities, such as sidewalks, and actual obstructions such as fences and drainage ditches. Programs to encourage walking would identify and eliminate these barriers, especially those within a 20-minute walk of high schools and commercial stores where teenagers are likely to go. Plans for housing subdivisions, shopping centers, highway bridges, and median barriers should be evaluated with eventual sidewalk or convenient crosswalk locations in mind. Builders may be asked to provide direct pedestrian sidewalks to and alongside major arteries to accommodate walk-trip desires. Provision for snow removal laws and their enforcement seems called for on all pedestrian paths in places with severe winter weather. New federal and state funding sources for suburban sidewalk construction and maintenance need to be found for working-class towns.

Automobiles

From the panelists' viewpoint, planners' investigations of programs for automobiles seem wiser and more desirable than improvements for other vehicle modes, since teenagers are likely to want car access until a better alternative to the automobile emerges. New systems of transportation are unlikely to achieve desired public objectives and significant ridership among teenagers unless they are designed to permit the emotional and social outlets and the travel convenience that driving and car ownership now provide. Such basic adolescent needs as love, respect, and self-confidence will not go away if they are forgotten in planning new systems or programs limiting mobility and vehicle ownership. The fundamental attitudes, values, and hopes that lie beneath teenagers' activity, travel, and mode preferences seem liable to be changed only by maturation and experience unless there are dramatic societal and family structure changes.

To panelists, congestion, pollution, and energy consumption were not serious problems; after all, they drove mostly at off-peak hours, chose to spend free time in parking lots and gas stations, and made mostly local trips. Public policies that discourage driving, car ownership, or gasoline purchases seem likely to have negative impacts on teenagers. According to panelists and youth counselors, alcohol and other drug consumption may increase, as may the frequency of gasoline and car theft, vandalism, and other crime and rebellious acts. Frictions between teenagers and parents, school and transit personnel, and other adults, are likely to intensify. School dropout rates may increase. These impacts may be far more destructive and costly to teenagers and society than current impacts of teenager automobile use.

The TMS approach recognizes the serious problems of car safety, pollution, and energy. Nevertheless, consideration of automobile programs would mean that transportation planning was not discriminating against the young whose travel needs cannot be met by transit. Our approach is to try to find ways to use personal vehicles and streets more efficiently and safely, while solutions to basic automobile-related problems are being found and implemented.

The first of our programs stresses efforts to help all car owners, not just teenagers. The program should reduce the costs and inconveniences of car ownership and operation such as insurance, fuel supply, poor car construction, and repair. If costs decreased, more parents might let their children drive family cars, cars per household might increase, and teenagers would have more chances for rides from their parents or friends.

Our second program would facilitate driving. It would overcome the probems and fears that prevent eligible people from driving. It would examine the driving behavior of teenagers in suburban settings where state laws already permit driving by teenagers who are younger than 16. If further evidence could be found to support recent findings that it is not youth itself, but inexperience or emotional adjustment problems at ages 18 to 20 that cause accidents among teenage drivers (9), driving license age requirements might be lowered. At the least, planners should oppose any legislation to raise the minimum driving age.

Lowering the driving age could be done conditionally with rigorous skill and rules tests. Young drivers might be allowed to drive only in off-peak times, only within their hometowns, and only with family cars. Traffic violations could result in postponement of eligibility for regular licenses. These conditional licenses would offer incentives for careful use of existing cars. They could greatly facilitate mobility for working-class teenagers in moderate- and low-density areas, who now have no friends who can drive, yet who come from homes with underutilized cars.

Third, driver education programs require major reexamination regardless of changes in minimum driving age laws. Problems associated with driver education effectiveness, cost, scheduling, and other aspects need review, as does the equitable distribution of school driving programs. Ideally, driver education should include behind-the-wheel training; effective education on buying an automobile, preventive maintenance, and safe operation; and exposure to transport modes and communication systems that might make some automobile trips unnecessary.

Our fourth program would increase the supply of automobiles for young travelers by making it easier for safe drivers to rent or share nonfamily cars for evening or weekend use. Potential sources of vehicles would be commercial car rental companies and public agencies and businesses whose car fleets are not used continually. Programs to increase local hitchhiking safety for travelers and motorists need exploration. Increasing access to existing cars has the advantage of increasing automobile mobility for teenagers without major investments by teenage drivers, taxpayers, those lending their cars, or drivers who give rides to strangers.

The last set of programs would help people who want to put time and effort into car construction and maintenance but who lack the all-weather facilities or skills. Planners should encourage private, do-it-yourself repair and diagnostic facilities. They could arrange for the use of public or private garage or school shop facilities and provide courses in car maintenance. These programs might also encourage driving safety by providing public or private roadways or test track facilities for car hobbyists who enjoy skillful racing and driving. Alternatively, certain roads, parking lots, or little-used airport runways might be scheduled for enthusiasts' use, just as certain roads are now scheduled for bicyclists' use.

SUMMARY

This paper has begun to describe existing mode use and preferences of participants in the teenager mobility study. Observations suggest that public policy for helping teenaged boys should be directed toward facilitating private and personal travel. Spending large amounts of taxes to preserve existing transit and taxi services, to upgrade conventional transit, to provide flexibly routed and scheduled dial-a-bus, or to extend rail transit into suburban areas seems unlikely to provide teenagers with transportation they will ride. The study teenaged males have negative attitudes toward existing analogous services. Their working-class parents would be unlikely to want to pay for public transportation construction and operating costs. These transit programs seem conceptually incapable of meeting the complete range of teenage traveler needs, regardless of the level of public expense. Unlike programs that are capital intensive and that use for-hire drivers and vehicles, the programs we have recommended to facilitate walking, automobile use, and other individual or small group travel require a minimum of additional public expense, regulation, and institutionalization; they could be modified or dropped if demonstration programs do not seem to help teenager mobility. Most important, they seem likely to be used and appreciated by the teenager subgroup that was studied.

The TMS has raised questions about the responsibility of planners to improve the lives of all people. The planning process must involve children of working-class families and other neglected subgroups, not just the visible, articulate adult middle-class majority. Improved methods are still needed to predict subgroup needs and priorities, response rates, incurred costs and benefits to transportation improvements, and implementation barriers to be encountered. Transportation system designers and managers need to learn how to modify construction or operation features in order to increase the marketability of their services.

The planning profession will have to grapple with inherent value conflicts among teenagers, parents, and other groups, as the profession becomes more pluralistic in its problem definitions, policy suggestions, and proposed programs. Age restrictions, like race and sex restrictions, have to be reexamined as fair criteria for limiting individual freedom and behavior. Planning will continue to improve as a profession only as it responds to the issues, ideas, and preferences of teenagers and other subgroups.

ACKNOWLEDGMENTS

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TRANSPORTATION ATTITUDE SURVEY FOR MODAL-SPLIT FORECASTING AS PART OF LONG-RANGE TRANSIT PLANNING

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The Orlando Urban Area Transit Study included a community attitude survey in its long-range transit planning process. The primary purpose of the attitude survey was to provide input to a modal-split model designed to determine patronage on a future transit system. Criteria for long-range planning of the regional transit system were obtained from potential users' attitudes. The basic information obtained from the survey is (a) attributes that the public considers important in satisfying what it perceives as acceptable transportation service; (b) minimum levels of service necessary to generate significant patronage of the future system; (c) factors that may cause choice riders to use transit rather than automobiles; (d) trip purposes for which the future public transit system would be used; (e) whether individual respondents would use a future transit system that met their specifications, as a rough indication of modal split; (f) socioeconomic groups with a greater tendency to use a future transit system; and (g) determination of automobile-captive, transit-captive, and free-choice ridership for different system alternates, trip purposes, and income levels. A pilot attitude survey of community leaders, coupled with a slide show presentation on regional public transit system concepts, preceded the telephone survey of the tricounty Orange-Seminole-Osceola region. An additional consideration in this study was that traditional calibration of a modal-split model would not be possible. Current bus service does not reflect the type of well-designed regional transit system for which we want to forecast patronage. This suggested use of a model that had been calibrated in a different urban region and that could be justified as "universally applicable" in theory. The community attitude survey served to confirm the basic assumptions of the disutility model that was adopted and provided the captive rider endpoints, thus making the model more realistic for application to the Orlando urban area.

•THE FIRST STEP in preparing the community attitude survey was a literature review of transit surveys conducted in other regions and an identification of variables that could influence modal selection and yield possible topics of questions on the survey form. The synthesis of this information, coupled with the goals of the long-range phase of the transit study, generated the first preliminary design.

The questions, wording, and layout of the survey had to provide the desired information yet be simple to implement within budgetary restrictions. The survey was designed with the following criteria in mind:

1. The questions should not require professional judgment or knowledge of transportation planning and operations to be understood or answered correctly by the respondent.
2. The questions should represent criteria that show variability.

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3. The questions should be able to quantitatively measure attitudes, relative importance, and minimum service levels desired so that results can be usefully applied to the modal-split model and long-range planning.

4. The answers should provide sufficient input to develop the modal-split model.

5. The questions should be simple and straightforward; the questions, wording, and survey format should not contain bias or cause confusion to respondents with either limited education or unfamiliarity with public transit.

The preliminary survey design was discussed with the East Central Florida Regional Planning Council and the Florida Department of Transportation. With minor modifications, the handwritten form was tested in a pilot study.

Pilot Study

The purposes of the pilot study of community groups and governmental officials were to familiarize community leaders with the long-range transit study and potential regional transit system concepts and to test the survey form and receive comments and suggestions on improving it. A slide show on futuristic transit hardware and regional public transit concepts was shown to each of the groups. The presentation emphasized multimodal "family of vehicles" concepts to indicate that we would be considering transit plans other than just more buses. Following this, attitude survey forms with a cover sheet picturing several new systems were handed out to the participants and the purpose of the survey was explained.

Participants were encouraged to offer suggestions on improving wording and layout of the survey, and many useful comments were received and incorporated into later versions of the survey. During the pilot study it became clear that, if the meaning of questions could be clarified for respondents when they took the survey, the results would be considerably more accurate and interpretation problems would be minimized. This, coupled with a review of techniques for implementing a random sample, led to the conclusion that the survey should be conducted by trained interviewers by telephone rather than by mail. The survey form was again revised to include suggestions from the pilot study group and reformatted and reworded to expedite a telephone interview and computer coding and processing.[1] The pilot study revealed that personal interaction between those administering and those taking the survey was an important consideration; therefore, a professional market research firm was hired to conduct the telephone interviews.

Sampling Technique

A sampling procedure was developed to ensure that socioeconomic groups (income levels in particular) would be proportionately represented on the survey. The regionwide percentage of households in each of five income levels was obtained from census data, and the desired minimum sample for each level was specified in the same proportion. Census tracts were then categorized by median income level, and a computer program generated a random sequence of tracts for each level, which ensured geographic randomization of the sample. Thirty interviews per tract were conducted until the sample size for that income level was satisfied. Additional controls were established for employment, sex, age, and county of residence. The overall sample size target was 1,277 interviews, approximately 1 percent of total regional households. However, additional interviewing had to be performed to obtain enough responses from the lower income groups; a total of 1,588 forms were actually processed. The telephone interview technique guaranteed reasonable approximation to our sample controls and eliminated many of the problems associated with mail-back surveys such as insufficient returns, interviewee confusion, and interviewee misunderstanding the real meaning of questions.

[1] The original manuscript included a sample questionnaire. This questionnaire is available in Xerox form at the cost of reproduction and handling from the Transportation Research Board. When ordering, refer to XS-52, Transportation Research Record 508.

The telephone survey results were stratified by

1. Income group,
2. Car ownership,
3. Rail transit experience,
4. Bus transit experience,
5. Housing type (single- or multiple-unit dwelling),
6. Age group,
7. Sex,
8. Employed and unemployed, and
9. County of residence.

TYPES OF QUESTIONS AND MAJOR SURVEY RESULTS

Transit Use

Potential conditions in 1980 and 1990, such as increased traffic congestion, air pollution, and energy shortage problems, were described to the interviewees. They were then asked whether they would use (yes or no) a future regional transit system that met their specifications. After this general question, two broad transit concepts were briefly described: a door-to-door system and a station/stop system that the users accessed by walking or driving. (Generic names such as dial-a-bus, dual-mode, and PRT were not used because most residents were unfamiliar with their meanings.) Respondents were then asked how often they would ride each of these systems—never, infrequently, half the time, most of the time, and all the time—for three trip purposes (work, shop, and recreation) and for "all trips to downtown."

Eighty-nine percent of the total sample said that they would use a modern future transit system; the range of answers for all stratification groups was between 83 and 94 percent. It is apparent that the respondents interpreted this question as "would you ever use such a transit system?" inasmuch as a drastically lower percentage of regular use was indicated by the sample. The high response to this question should be interpreted as representing a favorable community attitude toward accepting a modern regional transit system in the tricounty area but not necessarily toward riding it regularly.

For every trip purpose, more respondents said they would regularly use a door-to-door system than a station/stop system to which they would have to walk. Respondents would use both types of systems most frequently for work trips, followed by trips to downtown and shopping trips; recreation and other trips would generate the least transit patronage. Thirty-one percent of the respondents said they would use a door-to-door system for work trips all the time; another 20 percent said they would use it most of the time. Nineteen percent of the sample indicated that they would use a station/stop transit system all the time for work trips, and another 18 percent said they would use it most of the time. Responses to direct transit usage inquiries are shown in Figure 1.

Several special groups—low income, low car ownership, women, the elderly, persons with previous rail or bus transit experience, multiple-unit dwellers, and the unemployed—indicated higher-than-average transit use in both systems, but the difference was more extreme in the door-to-door configuration.

Ranking of Transportation System Attributes

Participants were asked to rank the importance of travel time, cost, and convenience in selecting transportation mode for work, shopping, and recreation trips (Table 1). Convenience was described to them as waiting time, walking distance, time to find a parking spot, proper schedules, availability of transit to the destination, and no transferring. Travel time was defined as running time on the vehicle, and costs included parking, transit fares, tolls, and gasoline.

The respondents clearly indicated (Fig. 2) that convenience was the most important item for all three trip purposes. For every trip purpose, travel time was considered the second most important and cost the least important attribute. Convenience received its highest rating (60 percent) in the shopping trip category. Travel time received its highest rating (28 percent) for work trips, but this was still less than the 50 percent of the sample that claimed convenience was most important for work trips.

Figure 1. Use of door-to-door and station/stop transit for various trip purposes.

Table 1. Entire sample ranking of most important transportation attributes.

Trip Purpose	Attribute	Percentage Responding Most Important	Ratio (cost = 1.00)
Work	Convenience	50	3.85
	Travel Time	28	2.15
	Cost	13	1.00
Shop	Convenience	60	3.75
	Travel Time	19	1.18
	Cost	16	1.00
Other	Convenience	51	2.63
	Travel Time	23	1.21
	Cost	19	1.00

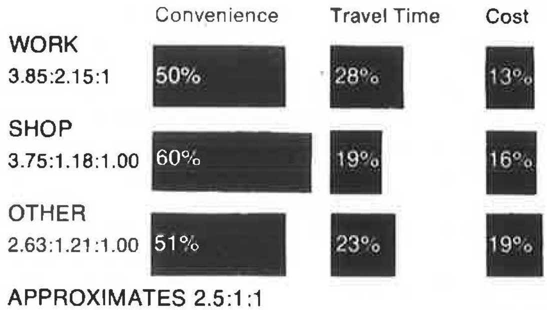

Figure 2. Ranking of most important attributes of transportation.

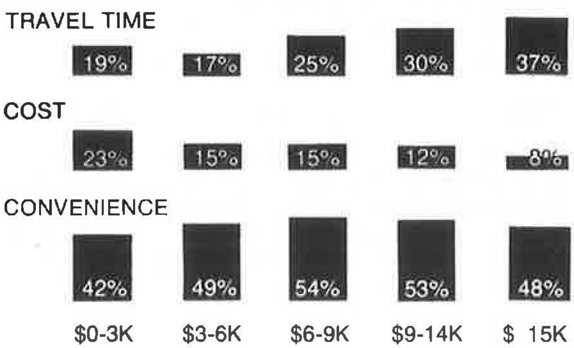

Figure 3. Importance rankings by income stratification.

Service Levels

Respondents were asked to suggest desirable service levels for walking time, walking distance, transit fares, and other items. It was felt that having the interviewee specify a service level was less biased than offering him predetermined categories to choose from.

The survey results indicated that the average time respondents would be willing to wait for a transit vehicle is 14 minutes for shopping and work trips. They would walk an average of two blocks to a transit stop and be willing to pay an average of 29 cents for a transit ride. More than 50 percent of the sample said they would not be willing to make transfers on a transit system. This is certainly an important consideration in designing a future regional system that will attract patronage.

Employed respondents were asked how long it takes them to travel to work; it is assumed that any future transit system would have to meet or exceed these travel times. As many as 27 percent can get to work in less than 10 minutes; more than 90 percent of the sample can get to work within a half-hour.

General Questions

Additional questions were included to obtain the stratifications mentioned previously to determine a profile of the sample. Over 88 percent of the sample indicated ownership of a car, and 51 percent were multiple-car households. Of those respondents who were employed, 92 percent had a car or truck available for their daily work trip, and 39 percent used that vehicle as part of their job during the day. Of the total sample, 89 percent had cars available for shopping and recreational trips.

The respondents were asked to indicate (out of a given list of 10) the three most important uses of their tax money for local services. The frequency of appearance of each tax use in the "top three" was tabulated. Health and hospitals were mentioned in 64 percent of the forms, education second at 60 percent, police third at 48 percent, and public transit fourth at 31 percent. Pollution control was next, 29 percent; followed by sanitation, 17 percent; highways, 11 percent; housing, 10 percent; welfare, 9 percent; and recreation and parks, 8 percent.

STRATIFICATION EFFECTS

Income Groups

There was a definite trend toward a higher "all the time" use of transit for all trip purposes as income decreased, although the range of values was not large. Whereas 25 percent of the lowest income group said they would use station/stop service for work trips all the time, 15 percent of the highest income group responded similarly. For the door-to-door service, the responses were 40 percent in the lowest group and 27 percent in the highest. As income increased, a greater proportion of the answers indicated "never" and "infrequent" use of the system.

The number of respondents indicating travel time as most important (for each trip purpose) significantly increased as their income increased, from 19 percent in the lowest group to 37 percent in the highest. Similarly, the percentage indicating cost as most important decreased with increasing income, from 23 percent in the lowest income group to 8 percent in the highest. These trends were most pronounced in the work trip category. However, in all stratifications, convenience remained of greatest importance. The trade-off between travel time and cost as income increases is shown in Figure 3.

The average waiting time specified for a transit vehicle decreased with income, from 17 minutes in the lowest group to 11 minutes in the highest; all groups indicated a two-block walking distance. The price specified for a transit ride increased only from 27 to 33 cents between income levels. A slightly greater percentage of the high-income group said they would not allow any transfers on the future system (44 percent in the lowest group, 52 percent in the highest). There is apparently a greater demand for certain conveniences in the higher income groups.

Car Ownership

Most of the trends related to increasing income are also exhibited by increases in the number of cars owned. Significant effects to be noted are that

1. Persons without cars indicated a willingness to wait as long as 19 minutes for a transit vehicle, whereas car owners would wait 12 to 14 minutes;
2. Use of transit "all the time" for both systems by no-car households was double that of the single-car owners for shopping, recreation, and downtown trips, and the ratio was 1:5 for work trips; and
3. A significant percentage of no-car households had cars available to them (neighbors, car pools, and so on) for shopping trips (37 percent), other trips (36 percent), and work trips (33 percent).

Transit Experience

Persons with regular bus or rail transit experience were more oriented toward using it in the future than those without experience, but they were also more aware of traditional transit problems and demanded higher levels of service. For all trip purposes, convenience was more important to previous transit users (54 percent) as compared to infrequent and nonexperienced users (49 percent). A greater percentage of the experienced group were in the "no transfers allowed" category, but travel times were relatively less important to them. More importance was placed on taxes used for public transit by persons with previous transit experience. Forty percent of the respondents who used bus transit frequently listed transit as a high-priority tax use, whereas only 27 percent of the infrequent users or nonusers did.

Other Stratifications

Residents of multiple-unit dwellings indicated 5 to 10 percent higher "all the time" use of transit in every category of system and trip purpose when compared to single-family homes; they also exhibited 20 percent lower car availability. Convenience was more important to the elderly, whereas women and the unemployed were relatively more concerned with cost and less with travel time than other groups.

CAPTIVE AND CHOICE RIDERSHIP

A major purpose of the transit use questions, for the door-to-door and station/stop systems, was to determine automobile- and transit-captive percentages; the remainder would be classified as free-choice travelers. The computer program that processed the attitude survey used the following rules to determine captive and choice respondents (by trip purpose, income group, and system type):

Type	Characteristics
Automobile captives	Need car in job; would "never" or "infrequently" use transit
Transit captives	Would use transit "all the time" and do not have car available; 50 percent who would use transit "most of the time" and do not have a car available
Free-choice travelers	Would use transit "half the time"; 50 percent who would use transit "most of the time" and do not have a car available; would use transit most or all the time but have a car available

Regionwide, the percentage of work trips was

Type	Door-to-Door System	Station/Stop System
Automobile captive	45.6	55.4
Transit captive	3.2	2.2
Free choice	51.2	42.4

For both systems and each trip purpose (Figs. 4 and 5), there is a gradual decrease in captive transit ridership as income increases, as well as a gradual increase in captive automobile ridership. For all income groups and trip purposes, the percentages of transit captive and free choice are greater for the door-to-door system than the station/stop system.

For each category, the trip purposes are listed in order of decreasing importance:

Type	Trip Purpose
Automobile captive	Recreation, shopping, work
Transit captive	Shopping, recreation, work
Free choice	Work, shopping, recreation

ATTITUDE SURVEY INPUT TO THE MODAL-SPLIT MODEL

The three major inputs of the community survey to the modal-split model are the definition of captive and choice ridership, the confirmation of "importance" weightings of travel time, cost, and convenience in the disutility equation, and the specification of service levels for transit network development producing travel times and costs. The modal-split flow chart (Fig. 6) indicates that total person trip tables are divided into 3 subtables on the basis of ridership: automobile captive, transit captive, and free choice. Automobile captive and transit captive are immediately assigned to their respective modes and are not subject to further modal split. Free choice is the only category to be subjected to disutility-based modal split. Free-choice transit trips are added to captive transit trips to get total transit tables; free-choice automobile trips are added to captive automobile trips to get total automobile trip tables. This procedure, which operates on each trip interchange (for work, shop, and other purposes), is described as follows:

1. A matrix of automobile-captive, transit-captive, and free-choice percentages by income group, system type, and trip purpose was defined by the attitude survey. For example, if 5 percent of the person trips are transit captive and 35 percent automobile captive, then overall transit trips can be no less than 5 percent and no greater than 65 percent. The trips that are neither transit captive nor automobile captive are considered free choice.

2. A disutility value Z of transit versus highways is computed for the particular trip interchange. This disutility value is computed from the following equation:

$$Z = 2.5\,(Ta + Tw - At) + (Tr - Ar) + \frac{(F - 0.5P - 5.7D)}{C}$$

where

Z = disutility of transit over highways in units of equivalent minutes,
Ta = walking time to and from transit,
Tw = waiting and transferring time associated with transit,
At = automobile terminal time at destination,
Tr = transit running time,
Ar = automobile running time,
F = transit fare,
P = parking cost at destination,
D = highway distance, and

Figure 4. Captive riders of door-to-door system by income stratification.

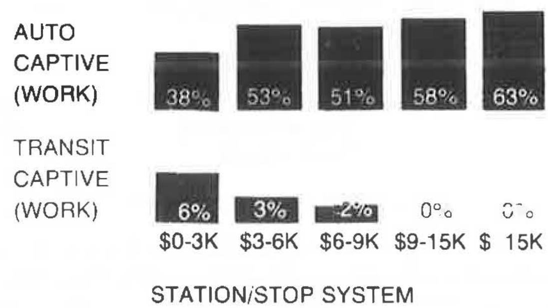

Figure 5. Captive riders of station/stop system by income stratification.

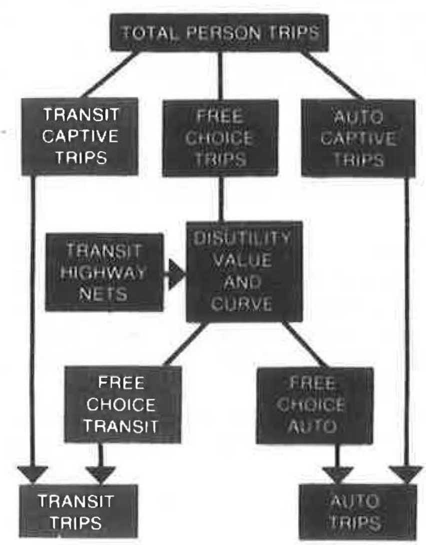

Figure 6. Modal-split model.

C = cost of 1 minute of time based on wage rate implied by median annual income of applicable zone of origin.

The attitude survey's responses to the service levels of waiting time, walking distance, and transit fare served as guides in the development of the transit network. This in turn yields the zone-to-zone excess and running time components and costs for input to the disutility equation. Furthermore, the weighting of 2.5:1:1 given to convenience, travel time, and cost respectively in the equation was confirmed by the results of the attitude survey importance rankings.

3. Once the disutility value Z has been computed, the percentage of free-choice riders that will use transit is read off the S-shaped disutility curve (originally calibrated in the Minneapolis-St. Paul metropolitan area). This percentage is applied to free-choice transit riders. The remainder of free-choice trips is defined as automobile trips.

4. Total transit patronage thus consists of transit captives plus some fraction of the free-choice travelers. Automobile trips consist of automobile captives plus the remaining fraction of free-choice travelers.

The entire procedure described above has been programmed as a FORTRAN subroutine to be inserted into the UMODE program of the UMTA Transit Planning Package.

SUMMARY

The community attitude survey served to confirm the basic assumptions of the disutility modal-split model and provided the captive rider endpoints, customizing the model for application to the Orlando urban area. The service level responses and profile of the sample aided the preliminary definition of characteristics of the regional transit network. A secondary but very important function of the attitude survey was to begin community orientation toward planning and acceptance of a future regional public transit system.

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INTERCHANGE DEVELOPMENT PATTERNS ON INTERSTATE HIGHWAYS IN SOUTH CAROLINA

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This paper describes the results of a study of interchange development patterns on Interstate highways in South Carolina. Data obtained at 131 interchanges were used to examine the relationships between the number of service stations, restaurants, motels, and non-highway-oriented businesses located at interchanges and five interchange characteristics. The interchange characteristics were ADT on the Interstate, ADT on the intersecting highway, distance to and population of communities within 10 miles of the intersection, distance to nearest major urban center, and distances to adjacent interchanges on the Interstate highway. The relationships between interchange development and interchange characteristics can be used to obtain rough estimates of anticipated development at proposed interchanges. Although the interchange development patterns and the relationships between development and interchange characteristics are directly applicable only in South Carolina, the data can be applied in other states with similar economic, geographic, and demographic conditions, especially in the southeastern United States.

•THE LARGEST highway construction program ever initiated was that authorized by the 1956 Federal-Aid Highway Act: The Interstate Highway System, since extended to 42,500 miles, is characterized by high design standards that produce high-speed, multilane, controlled-access thoroughfares with separate travel lanes in each direction and grade separations at all intersecting highways. The development of this type of highway has made highway planners increasingly aware of the social and economic impacts a modern highway can have on the communities through which it passes. That the Interstate System will link 90 percent of the cities in the United States with a population of 50,000 or more and that when completed it will carry 20 percent of the total motor vehicle traffic but comprise only 1 percent of the total highway mileage in the country have caused factors such as patterns of land use and commercial development adjacent to the highway system to become important considerations in the location and design of modern highways.

The 1956 Federal-Aid Highway Act prohibits commercial roadside development within the Interstate highway rights-of-way. Therefore, access points, or interchanges, become the focal points of the Interstate Highway System because they provide ingress and egress to the system, as well as access to commercial, industrial, and residential development. Because all of the Interstate highway traffic must be channeled through interchanges, the areas surrounding the interchanges are desirable locations for economic development. Another attractive characteristic of the interchanges is that the long-distance traveler does not have to travel far from the highway to obtain food, lodging, and gasoline. Also, many businesses and industries that do not necessarily attract customers from the highways do require frequent and direct access to the highways through the interchanges.

To maintain a satisfactory level of operation through the interchanges along the Interstate Highway System, or any controlled-access highway for that matter, careful

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planning is necessary during the design stages of highway development. Unexpected or uncontrolled economic development can cause increases in traffic that will cause the interchange to reach design capacity prematurely and eventually to break down functionally, resulting in tremendous private and public economic losses.

A model needs to be developed that can predict the development of commercial establishments at an interchange based on the traffic and locational characteristics of the interchange. A study of interchange development on the Interstate Highway System in South Carolina was initiated with the objective of developing this type of predictive model.

The results of the study can be used in several ways. First, the model can be used to provide a basis for coordinated planning on the remainder of the Interstate System in South Carolina and in other states with similar demographic and economic characteristics. Second, the data can be used to predict the amount of economic development at existing interchanges along non-Interstate highways that have been constructed to Interstate standards. The model will also be useful in planning the interchanges proposed for non-Interstate highways that are to be upgraded to Interstate standards. Third, the results of the study will provide a method of planning for interchanges that have already been constructed but are not yet fully developed. Fourth, the results of this study can be used as an integral part of a comprehensive analysis of the economic feasibility of an interchange being planned for future construction. The last three applications are most valuable, for approximately 70 percent of the entire Interstate Highway System is already complete and open to traffic.

The study had three objectives. The first objective was to record the existing economic development at each interchange along the sections of the Interstate System in South Carolina that were open to traffic at the time the study was initiated. Future periodic checks of the interchanges can be made to provide an accurate record of the changes in development, thus providing information on development trends for each type of interchange. A second objective was to determine the interchange characteristics that influence economic development at interchanges and to quantify these characteristics so that each characteristic may be evaluated for every interchange under consideration. The third objective was to develop data that could be used to predict the amount of economic development at an interchange based on the characteristics of the interchange.

BRIEF LITERATURE REVIEW

Interchange development has concerned highway planners for many years. The initial studies involved Mass-128 around Boston (4, 5). A tremendous amount of unexpected industrial and commercial sites developed along the highway and caused early functional obsolescence of the facility.

Several highway departments began studying the effects of development on the interchange traffic and kept records of the economic development at the interchanges along Interstate highways (1, 2). The Alabama Highway Department used aerial photography annually to record development along the entire Interstate System in the state. The Michigan Department of State Highways (2) studied a 180-mile section of Interstate 94 in an attempt to determine the variables that affected economic development at the interchanges. Neither study reached any significant conclusions concerning the characteristics of interchange development, however.

Several agencies and individuals later attempted to develop models that could be used to predict interchange development. Fowler, Sanders, and Stocks (7) first attempted to predict interchange development based on the number of years the interchange had been opened to traffic and the distance to and population of the nearest urban area. Models were developed that would predict the number of gasoline pumps, the number of restaurant seats, and the number of motel rooms. None of the models proved to be very satisfactory, however.

Sauerlender, Donaldson, and Twark (8) conducted a similar study but, in addition, related interchange development to four other variables: type of interchange, ADT on Interstate highway, ADT on intersecting highway, and topography of the interchange area. No statistical analysis was conducted to test the significance of each variable, but several important conclusions were reached. The most significant findings of this study were as follows:

1. Economic development was closely related to the average daily traffic on the intersecting highway,
2. Development was related to the topography, and
3. Development was related to the distance to the nearest urban center.

Twark (10) conducted a more extensive study to predict economic development at rural interchanges by using multiple regression techniques. He examined 105 interchanges along the Interstate Highway System in Pennsylvania. Three separate models were developed. The first model predicted the number of service stations, the number of motels, the number of restaurants, the number of non-highway-oriented businesses, and the average annual rate of growth in market value of real estate in the local community. In each case, the percentage of sample variation explained was very low. A second model was developed in an attempt to improve the proportion of sample variation explained by the first model. The second model predicted the number of gasoline pumps, the number of motel rooms, the number of restaurant seats, the number of non-highway-oriented businesses, and the average annual growth in the market value of local community real estate. Sample variation explained was improved in the restaurant and motel equations only, however. The third model was developed to predict highway-oriented development, non-highway-oriented development, and the average annual rate of growth in the market value of real estate in the local community. None of the relationships in the third model showed any improvement in percentage of sample variation explained over those in the first and second models.

Stein (9) attempted to define other variables that could be used to predict interchange development that had not been previously used. The most significant variable that he introduced was the use of travel time rather than the distance in miles to nearby urban areas as a measure of spatial separation.

Babcock and Khasnabis (3) analyzed the changes in land development that took place along 550 miles of controlled-access highways in North Carolina. The land areas were analyzed in terms of the rural, suburban, or urban interchange characteristics. Land development was broken down by whether it appeared to be attributable to the highway development. In rural areas, the predominant land developments were service stations and were so scattered that they could not be predicted. In suburban areas, service stations, motels, and industries were more equally distributed, were denser, and could be predicted reasonably. In urban areas, land developments could be predicted, but the factors required for the models were so numerous that statistical analysis of the factors was impossible.

A more comprehensive review of literature related to interchange development studies has been presented by Epps (6).

METHOD OF ANALYSIS

Extensive field analysis of the sections of the South Carolina Interstate Highway System that were open to traffic was conducted in an effort to determine the characteristics of interchange development. The study encompassed 131 interchanges along four Interstate highways. The solid lines in Figure 1 show the sections of the Interstate Highway System that were included in the study. Two of the highways, I-85 and I-26, are complete and open to traffic throughout the state. I-20 is now complete from the Georgia state line to the intersection with US-601 near Camden, whereas I-95 is open from the North Carolina line to the intersection with US-310 south of Sumter. Construction of I-77 has just begun. Approximately 385 miles of highway were included in the study; only the section of I-20 from the Georgia state line to the intersection with SC-6 west of Columbia was omitted.

Each of the 131 interchanges was studied thoroughly by means of a site investigation, detailed county highway maps, and traffic volume maps. During each site investigation, a diagram of the interchange was sketched to record the number of the intersecting highway, the type and configuration of the interchange, and the type and location of each

Figure 1. South Carolina Interstate Highway System.

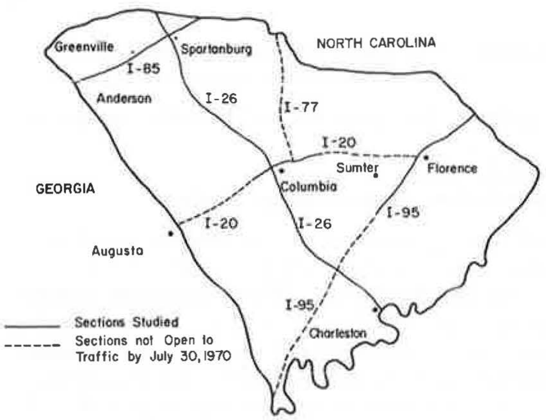


Figure 2. Completed interchange diagram.

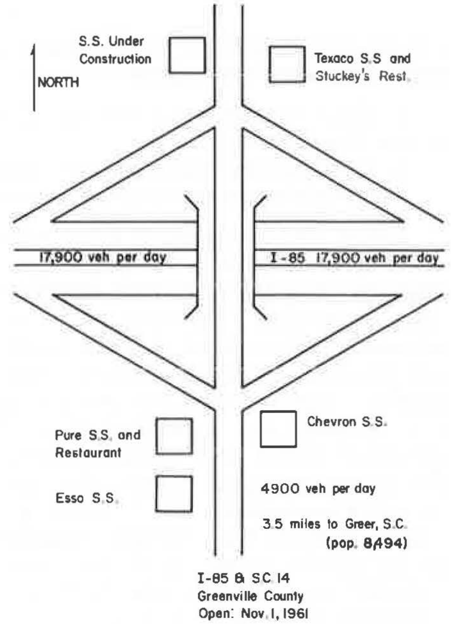


Figure 3. Amount of interchange development and ADT on Interstate highways in South Carolina.

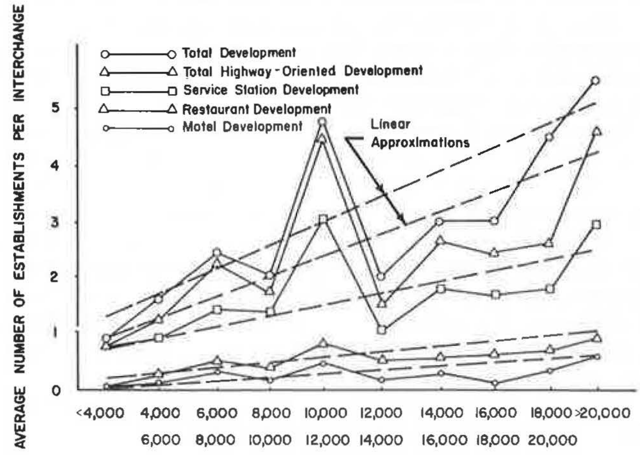
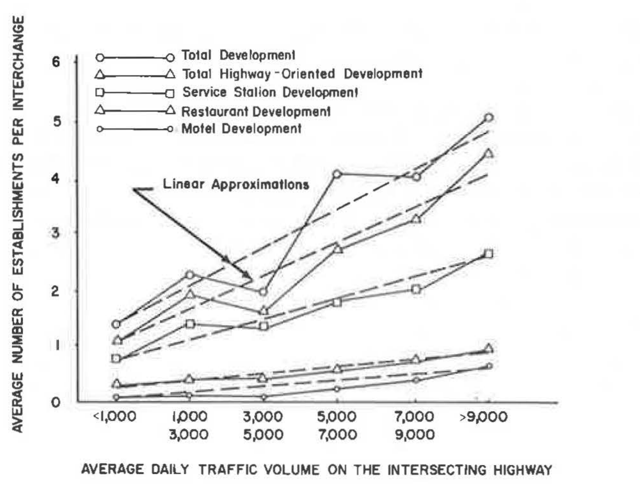


Figure 4. Amount of interchange development and ADT on intersecting highways in South Carolina.



unit of economic development in the interchange area. Other information on topography, residential development, and factors that might affect economic development were also noted on the interchange diagram. Information concerning the characteristics of the interchanges was compiled from county highway maps, the 1969 South Carolina Primary Highway Traffic Flow Map, county traffic volume maps, and other data supplied by the Traffic and Planning Division of the South Carolina Highway Department. The interchange characteristics recorded on the diagram consisted of the population of and the distance to communities near the interchange, ADT on the Interstate highway and the intersecting highway, the distances to adjacent interchanges in either direction along the Interstate highway, the distance to and population of the nearest major urban center by the shortest route, and the date the interchange was open to traffic. Figure 2 shows an example of a completed interchange diagram.

Several interchange characteristics were found to affect the amount of economic development attracted to the interchange: interchange type, volumes of traffic on the intersecting highways, distance to and size of the nearby communities, distance to the nearest large urban center, and average distance to adjacent interchanges. Of course, there are other important interchange characteristics that relate primarily to the economy of the area surrounding the interchange, but these factors are very difficult to measure.

All of the interchanges studied were classified as either complete or incomplete. A complete interchange is an interchange that allows a driver traveling in either direction on either of the intersecting highways to make any desired traffic movement and travel in any direction he desires, e.g., diamond, partial cloverleaf, full cloverleaf, trumpet, and split diamond interchanges. An incomplete interchange, e.g., a half diamond does not allow a driver to make certain traffic movements on either of the intersecting highways. An additional category used to classify complete interchanges further was a restricted interchange. A restricted interchange was defined as an interchange that allows a driver to make any desired traffic movement from either of the intersecting highways, but does not allow direct access to the adjacent land areas surrounding the interchange. An example is the intersection of two controlled-access highways. Six restricted interchanges were found on the sections of Interstate included in the study.

RESULTS OF THE STUDY

Interchange Type

Of the 131 interchanges studied, only 12 were categorized as incomplete or restricted. The incomplete or restricted interchanges only contributed four units of economic development, all of which consisted of non-highway-oriented development. Slightly less than 50 percent of the interchanges (65) were diamonds, whereas there were 40 partial cloverleaves (30 percent), 15 full cloverleaves (11 percent), two trumpets, one split diamond, three half diamonds, and five specialized or modified interchanges. There were 342 units of economic development located at the 119 complete interchanges composing almost 99 percent of the total economic development found on the 131 interchanges studied.

Interstate Highway Traffic Volume

Two important interchange characteristics are ADT on the Interstate highway and ADT on the intersecting highway. Figure 3 shows the relationship between ADT on the Interstate highway and average amount of economic development at the interchange. The solid lines represent the actual data from the 131 interchanges included in the study. The dotted lines represent linear approximations of the development patterns of each type of business establishment as a function of Interstate highway traffic volume. The linear approximations were used in an effort to examine the degree to which the amount of economic development varied linearly with the traffic volume on the Interstate highway.

As shown in Figure 3, ADT on the Interstate highway exhibited a very small effect on motel and restaurant development. Service station development, however, increased significantly as ADT on the Interstate highway increased, but not in a linear manner. Interestingly, non-highway-oriented development, the difference between total development and total highway-oriented development, also increased as ADT on the Interstate highway increased, a rather unexpected finding.

Traffic Volume on Intersecting Highway

The average daily traffic volume on the intersecting highway had a significant effect on the development at the interchanges. Figure 4 shows that the intersecting highway traffic volume exhibited an almost linear influence on the amount of all types of interchange development. However, motel and restaurant development was only slightly affected by increases in ADT on the intersecting highway, whereas service station development showed a significant response to increasing traffic volume. Again, non-highway-oriented development increased slightly as ADT on the intersecting highway increased.

Community Factor

The other interchange characteristics investigated dealt with the location of the interchange in relation to nearby towns and communities, major urban centers, and adjacent interchanges. Each of these characteristics was also found to influence the amount of economic development at the interchange.

Communities located near the interchange offer a reasonable potential for business activity. The relative size of the community, measured by the population, provides an indication of the potential impact that the community can have on the economic activity at interchanges within or adjacent to the community. The economic activity is determined primarily by the volume of traffic generated by and attracted to the community. The distance from the community to the interchange has a modifying effect on the influence that the community will have on the business activity and volumes on non-Interstate highway traffic in the immediate vicinity of the interchange. For the proposed analysis, 10 miles was considered to be the maximum distance at which a local community would significantly influence interchange economic development. Based on the assumption of the 10-mile radius of influence, a variable that will hereafter be referred to as the community factor was developed. The community factor of each interchange was calculated by summing the gravity factors of each community within 10 miles of the interchange. The gravity factor of a community is designed to measure the influence the community would have on an interchange located a specified distance away. The gravity factor was calculated for each community by dividing the population of the community by the square of the distance from the community to the interchange under consideration. The distance was squared to reflect the effect that spatial separation has on trip distribution, as has been determined in urban transportation planning studies. The community factor for a single interchange is represented mathematically as

$$\text{Community factor} = \sum_{i=i}^{n} \frac{\text{population}_i}{\text{distance}_i^2}$$

where n = the number of communities within 10 miles of the interchange.

Figure 5 shows the relationship between community factor and interchange development. The effect of the community factor on total development, total highway-oriented development, and service station development was significant, but the relationships were clearly not linear. Motel and restaurant development was not significantly affected by the community factor, although the response of each factor was roughly linear in nature.

Distance to the Nearest Major Urban Center

Proximity to a large urban center with a population greater than 25,000 affects the amount as well as the types of economic development at an interchange. More motels and restaurants are developed at interchanges near urban areas than at interchanges farther from urban areas (Fig. 6). Also, non-highway-oriented businesses tend to compete more for land at interchanges near urban areas and make up a significant proportion of the total development. As the distance from the urban area increases, all types of development decrease.

At longer distances from the urban centers, service station development makes up a larger proportion of the highway-oriented development, and at distances over 40 miles it makes up almost 100 percent of the highway-oriented development as well as total development. The amount of motel and restaurant development decreases approximately linearly as the distance from the urban center increases. However, service station development, total highway-oriented development, and total development decrease rather erratically as the distance from the urban center increases.

Distance to Adjacent Interchanges

The distance to adjacent interchanges has been shown to be a significant factor in determining the development potential of an interchange. When interchanges are closely spaced, businesses tend to cluster about the interchanges. This clustering effect, however, is due to the higher probability of urban land use in the vicinity of closely spaced interchanges. Figure 7 shows the relationship between the amount of interchange development and the average distance to adjacent interchanges. This relationship is similar to that between interchange development and the distance to a major urban center (Fig. 6). However, the responses shown in Figure 7 are more linear in nature than those shown in Figure 6. Interchange spacing of less than 1½ miles occurs more commonly in urban areas, whereas spacing of more than 6½ miles is found primarily in rural areas. The amount of all types of development decreased as average interchange spacing increased. For interchange spacings greater than 6½ miles, service stations constituted 100 percent of the total development, exactly the result for interchanges located more than 40 miles from a major urban area as noted in Figure 6.

PREDICTING INTERCHANGE DEVELOPMENT

The data shown in Figures 3 through 7 can be used to obtain approximate estimates of the amount and composition of the development that will locate at a proposed interchange. Based on the data collected in South Carolina, the following approach to estimating the expected development at interchanges is suggested.

1. Obtain accurate estimates of the traffic volumes on both intersecting highways, distances to and populations of nearby communities, distance to the nearest urban center with a population of at least 25,000, and distances to adjacent interchanges.
2. Using either the actual relationships between development and interchange characteristics shown in Figures 3 through 7 or the linear relationships shown by the dotted lines in these same figures, obtain an estimate of the average number of units of development for motels, restaurants, service stations, and total development for each of the five relationships.
3. Average the five estimates for each type of business establishment and round the values to the nearest whole unit of development to obtain estimates of the expected units of each type of development. Special care should be exercised in the rounding process to ensure that, if the units of development for some types of business are rounded up, other types of business should be rounded down.

This procedure results in an estimate of the number of motels, restaurants, service stations, and non-highway-oriented establishments expected to locate at each proposed interchange. It should be noted that the estimates obtained from this procedure may not be exact for a specific interchange being considered. However, on the average an interchange of the type being analyzed could be expected to attract the amount of develop-

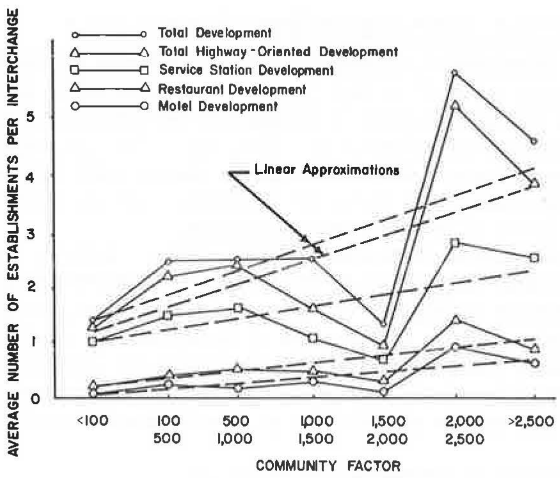


Figure 5. Relationship between interchange development and community factor.

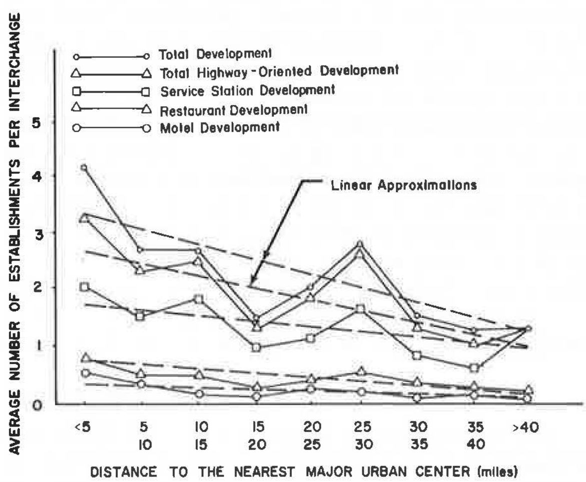


Figure 6. Relationship between interchange development and distance to nearest major urban center.

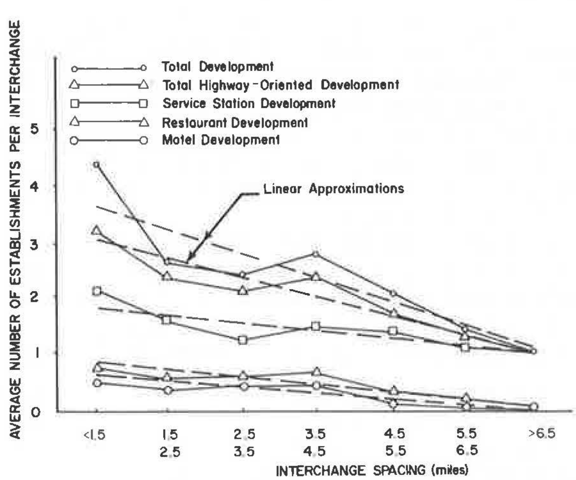


Figure 7. Relationship between interchange development and average distance to adjacent interchanges.

ment indicated by the estimate. The rough estimates of interchange development can be used in planning traffic control, traffic operations, and land use at proposed interchanges. The estimate of the expected development will vary slightly depending on whether actual or linear relationships between the amount of development and the five interchange characteristics are used. Also, the amount of variation between estimates obtained by the use of the two different relationships is higher for some types of businesses than for others.

It should also be emphasized that the relationships between the amount of development and the interchange characteristics are directly applicable only for conditions in South Carolina. For estimating interchange development in other states, the relationships should be derived from data collected in that particular state. However, it is believed that the linear relationships shown by the dotted lines in Figures 3, 4, 5, 6, and 7 are reasonably accurate for other states where the population distribution and economic characteristics are similar to those in South Carolina.

Statistical Analysis of Interchange Development Data

In an attempt to investigate in more detail the relationship between the amount of interchange development and the characteristics of the interchange, we conducted a limited statistical analysis of the data. The statistical analysis consisted of using multiple regression techniques to relate the amount of development at interchanges to a series of variables related to the traffic, demographic, and locational characteristics of the interchange. A primary aim of the statistical analysis was to improve the predictability of the amount of development at a proposed interchange.

A computer program known as the statistical analysis system (SAS), developed at North Carolina State University at Raleigh, was used in the statistical analysis. SAS is a multipurpose, versatile system that is applicable to many statistical data analysis problems. However, the version of the SAS program used in this study did not provide a stepwise regression capability to improve the derived predictive equations. The program was used to fit the input data to a model having specific dependent and independent variables. The system was used in this study in an attempt to develop multiple regression equations that would predict the average number of units of each type of economic development at a proposed interchange.

A regression equation was developed for each of the three highway-oriented types of businesses: service stations, restaurants, and motels. No attempt was made to develop an equation for non-highway-oriented businesses because of the poor results obtained by Twark (10). A fourth multiple regression equation was designed to predict the total number of development units expected at an interchange. Summing of the expected highway-oriented development units and subtracting the result from the expected total development would yield an estimate of the non-highway-oriented development at the interchange.

Initially, eight variables were used in the multiple regression equations generated by the SAS program: ADT on the Interstate highway, ADT on the intersecting highway, distance to nearest major urban center, interchange type classified as complete or incomplete (restricted), community factor, average distance to adjacent interchanges, amount of time the interchange has been opened to traffic, and population of nearest major urban center. After several computer trials, the variable concerning the time the interchange had been opened to traffic was eliminated from the analysis because it did not contribute to the reliability of the equations.

The traffic, locational, and demographic characteristics for each interchange were placed on a single punch card, and the data for the 131 interchanges were analyzed by the SAS subroutine on the IBM System 360/50 computer at Clemson University. Each regression equation was developed after several trials because the SAS program could not perform a stepwise multiple regression procedure. After each run of the program, the variables that were not significant at the 5 percent level were removed, and the program was rerun.

The multiple regression equation for the estimation of the total number of units of development at a proposed interchange proved to be the most reliable of the equations that were developed. The significant variables used in the equation were ADT on the Interstate highway, interchange type, population of the nearest major urban center, and ADT on the intersecting highway. The multiple regression equation for total interchange development explained slightly more than 40 percent of the variation in the amount of development at the 131 interchanges. The coefficient of determination, R^2, for the equation was 0.4042.

The variables used in the multiple regression equation for service station development were interchange type, ADT on the Interstate highway, population of the nearest major urban center, and ADT on the intersecting highway. The equation explained slightly more than 33 percent of the sample variation; $R^2 = 0.3319$.

The multiple regression equation for restaurant development explained only 23 percent of the sample variation with an R^2 of 0.2297. The significant variables of the equation were interchange type, population of the nearest major urban center, and ADT on the Interstate highway.

The multiple regression equation for motel development used the following significant variables: interchange type, ADT on the intersecting highway, ADT on the Interstate highway, and population of the nearest major urban center. The equation explained slightly more than 18 percent of the sample variation with an R^2 value of 0.1853.

The obvious nonlinear relationships between the independent variables and the dependent variable (Figs. 3, 4, 5, 6, and 7) caused the researchers to consider the possibilities of improving the linearity of the relationships by using several applicable transformations on the dependent and independent variables. In an attempt to improve the percentage of sample variation explained by the multiple regression equations, a square root transformation was applied to the dependent variable and a logarithmic transformation was applied to the independent variables. Neither of the transformations improved the percentage of variation explained. Logarithmic transformations on some of the independent variables resulted in even lower percentages. With these results, further attempts to describe the nonlinear characteristics of the relationships were abandoned.

The original purpose of the statistical analysis was to provide reliable multiple regression equations that could be used to predict the amount and type of economic development attracted to an interchange based on the traffic, locational, and demographic characteristics of the interchange. Because of the low percentages of sample variation explained by the multiple regression equations, it was concluded that the equations were not particularly useful for predicting interchange development. The relationships between the amount of interchange development and the characteristics of the interchange that were shown in Figures 3, 4, 5, 6, and 7 appear to be more useful for estimating the number of units of each type of business attracted to the proposed interchange. The relationships shown in the figures are particularly advantageous because they provide a visual representation of the variation in the amount of development as a function of the interchange characteristics. Until suitable multiple regression equations are developed to predict the interchange development, the procedure outlined previously is recommended. It was difficult to overcome the variability of the interchange development patterns by using multiple regression techniques.

The collection of the data needed to relate the amount of development to interchange characteristics is a time-consuming process. For the analysis of a single proposed interchange or even several proposed interchanges, the time required to gather sufficient information to develop the relationships could not be justified. However, most of the information must be gathered only once, and an organization that is confronted frequently with proposed access problems would profit greatly by investing the time necessary to gather information concerning interchange development patterns on sections of controlled-access highways. Periodic updating of the basic data would be required to ensure that current data are used in the analysis of proposed interchanges. The periodic updating of the data should not present a significant problem, however.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In the past, highway planners have had to rely primarily on intuition in planning for economic development around interchanges. Too often the development has been severely underestimated and the interchange has reached its design capacity far before the design year. Perhaps some of the serious traffic operation problems that have developed at existing interchanges are an indication that little or no serious consideration was given to potential interchange development in the highway planning and design stages.

Several mathematical models have been developed that can be used to predict interchange development, but each model has presented major problems to those planners who attempted to use them. The initial models that were developed used variables that were easy to evaluate for each interchange, but the variables selected were not sufficiently descriptive to predict the amount of development at the interchange accurately. The later models predicted the amount of development satisfactorily, but several of the variables in the models were very difficult to evaluate for each separate interchange.

The primary intent of the present study, therefore, was to develop an approach that used variables that were not difficult to evaluate for each particular interchange and also provided an accurate estimate of the levels of economic development that could be expected at the interchange. Of primary importance was the requirement that the variables used in the approach be readily measurable for each interchange.

Five interchange characteristics were found to affect the amount of development found at an interchange: ADT on the Interstate highway, ADT on the intersecting highway, location and population of the communities within 10 miles of the interchange, distance to the nearest major urban area, and average distance to adjacent interchanges in either direction along the Interstate highway.

Each of these variables was examined in relation to the amount of economic development found at the 131 interchanges along the South Carolina Interstate Highway System. Because little development was found at interchanges that did not provide complete access to the motorist or did not allow the motorist to return to the highway in the direction desired, only those interchanges previously designated as complete and unrestricted would be expected to attract any appreciable amount of economic development. No analysis was made to determine the relative attractiveness of the various types of complete and unrestricted interchanges, however. An estimate of the level of development expected at a given interchange can be determined from the relationships between interchange development and the five interchange characteristics shown in Figures 3, 4, 5, 6, and 7. The major contribution of this study is considered to be the documentation of the relationship between the amount of interchange development and the interchange characteristics determined from an analysis of the Interstate System in South Carolina.

Multiple regression techniques were used in an attempt to predict the anticipated development at proposed interchanges by using the variables listed and the population of the nearest major urban center. However, low correlations were obtained between the various interchange characteristics and the amount and composition of commercial development located at the interchange. Therefore, it was concluded that the relationships between the five interchange characteristics and the amount of development at an interchange were more pertinent and useful than the multiple regression prediction equations.

The relationships shown in Figures 3, 4, 5, 6, and 7 cannot be used to predict the exact number of establishments that will locate at a proposed interchange. However, for a series of interchanges, the average business development predicted for the interchanges would reasonably approximate the actual development. Thus, the development predicted for a particular interchange from the relationships shown in Figures 3, 4, 5, 6, and 7 can be used as a reasonable estimate of the development that is likely to occur and can be used as a guide in traffic and land use planning at the interchange.

In the past, interchange planning has been conducted rather haphazardly and often with disastrous results. The data on interchange development presented herein can be used to provide both highway and land use planners with a reasonable estimate of the amount and type of commercial development expected to locate at a proposed interchange. With this information, planners can provide for the proper development of the interchange by designing the geometric configuration and traffic control provisions of the interchange and the location of the various commercial development units within the interchange area with the primary intent of minimizing the effect on the traffic flows through the interchange area.

The data on interchange development analyzed in this study have several important practical applications. First, the model can be used in the planning and design of the interchanges anticipated along the remainder of the Interstate Highway System to be constructed in South Carolina. Because more than 70 percent of the South Carolina Interstate Highway System is open to traffic at this time, this application is rather limited, however.

Second, the data can be used to estimate anticipated development at interchanges along non-Interstate highways that are being upgraded to Interstate highway standards. Because many states are attempting to develop a system of primary highways to provide safe and efficient travel by upgrading existing highways and constructing new primary highways, the data can be very helpful in the interchange planning and design considerations involved in this process.

Third, the data can be used in planning for interchanges that have already been constructed and are not yet fully developed. As nearby towns and cities grow and as traffic on the intersecting highways increases, new development can be anticipated at the best available locations within the interchange area. The new development can be predicted and the interchange area can be properly planned by using the data on interchange development characteristics.

A fourth application of the data would be as a part of a comprehensive economic feasibility analysis of a proposed interchange. The total costs associated with providing the interchange, including construction and accident costs, can be compared to the benefits received from the interchange, such as savings in travel time and income from commercial development at the interchange, to determine the economic feasibility of the interchange.

An important consideration in applying the data to different geographic areas should be emphasized. The data were obtained from the existing interchanges on Interstate highways in the state of South Carolina. The applicability of the data would necessarily then be limited to South Carolina or other states that have similar demographic and economic characteristics. These data are believed to be representative of conditions existing in the southeastern United States. However, to ensure reliable data, a state would be required to develop interchange development data that reflect the economic, demographic, and traffic characteristics of that particular state.

There are several aspects of the interchange development problem in which further research would minimize or alleviate some of the problems encountered during the course of this study. These recommendations are concerned primarily with the development of additional data that could be incorporated into mathematical models for use in predicting the amount of economic development that will be attracted to a proposed interchange.

The initial recommendation concerns the development of several additional measurable variables that reflect the effects of the communities surrounding a proposed interchange. These variables should represent such community growth trends as changes in population, per capita income, and average real estate values. These additional variables would then be combined with the traffic and locational variables and used as basic input data in developing suitable multiple regression equations. Such growth-descriptive variables are very difficult to quantify, and gathering such information for the large number of interchanges that would have to be examined to provide statistically reliable data could prove to be a difficult and expensive task.

Another recommendation for future research would be refinement of the multiple regression equations for predicting interchange development. The multiple regression equations based on the traffic and locational data of existing interchanges are static in nature. The mathematical models only predict the final total amount and the general types of development that might locate at a particular interchange site. As the Interstate System nears completion, comprehensive data can be gathered on the dynamic development patterns of the various types of business establishments. The necessary information must be gathered over a significant period of time after the entire system has been opened to traffic with the intention of developing dynamic mathematical models that would predict not only the amount of development that would occur but also the sequence in which these establishments would locate at the interchanges. Aerial photographs taken annually of completed sections of Interstate highway in several states such as the program in Alabama (1) would provide the information necessary to derive multiple regression equations that describe the dynamic nature of interchange economic development. The data on the typical sequence in which interchange development occurs would also form a basis for classifying the degree of maturity of the development pattern at existing interchanges. This information could be very useful in traffic and land use planning for existing interchanges.

Another recommendation relates to a logical substitute for one of the variables used in the analysis presented in this report. The substitution of travel time for distance (mileage) to the communities or major urban centers would more reasonably reflect the alignment, pavement conditions, and traffic congestion on the existing highway. Trip distribution and assignment research in urban areas has shown conclusively that travel time is a more sensitive variable than travel distance in measuring the effects of spatial separation on the characteristics of travel. The use of travel times would necessitate a slightly more extensive data gathering procedure inasmuch as the major routes to the communities surrounding each proposed interchange would have to be traveled to obtain a reasonable estimate of the average travel time. Alternatively, realistic estimates of average travel speeds could be used to compute the travel times. The travel time in minutes could then be used in place of the distance factor to determine the effect of each surrounding community and the nearest urban center on interchange development.

Another suggestion for future research is collecting information on the development patterns of the various types of business establishments located at interchanges on controlled-access highways in other states. Relationships between the amount of development and the various interchange characteristics similar to the relationships developed in this investigation for South Carolina can be developed in other states. If data on the relationship between interchange development and interchange characteristics were available for several states, a comparison of the relationships between states that have either similar or different economic, geographic, and demographic characteristics could be made. An evaluation of the differences in interchange development patterns between states might also lead to a more complete understanding of the nature of interchange development. Data on the nature of the variation in interchange development patterns with economic, geographic, and demographic conditions would provide a basis for making decisions on the applicability of data collected in one state to analysis of interchange development in other states. Combining interchange development data from several states would also provide a larger data base for developing multiple regression equations relating the amount of development at an interchange to interchange characteristics.

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ADVERSE AND BENEFICIAL EFFECTS OF HIGHWAYS ON RESIDENTIAL PROPERTY VALUES

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Four residential communities bisected by Interstate highways were examined to determine the effects of regional accessibility and highway-generated disturbances on property values. Disturbances measured within each community included noise, carbon monoxide, nitrogen dioxide, hydrocarbons, and particulates. Data on traffic mix, volume, and speed were obtained simultaneously. Residents were interviewed to determine their perceptions of highway disturbance and other pertinent information. Data were gathered on all valid property sales from 1969 to 1971. Noise pollution level (NPL) contour lines and CO isopleths were plotted for each community. The NPL regression coefficient was significant in explaining variation in property values in all communities and showed an average loss of $2,050 per property abutting the highway. Based on the high degree of multicollinearity between the NPL and CO variables in the regression model, the NPL coefficient reflects more than just noise-induced property value losses. The relationship among NPL, distance from the highway, and property value loss was determined. There was a high degree of correlation between measured noise (NPL) and perceived noise. Residents objected to noise more than any other highway-originating disturbance. Property value increases due to regional accessibility amounted to $5 million in one community, whereas highway-induced property value losses in the same community were $300,000. Total highway-induced property value losses in the four study communities amounted to about $2.3 million or an average of $1,120 per property.

•BEFORE rational decisions and choices can be made regarding highway location and design alternatives or noise and air pollution abatement programs, it is desirable to have as much information as possible about the relevant benefits and costs. Some of the indirect or social benefits and costs, however, are particularly difficult to measure or estimate. Nevertheless, legislation has been passed and regulations adopted to control vehicular emissions and noise, but the resulting benefits and costs to society have not been adequately considered, primarily because so little is known about them. Benefits to society from pollution abatement programs, whether achieved through highway location and design or through noise and engine emission controls, are the reductions in the costs resulting from pollution.

Motor vehicles are among the major sources of noise and air pollution in urban areas. It has long been suspected that the noise and air pollution from cars and trucks lowers the values of certain kinds of properties (land uses) abutting or close to major highways, just as the benefits of regional accessibility or locational advantage increase the property values of highway-oriented activities. To the extent, then, that property values reflect these adverse and beneficial effects, we can obtain at least partial estimates of the social or indirect costs and benefits of highways.

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This paper reports the findings of a study sponsored by the Federal Highway Administration. This study was the first to attempt to simultaneously determine the adverse effects of highway-originating disturbances and the beneficial effects from improved regional accessibility on property values in highway communities.

The main objectives of the study were to determine the effect of various highway-generated pollutants on property values, to determine the distance from a highway within which these pollutants are discernible by residents, and to estimate the beneficial influence of regional accessibility on property values.

STUDY AREAS

Four urban communities were selected for study: Bogota, N.J. (including portions of the towns of Ridgefield Park and Teaneck), along I-80; North Springfield, Va., along I-495 (Capital Beltway); Rosedale, Md., along I-95; and Towson, Md., along I-695 (Baltimore Beltway). Residential development is the predominant land use in all four communities. Bogota is an old community and was fully developed at the time I-80 was constructed. Rosedale and Towson were partially developed at the time of highway construction. North Springfield was in an early stage of development when construction of I-495 began. Table 1 gives descriptions of these areas.

The four areas were selected primarily because (a) residential development was the predominant land use and it was felt that this land use more than any other would most likely reflect the negative influence of highway-generated pollutants on property values; (b) the communities were sufficiently large and extended far enough away from the highways so that an area could be delineated in which no adverse highway effects would be felt (a control zone); and (c) the communities were not close to a major highway interchange where property value gains reflecting the highly beneficial aspects of locational advantage would be apt to mask any possible adverse effects on property values.

DATA REQUIREMENTS

Within each study area data were gathered in 1971 and 1972 on the quantity and dispersion of highway-generated noise and air pollution; traffic volume, speed, and mix; property values; and household characteristics.

Noise measurements were taken at different locations within each study area and at various times during each day. Four different weekdays were sampled in each of the four study areas. Direct sampling of traffic volume, mix, and speed on the Interstate highway, using hand counters and movie cameras, was done concurrently with the noise sampling. Air pollution data were gathered at various locations within each study area at different times of the day during a 3-day period. Air pollutants measured were carbon monoxide, total hydrocarbons, nitrogen dioxide, and particulates. Two mobile air-monitoring vans were used: One was stationed permanently on any one day at a location downwind and adjacent to the highway; the second van moved to various locations within the community and away from the highway. The permanent van also monitored wind speed and direction, temperature, and humidity.

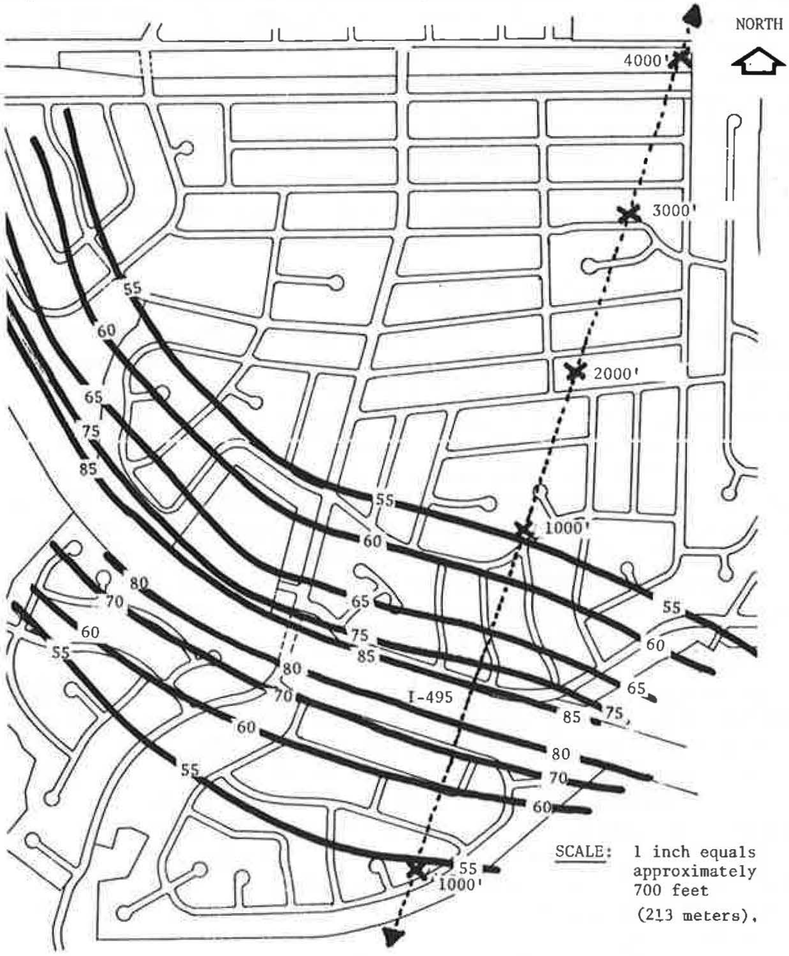
A total of 1,114 households were interviewed in the four communities. A stratified random sampling procedure was used in order to get adequate responses from abutters, nonabutters, and people recently purchasing homes. The questionnaire was designed to elicit information primarily on the attitudes of residents toward pollution from highways plus certain other highway effects on the community, the daily activities of residents around the home, their response to highway effects in terms of home alterations, changes in resident's work and recreation habits, the extent of social interactions in the community, and a number of socioeconomic and demographic variables.

Property value data gathered were the bona fide real estate transactions for 324 residential properties in the four study areas for the years 1969 to 1971 as obtained from public records. In addition, sales data were obtained for 84 residential properties in various locations throughout Fairfax County, Virginia, to determine the positive effects of I-495 on property values resulting from improved regional accessibility.

Table 1. Selected characteristics of the four study areas.

Characteristic	Bogota	Rosedale	Towson	North Springfield
Interstate on which located	I-80	I-95	I-695 and I-83	I-495
Year highway opened	1964	1955	695-1961; 83-1955	1961
Highway directional alignment	E-W	NE-SW	695-E-W; 83-N-S	NW-SE
Number of lanes on Interstate	10	6	695-8; 83-4	4
1970 ADT	69,670	54,500	73,374	65,400
Average percentage of trucks	18	13	9	9
Zoning and/or other land use regulation (year first adopted)	1929	County—1945	County—1945	County—1941
Population, 1970	27,356	9,248	7,690	17,117
Average value of housing, dollars	28,400	24,800	32,600	33,300
1970 median income, dollars	12,951	11,417	13,052	17,347

Figure 1. NPL contour lines for North Springfield study site.



The noise pollution level (NPL) developed by Robinson (1) was the objective measure of noise selected for the study. This measure recognizes two sources of annoyance from noise: a steady or nonfluctuating noise and intermittent, short-term fluctuations. Measured on the dBA scale, NPL relates very well to perceived annoyance from noise and provides a higher correlation with human responses to fluctuating noises of various types than do other measures.

A model provided by the National Cooperative Highway Research Program (2, 3) was used in conjunction with the field measurements of noise to estimate noise levels at various distances from the highway in each study area. The model accounted for variations in traffic characteristics (volume, speed, and mix), topography, barriers, vegetation, highway design (elevated or depressed), and roadway characteristics (configuration, pavement type, and grade).

This methodology was used to draw noise contour lines for each study area showing the distance variations in noise level reductions as distance from the highway increased. Figure 1 shows a typical NPL contour line for one of the study areas. The maximum and minimum (ambient) NPLs in the four study areas and the distances from the highways at which the NPL is reduced to ambient are given in Table 2.

An integrated point source model was used to predict CO concentrations in all study areas except Bogota for average traffic volumes and meteorological conditions from 4 to 5 p.m. on weekdays. Isopleths could not be calculated for Bogota because of high background concentrations of air pollutants, which prevented detection of highway-originating pollutants. In the other three study areas the federal CO standard of 9 ppm over an 8-hour average would not be exceeded under normal weather and traffic conditions.

FINDINGS OF THE STUDY

Because the four communities were not selected at random, the findings cannot be assumed to apply automatically to other highway communities. However, in many respects the study areas are much like many suburban residential communities along major highways near large cities. For this reason, it is expected that the findings may be applicable to many housing developments near major highways.

Analysis of data from the household questionnaire showed that noise is the greatest source of annoyance from the highways to people outdoors. People indoors are annoyed about to the same degree by noise as by dust on windowsills. Odors from the highway are not major sources of annoyance to people indoors or outdoors. Bogota was the only study area in which a disturbance (dust) to people indoors was more strongly stressed than any outdoors disturbance. In all four communities, 58 percent of the abutters were annoyed by highway disturbances, whereas only 12 percent of the nonabutters indicated annoyance.

There was a positive relationship between the degree of annoyance from noise and the extent to which homeowners felt their property values had been adversely affected. People who found the highways convenient for traveling to work, shopping, or socializing were less annoyed by noise, dirt, and odors than infrequent highway users. Residents in these study areas apparently did not grow accustomed to highway noise. The average length of residence was 9 years, and long-time residents reported as much annoyance as newcomers. The degree of annoyance from noise was not associated with income, age, or sex. Blue-collar workers found disturbances from the highway equally as trying as the executive, and there were no significant differences reported between the generations or the sexes.

An important aspect of this phase of the research was to relate people's perceptions of highway disturbances to distance from the highway. Table 3 gives these findings for noise and odors, both indoors and outdoors.

Stepwise multiple regression was the principal statistical tool used to determine the relationship between property values (the dependent variable) and a number of highway-related variables. The model was of the form

$$V = f\,[(H_1,\ H_2, \ldots,\ H_a),\ (N_1,\ N_2, \ldots,\ N_6),\ X_1,\ X_2,\ X_3,\ X_4]\ \epsilon$$

Table 2. NPL and distance from highway at which NPL is reduced to ambient.

Study Area	NPL (dBA)		Distance (feet)	
	Maximum	Ambient	Minimum	Maximum
Bogota	80	70	100	600
North Springfield	85	55	900	1,150
Rosedale	90	60	800	1,200
Towson	85	55	550	900

Note: 1 foot = 0.3 meter.

Table 3. Maximum distance from highway within which at least 15 percent of respondents were annoyed by environmental stimuli from Interstate highway.

Environmental Stimulus	Distance From Highway (feet)				
	All Areas	Bogota	North Springfield	Rosedale	Towson
Indoors					
Noise	800	400	600	1,000	1,200
Odors[a]	—	—	—	—	—
Outdoors					
Noise	800	600	800	1,000	1,000
Odors	600	400	600	—	—

Note: 1 foot = 0.3 meter.

[a]Less than 15 percent response of annoyance in all areas.

Table 4. Results of regression analyses.

Variable	Bogota		North Springfield		Rosedale		Towson		All Areas	
	Regression Coefficient	Student t	Regression Coefficient	Student t	Regression Coefficient	Student t	Regression Coefficient	Student t	Regression Coefficient	Student t
10 No. of floors			1,201	2.04						
11 Age of head					94	4.04				
16 Lived near highway					-853	1.73				
27 No. of rooms			839	3.12	273	1.34			453	2.11
28 No. of bathrooms			1,578	2.16	850	1.66	4,291	3.73	2,138	4.14
30 Central air conditioning							2,338	1.59	1,988	3.41
33 Corner lot	4,708	3.30								
50 Rosedale									-6,262	8.47
61 Wood-brick-asph.-asb.					2,923	5.50				
63 Split-level					3,056	4.39				
64 Ranch					1,629	2.47				
74 Finished basement			1,807	1.94					2,298	4.10
94 NPL-NCHRP	-646	2.24	-69	1.42	-60	1.25	-141	2.28	-82	2.37
96 Age of house	-168	4.38	-569	3.88			-385	1.74		

Note: Where there are no regression coefficients, the variable was not significant at the 10 percent level.

Table 5. Data used in regression analyses.

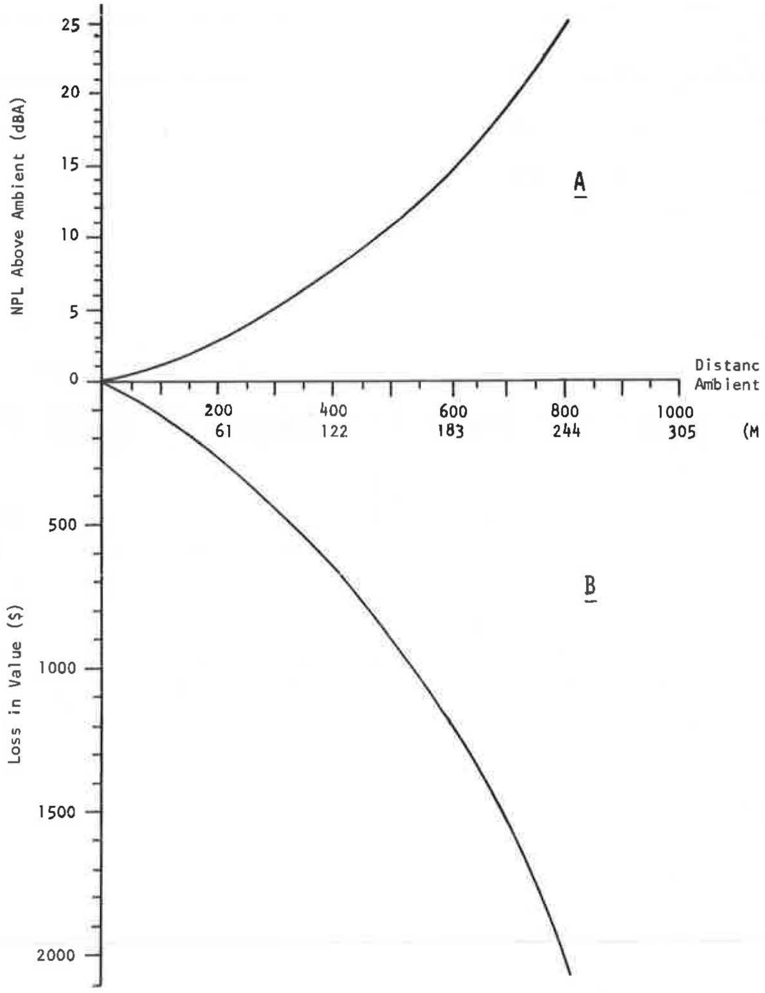
Characteristic	Bogota	North Springfield	Rosedale	Towson	All Areas
Constant, dollars	81,015	30,306	19,093	31,918	26,797
Sample size[a]	32	75	39	54	200
R^2 corrected	0.48	0.67	0.78	0.52	0.60

[a]Sample size refers to valid property sales.

Table 6. Estimated effect of highway disturbances on value of abutting properties.

Characteristic	Bogota	North Springfield	Rosedale	Towson	All Areas
Average value of properties, dollars	29,100	33,600	25,100	33,100	31,100
NPL-NCHRP regression coefficient	-646	-69	-60	-141	-82
Measured NPL, dBA					
Maximum	77	77	80	80	80
Minimum	70	55	60	55	55
Difference	7	22	20	25	25
Cost to abutting properties					
Amount, dollars	-4,522	-1,518	-1,200	-3,252	-2,050
Percentage of decrease	15.5	4.5	4.8	10.7	6.6

Figure 2. NPL above ambient related to distance and loss in property value for all areas combined.



where

V = selling price of land plus improvements,
$H_1, H_2, \ldots, H_a$ = highway-related variables,
$N_1, N_2, \ldots, N_6$ = non-highway-related variables,
X_1 = dummy variable for Bogota, N. J.,
X_2 = dummy variable for North Springfield, Va.,
X_3 = dummy variable for Rosedale, Md., and
X_4 = dummy variable for Towson, Md.

Besides the highway-related variables, many other independent variables were used to explain variations in property values. A total of 95 variables were tested. The final results of the regression analyses for each study area and for all areas combined are given in Tables 4 and 5.

Several highway-related variables were significant in some of the intermediate regression equations, and a higher R^2 was achieved by using them. But the NPL variable appeared most frequently in the regression equations, and noise was the highway disturbance most frequently cited by people on the household survey. For these reasons and because of the high degree of multicollinearity between highway pollutant variables, NPL was selected as the highway-related variable for all equations. The regression coefficient for NPL shows that, for each increase of 1 dBA of noise, the value of property decreased a maximum of $646 in Bogota and a minimum of $60 in Rosedale. The average loss in value for all areas combined per dBA increase in NPL was $82. The difference between the lowest ambient level (55 dBA) and the highest NPL above ambient (80 dBA) in the sample of properties was 25. This difference times the coefficient of -82, or $2,050, is the amount, on the average, by which the price of a property abutting a highway was affected by highway-originating disturbance. This value represents a decrease of approximately 6.6 percent below the average price of properties in the four study areas. Table 6 gives the effect of highway disturbances on value of abutting properties for all study areas.

It should not be assumed that the values shown by the NPL coefficient reflect the adverse effects of noise only. The high degree of multicollinearity between NPL and CO level indicates that the NPL variable also accounts for some of the adverse effects from automobile emissions. The effects from these two major sources of highway disturbances could not be factored out in the regression model. It was hoped at the beginning of the study that the separate effects of noise and air pollution on property values could be identified, but this objective was not realized. This provides a worthwhile opportunity for future research.

The decrease in NPL is not linearly related to distance from the highway; rather, the rate of decrease in noise lessens as distance from the highway increases. The curvilinear relationship among NPL, loss in property value, and distance from the highway was developed for each study area. Figure 2 shows the results for all areas combined. Table 7 gives the loss in value related to dBAs above ambient and distance from the highway for all study areas.

The total losses for all properties in all areas combined amounted to about $2.2 million. The estimates of property losses do not necessarily indicate the total social cost or loss from adverse highway environmental effects. To the extent that some households may make expenditures to reduce noise, such as by insulating the home or installing storm windows, these costs are not included. Moreover, on a theoretical basis, consumer surplus may be an additional social cost not accounted for in the estimates given above.

Statistical analysis was performed on the relationship between perceived noise reported by residents in the four highway communities and noise measured by instrumentation as NPL. The regression coefficients for the above relationships were highly significant in almost all cases. The results are shown graphically in Figure 3. The close agreement between measured noise and perceived noise substantiates the usefulness of NPL as an indicator of disturbance from highway-generated noise.

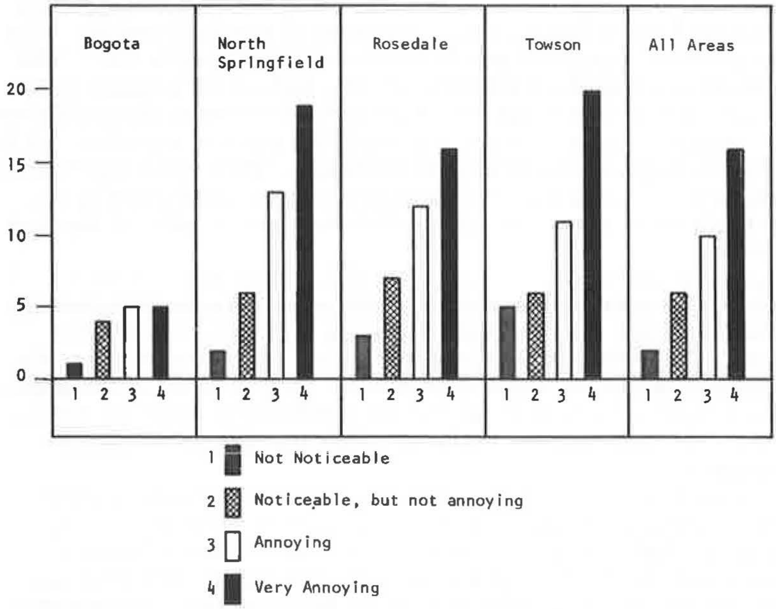
A worthwhile finding of this study not originally contemplated was a validation of the NCHRP highway noise prediction technique. It was found that, within the first 400

Table 7. Loss in property value related to noise level above ambient.

NPL Above Ambient (dBA)	Average Loss in Property Value (dollars)	Distance From Highway to Ambient Zone (feet)
25	2,050	800
24	1,968	785
22	1,804	755
20	1,640	720
18	1,476	680
16	1,312	635
14	1,148	585
12	984	530
10	820	470
8	656	410
6	492	330
4	328	240
2	164	130

Note: 1 foot = 0.3 meter.

Figure 3. Average NPL above ambient for each level of perceived noise outdoors.



feet (122 m), the field data and the predicted data (NCHRP) were within ± 3 dB. As long as the noise remained Gaussian in its distribution, the prediction technique could be used to fill in those areas in the study communities where field measurements were not taken.

NPL was used to define impact zones in each of the study areas. The ambient NPL contour lines in each study area were used to denote the boundaries between the impact zone and the control zone. The control zone, or the ambient zone, is that area in which highway-generated pollutants become so dispersed or absorbed into the environment that they have virtually no effect on the majority of people residing therein. The impact zone is the area within the community in which the highway effects are felt and many, but not necessarily all, of the residents are disturbed by these effects. Figure 4 shows the delineation of an impact zone for the Bogota study area.

The estimates of highway environmental effects on property values are really gross cost figures. To provide a more balanced and realistic view of the effects of a major highway on property values in a residential community requires that the influence of improved accessibility also be considered. The North Springfield study area was analyzed in depth for this purpose. The Metropolitan Washington Council of Governments (COG) has calculated accessibility indexes for two time periods, 1960 and 1968. These indexes, together with other variables, were regressed on the property sales data for Fairfax County to estimate the value conferred on residential properties by regional accessibility. Results indicated that a value of $197 was on the average associated with each one-hundredth unit increase in the COG index. In the North Springfield study area, the increase in the COG accessibility index was 0.15 from 1960 to 1968. The increase in value per property due to improved accessibility in North Springfield, then, amounted to about $2,950.

The findings are quite conclusive that in North Springfield the net effect of the highway was to raise the values of all properties, but the increase in the value of abutting properties was less than the increase in value of nonabutting properties because of the environmental effects of the Washington beltway.

The benefit conferred on each property in North Springfield from improved accessibility, primarily as a result of the Washington beltway, was about $2,950, or almost 9 percent of the value of the average property. The adverse highway environmental effects on abutting properties reduce the value by about $1,518 or almost 4.5 percent. Table 8 gives an indication of what the net effects on the entire community amount to and shows that the highway-induced benefits that property owners realize in North Springfield total about $5 million, compared to highway environmental costs of only about $303,000. This gives a net gain, considering all property owners together, of about $4.7 million.

SUMMARY AND CONCLUSIONS

In summary, the study shows conclusively that for residential properties not within a narrowly defined interchange zone the adverse environmental effects of a major limited-access highway lower the value of properties near the highway as compared to properties more distant from the highway. In each of the four study areas examined, one or more highway-related variables, all with negative coefficients, proved significant in explaining variation in selling price of residential property. Noise is the most disturbing effect from highways, the one that people perceive most readily and frequently, and the one to which they object the most.

It is readily apparent that, if highway administrators and engineers are to mitigate the adverse effects of highways on neighboring residents, they must concentrate more effort on the reduction of noise. Significant reductions in noise generated by highway traffic may do much to reduce the objections now raised by many people living in highway communities or neighborhoods through which proposed highways will pass. Future development should be controlled near major highways. Land uses that are not adversely affected by highway noise could be permitted on lands close to highways, but residential, recreational, and other activities where quiet is desired could be restricted to sites in the ambient noise zone of the community.

Figure 4. Highway environmental impact zone for Bogota.

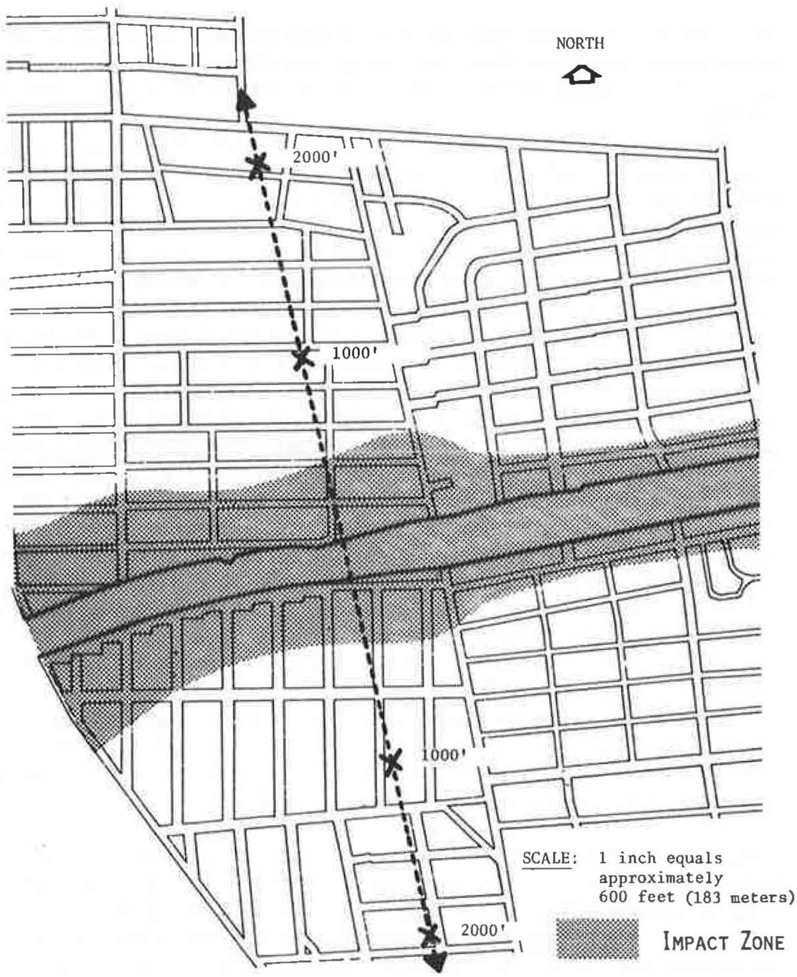


Table 8. Net effects of highways on property values in North Springfield.

Distance From Highway (feet)	Number of Properties	Loss in Value From Highway Effect Per Property (dollars)	Gain in Accessibility Value Per Property (dollars)	Total Loss in Value, Highway Effects (dollars)	Total Gain in Value, Accessibility (dollars)	Net Effect of Highway on Property Values (dollars)
<150	5	2,100	2,955	10,500	14,775	4,275
150-300	87	1,350	2,955	117,450	257,085	139,635
300-450	87	825	2,955	71,775	257,085	185,310
450-600	109	550	2,955	59,950	322,095	262,145
600-750	96	300	2,955	28,800	283,680	254,800
750-900	96	125	2,955	12,000	283,680	271,680
900-1,050	88	25	2,955	2,000	260,040	257,840
>1,050	1,126	—	2,955	—	3,327,330	3,327,330
Total	1,694			302,475	5,005,770	4,703,095

Note: 1 foot = 0.3 meter.

Table 9. Current FHWA noise level standards and suggested standards.

Land Use Category and Activity	Present FHWA Standards[a] (dBA)	Suggested Standards (dBA)
A. Serenity and quiet mandatory	60 (exterior)	5 above ambient (exterior)
B. Residences, schools, churches, libraries, recreation areas, parks, etc.	70 (exterior)	10 above ambient (exterior)
C. Developed lands not included in categories A and B	75 (exterior)	15 above ambient (exterior)
D. Undeveloped lands	none[b]	none
E. Residences, motels, schools, churches, libraries, hospitals, auditoriums	55 (interior)	55 (interior)

[a] From PPM 90-2, U.S. Department of Transportation, Federal Highway Administration, April 26, 1972.

[b] In special cases, standards may be applied to anticipated future land use activities on currently undeveloped land.

An approach to estimate the decreases in property values near highways as related to NPL and distance from the highway (Table 7) can be helpful to highway planners analyzing the costs and benefits of alternative highway locations or designs.

An important finding of the study is that the level of noise above the average ambient noise level for a community is more important than the actual noise level itself in the impact zone. Traffic generating an NPL of 85 dBA measured 100 feet from the highway in a community that has a low ambient noise level of, say, 55 dBA will disturb more residents to a greater degree than will the same highway in a somewhat similar community with a high ambient noise level of, say, 75 dBA.

The findings of this study suggest that the federal interim noise standards (PPM 90-2) should be revised. The present standards are in terms of absolute noise pollution levels. However, the difference between noise generated by the highway and ambient noise levels is more meaningful than the absolute level of highway-generated noise. The standards should be revised so that they are in terms of noise levels above the ambient level for the various land use categories. In this way the present noise characteristics and qualities of the community are taken into consideration and are better protected. Where costs of noise abatement are borne by the same society that would benefit from such noise abatement it would not be optimum in the economic sense to use a uniform noise level standard for all residential areas. A standard that takes into account the ambient noise level would be more efficient. The present standards (maximum permissible dBA's) should be adjusted downward. These suggestions are given in Table 9.

Economic analyses suggest that there would be a gain in economic efficiency if the standard were revised to specify that for residential land areas the maximum level of highway noise should not exceed the ambient level by 10 dBA. Using a figure of 10 dBA above ambient for a standard has further justification based on people's perceptions of noise as revealed in findings of the household survey. People reported that they were "very annoyed" when noise levels were more than 10 dBA above ambient.

Earlier studies were unable to uncover adverse impacts of highways on property values. This might be due, at least in part, to the general demand for a better environment becoming more popular in this country. This, together with the success of this research in uncovering and measuring the extent of the impact in four study areas, suggests that the social cost of highway-generated nuisances may be increasing over time. As efforts to improve the overall quality of the environment become more successful, there will be more insistent demands that most remaining highway-generated nuisances be eliminated. On a generally ugly landscape a single blight attracts little or no attention, but when that landscape is improved and becomes more attractive a single blot will stand out.

These considerations suggest that cleaner and quieter transportation will be required generally. In addition, the insulation of unavoidably noisy transportation from areas where noise is offensive may be necessary. The latter requirement implies the need for effective land use controls on the one hand or possible costly highway design features, such as underground or sunken arteries in central business districts, on the other. The costs of such systems may appear to be prohibitive at this time but may not be so in the near future. Increasingly strong objections to highway nuisances will have increasingly strong effects on the value of land where these nuisances occur. The tendency will be to increase the social benefits derived from the removal or avoidance of such nuisances. This, in turn, may justify the higher costs that will be required if the higher social benefits are to be realized.

The findings of this study imply that it is very desirable that government agencies be kept informed of the social costs and benefits associated with proposed highway constructions. Efforts such as those reported here should be refined and continually updated so that highway location and design decisions may be made on a more rational and objective basis with a view to minimizing the social costs of such projects and maximizing the social gains that may be derived from them.

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POLICY AND PLANNING IN THE LAKE TAHOE BASIN: THE CASE OF TRANSPORTATION

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Regional transportation planning given environmental constraints is addressed for the Lake Tahoe Basin of California and Nevada. The interrelationships of population densities, land use regulations, and existing transportation facilities with future project and system-level transport investments are explored for three development alternatives. The conflicts between technical planning methodology and environmental policy considerations are discussed, and recommendations are made for institutional changes that would allow broader policy considerations and systems alternatives to be evaluated in the planning process. Major freeway projects previously planned for this mountain resort environment are rejected as improper transportation solutions, and greater reliance on local traffic and land use improvements is encouraged in the study findings. Certain aspects of the planning strategies and conceptual solutions are applicable to regional transportation planning efforts elsewhere.

•THE AD HOC planning effort described in this paper was commissioned by a private environmental group made up of concerned residents of the Lake Tahoe Basin. It was administered by a bistate (California-Nevada) planning organization, the Tahoe Regional Planning Agency (TRPA), as a portion of regional planning efforts carried out in 1970-1971. The region is an area of some 500 square miles dominated by one of the largest high-altitude lakes in the world.

Lake Tahoe is surrounded by the Sierra Nevada Mountains and, viewed in the context of its natural setting, is still one of the most attractive areas in the western United States. Because it is so attractive, the basin offers a variety of opportunities for commercial development. However, since the end of World War II, development has advanced to the point that the natural qualities of the lake and the basin are threatened.

An interstate compact of 1969 created the Tahoe Regional Planning Agency whose task was to achieve, through a careful program of planning, an acceptable balance between development and environmental protection. Previously, attempts to devise a management plan and to persuade federal, state, and local agencies and private corporations to cooperate in the implementation of a plan had been largely voluntary. The TRPA promised to be an improvement over previous responses, however, because it was empowered to enforce the plan that it devised. Yet it was grossly underfinanced and faced almost unrealistic deadlines. Thus, outside help was mandatory if planning timetables were to be met.

The findings of the conceptual transportation study reported here conflicted with analyses performed previously by two state highway agencies; these analyses had recommended extensive freeway construction for the region. Instead, conservation-oriented perspectives were introduced, which questioned both the need for such high-capacity facilities and the validity of overall growth assumptions on which such highway planning had been based. At a time when so many highway projects are being challenged

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for environmental reasons, this study represents one of the first systems analyses of transportation issues as viewed from an environmental perspective. It offers alternatives to freeway construction through arterial street and traffic signalization improvements, transit investments, innovative land use concepts, and enforcement of traffic restraints.

Technical expertise made available to environmental groups for analysis of systems level planning questions can provide insights into the transportation planning process. Although conflict is often provoked by the introduction of such different perspectives, the means of resolving this conflict may be identified in such a process as well. This case study shows how the critical function of diverse bases for technical information and analysis can aid decision-making for transportation improvement and environmental quality.

Transportation was one of five functional categories of regional planning called for in the Tahoe bistate compact. It was one of the most important categories because of its potential effects on the stimulation or retardation of growth in the region and on the distribution of that growth. Of these planning categories, including land use, conservation, recreation, and public services, transportation has been the most technically sophisticated aspect of regional planning for years (1).

This is due in part to historic accident, funding availability, and procedural requirements linked to the growth and development of federal-aid highway programs. Much land use planning, or at least the associated process of data collection, owes its start to the technical demands of comprehensive transportation planning as specified by federal law for urban areas of 50,000 or more population (2). Although the Lake Tahoe Basin has never qualified as an urban area under such laws, it could be expected to benefit from the technical sophistication of the transportation planning methods developed elsewhere.

But technical sophistication in planning methodology calls for substantial resources of time, money, and expertise—elements all lacking in a rushed and underfinanced planning venture leading to adoption of a regional plan for Tahoe. A substitute strategy of ad hoc conceptual planning, with simplified technical analysis selectively applied, was the best stopgap that this study could employ. In the future, perhaps it would be possible to mount a more thorough transportation analysis at Tahoe to refine the hurried analyses that of necessity had to be undertaken as a first step.

In retrospect, with much of the detail of traffic data and computer modeling set aside, the issues that became highlighted were far different from those that had previously been identified and involved difficult policy choices concerning land use and resource allocation in many portions of the Tahoe basin. Beyond that, they raised a number of challenges to state and federal transportation programs that appear to be needlessly rigid in their choice of technical solutions and needlessly destructive of the environment in their implementation.

The alternatives for transportation planning that were explored for TRPA in 1970 were conceptual and, to a large degree, outside the bounds of accepted technical practice for local, state, and federal agencies with existing responsibilities in the highway planning and construction field. But these very agencies had created the opportunity for such a conceptual review of alternatives by their own demonstrated inability to solve problems by themselves.

Examples of such agency failures, or unresolved dilemmas, included a major and protracted controversy over spanning the scenically outstanding Emerald Bay with a low-level bridge or tunneling through the adjacent mountains for a high-level, four-lane, all-weather route (Calif-89), as well as a more recent controversy within the city of South Lake Tahoe itself (US-50) over meadows or freeway development.

The regional plan for the Tahoe basin that was finally adopted in December 1971 rejected many of the suggestions for freeway-scale facilities in the basin made in previous plans, and it accepted the proposal that a major study effort be undertaken over a 2- to 5-year period, aimed at planning in detail whatever new transportation alternatives might be required to serve the basin population and land use distributions as finally decided on by the 1970-71 regional planning effort. However, because the same highway agencies that had failed earlier to account for the basin's unique environmental and transportation requirements are responsible for designing the new study, the issues surrounding transportation policy and planning for the basin are far from being resolved.

Political and institutional changes may be required before compatible mobility and environmental solutions can be achieved at Tahoe and elsewhere. The organizational and personal resistance to institutional change is not surprising, at least not to social scientists and practicing politicians. Nevertheless, such resistance must be recognized as limiting to development of new types of transportation policies. Should the technically sophisticated planning that has legitimized predetermined solutions and masked policy choices elsewhere be allowed again to prevail at Tahoe, the opportunity to explore fresh alternatives, which was presented in 1971 by the ad hoc planning effort discussed in this paper, may be lost permanently.

CONCEPTUAL PLANNING ALTERNATIVES

Most transportation planning in the United States, whether for entire regions or for individual facilities, has commenced with the twin assumptions that travel demands are known or predictable and that they should be accommodated.

The transportation study discussed in this paper from the outset took the form of a policy study that presented political choices, rather than an engineering study that implied technical choices (3, 4).

An extensive and technically complex methodology for traffic estimation, based on land use data, traveler characteristics, automobile ownership patterns, travel times, and other factors has been built up over the past several decades, largely in conjunction with federal highway programs. If present travel, population, and land use characteristics of a region are known, as the theory goes, then future travel demands can be predicted accurately through knowledge of future land uses and anticipated population characteristics (2).

The use of this methodology assumes that substantial amounts of time and other resources are available to gather extensive data, such as inventories of current land use, traffic flows, and population characteristics. And, equally important, the methodology presupposes that land use arrangements and population levels for some future planning horizon are both known and desirable. These assumptions could not be met at the time the transportation study discussed here was begun, even though there existed an interim plan for the Tahoe basin approved by TRPA (5). Simply stated, the interim plan had been approved without any reliable estimates of how many people would use the basin, as either residents or visitors, if the plan were implemented. It was not even known whether the plan was sufficient to provide some of the basic services that the various users of the basin could be expected to demand.

Recognizing the uncertainty of future population estimates, the Advisory Planning Commission (APC) to TRPA decided to undertake a transportation study and requested that three alternative levels of population be investigated: 125,000, 250,000, and 450,000 visitors and residents on a peak summer day in some future but unspecified year. There was no indication of which level was preferred, although because 250,000 was centered between higher and lower population limits the APC might see that level as a desirable and feasible level of basin activity. As it turned out, when population data were being generated for the transportation study by the TRPA staff, present peak summer population already exceeded the 125,000 lower limit (150,000 persons per day at 1970 development levels), and the interim plan zoning allowed for up to 750,000 people if allowable projected dwelling units were built and fully occupied.

Crude data on existing traffic flows and population distribution were improvised from past highway counts made annually by the state highway agencies of California and Nevada and from simple map interpretations. They were good enough for rough judgments on the nature of existing problems and the probable nature of future ones. But an effort at anything more than highly rudimentary quantitative analysis of travel demand would have been totally meaningless. The space limits of this paper preclude detailing the analysis carried out, but this is available in the text and appendixes of the report on which this discussion is based (6).

The second assumption of most previous transportation planning studies was that travel demands should be accommodated through the design and construction of public works. Because much of the regional planning effort under way at Tahoe was directed to the question of how much growth and development could be accommodated in the basin within more or less objective environmental constraints (as well as more subjective constraints based on value judgments about the quality of living and recreational experiences that should be available in the basin), questions relating to transportation needed to be posed in a way that recognized such constraints. Thus, judgments would have to be made on whether projected travel demands should be served if the environmental damage associated with providing new highway facilities was found to be large, at least in certain instances. If demands were not to be served, then population might have to be limited to reduce demand, new modes of travel such as public transit or lakeshore ferries might have to be generated, and less damaging traffic patterns might have to be encouraged through land use and street design in particularly difficult areas such as the Stateline casino/motel area or the fragile topography of Emerald Bay.

Thus, travel demand, no matter how crudely or elegantly computed, would not have attached to it the assumption that has traditionally been implied by such a term as highway needs, namely, the assumption that needs would be met. This is a highly value-laden concept that has previously placed traffic movement above virtually all other criteria in highway investment decisions. Where, how, and how much travel demand could be served, without undue environmental damage, would instead become the basic transportation input to the basin planning study. This approach, encouraged by the League to Save Lake Tahoe study sponsors, promised to highlight rather than obscure the environmental and developmental policy questions that must be faced before more technical transportation decisions are made.

The absence of technical criteria for judging outcomes of such a planning study led to a highly conceptual framework of inquiry and analysis. With so many unknowns, with severe constraints on time and resources, and with advocates of environmental values competing for the future development of the region with those espousing traditional economic interests, an open attempt to raise issues and specify alternatives seemed desirable. The approach chosen by the study team and the TRPA staff, with the consent of the APC, was that of exploring three different transportation policies for Tahoe. The identification of these alternatives was not intended to imply that any one should be viewed as a recommended policy for adoption, nor were the three alternatives presumed to represent the full range of policy options that might be seriously considered for implementation in the basin. Each alternative was chosen to represent a more or less limiting condition of technical and economic feasibility under each of three dominant assumptions:

1. Maintaining the status quo (do-nothing alternative),
2. Constructing the full complement of state and local highways shown on the interim plan (full highway alternative), or
3. Shifting to highly innovative transport modes and land use policies to retain environmental values while increasing personal mobility, but perhaps at the furthest limits of economic cost (innovation alternative).

These three alternatives, which may be thought of as bounding the space of acceptable compromise among environmental integrity for the basin, personal mobility for its residents and visitors, and economic and institutional achievement cost, were to be analyzed within the limitations of available time and data. Each was to be examined in the context of the three population levels that the APC identified. It was hoped that a subsequent study, with more adequate resources and a more narrowly focused charter, could take the transportation element of the Tahoe plan closer to implementation by choosing among the policy alternatives that had been exposed by the conceptual analysis, or some variation thereof, and by recommending actions to achieve a desired outcome.

ISSUE IDENTIFICATION AND STUDY FINDINGS

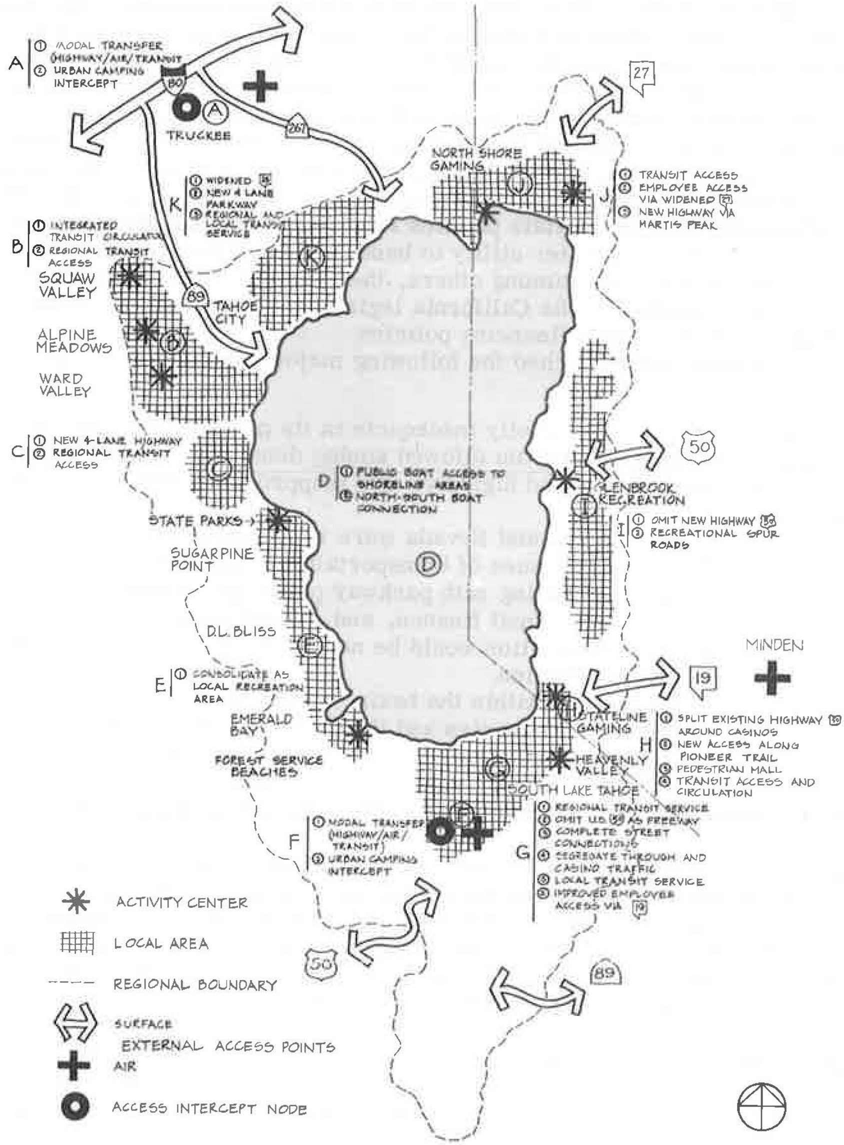
Even the limited technical analysis in this study pointed to weaknesses in existing institutional and financial arrangements in terms of providing transportation facilities that were compatible with the most modest environmental protection policies. The bulk of the money that might normally become available for transportation projects in the Tahoe region from state and federal sources would be earmarked for freeways of dubious value relative to the mobility problems of the basin. Moreover, funds for other, more local movement systems, which appear most deficient now and into the future, would simply not be available in county and city treasuries at the levels required under any but zero population growth assumptions. Although further, more detailed technical studies might be recommended as part of future transportation planning, it seemed clear that working for fundamental changes in state policies regarding transportation finance and local options would be of vastly greater utility to basin planners than additional engineering analysis. For this reason, among others, the author has been working for the past year as a special consultant to the California legislature on matters of statewide transportation planning and transit financing policies.

The transportation planning study reached the following major conclusions in December 1970.

1. The Lake Tahoe interim plan was wholly inadequate in its planning for transportation facilities for populations projected from allowed zoning densities. Furthermore, reliance on a system of regional high-speed highways was inappropriate for almost any future population distribution.
2. The state legislatures of California and Nevada were responsible for dealing with the impasse caused by the complex issues of transportation-environment interaction. New authority or flexibility in dealing with parkway planning, revenue sharing with local jurisdictions for arterial and transit finance, and related matters of special transportation charges and land use acquisition would be needed for creative resolution of the conflicts inherent in the Tahoe situation.
3. The planning for all state highways within the basin, including those already subject to freeway agreements between state agencies and the counties, should be subjected to review during a 2- to 5-year period under the requirements of legislation that emphasizes the simultaneous consideration of community values, aesthetic values, regional transportation requirements, and location decisions in the selection of state highway routes.
4. Local jurisdictions, whether county or city, did not and would not have the funds available to pay for the needed transportation improvements under any alternative studied, including the do-nothing alternative, unless population levels were substantially reduced from those allowed by interim plan zoning. Without new sources of funds for the provision of transportation services, it seemed unlikely that the basin could provide travel facilities for more than a peak daytime population of 250,000, one-third of that allowed by the interim plan.
5. The principal traffic problems within the basin arose from a mixing of local and regional traffic and a lack of adequate local facilities. Existing highways could handle as much as double the current basin population if a limited number of arterial streets were built in certain critical areas. An investment of $25 to $50 million would be required to adopt this status quo alternative.
6. Costs for the full highway and innovation alternatives were each over $300 million and required difficult-to-come-by institutional and financial changes. Such investments would be required, however, if basin population growth was not to be limited. The innovation alternative, while no less expensive than the full highway investment, would produce less environmental impact and equal or better mobility.

Of these conclusions, perhaps those relating to the state legislature and the state freeway and expressway system of California stood out as most significant at the time of the study. They remain so today, although some changes in state law have begun to recognize the need for greater local flexibility in transportation programs, and more may soon be on the way. Problems similar to those at Tahoe have begun to be recognized in the heavily urbanized regions of California, and the Tahoe region may find powerful allies in future attempts to secure the funding and program flexibility to construct and operate new types of transportation facilities. These needed legislative and

Figure 1. An innovative transportation concept for the Lake Tahoe region.



administrative changes are beginning to be so widely recognized that it now seems likely that they will come about within the 1975 to 1980 period suggested above. Certainly the prospects for such changes in 1974 are substantially brighter than they were in 1970.

AN EXPANDED SET OF POLICY CHOICES

The many policy choices that become available in transportation and land use planning when the narrow focus on state-financed freeways is expanded are shown in Figure 1. They range from intercepting basin visitors at the perimeter of the region and transferring them to transit vehicles for much of their travel within the region, to redesigning the congested Stateline area at the south shore to bypass through traffic and to provide a central mall for pedestrians and transit vehicles.

An essential point in the analysis of travel behavior (both present and future) underlying these concepts was the consideration of travel in four distinct categories, rather than simply as traffic whenever it occurred. People take trips of varying lengths and for varying purposes, and knowledge of the trip lengths and purposes is important in formulating transportation and land use plans. Travel was divided into four general categories for the purposes of this study: (a) activity center travel, (b) local area travel, (c) regional travel, and (d) external access travel. These are shown schematically in Figure 1.

Activity centers are relatively small, intensely developed areas of specialized activity, such as gaming centers, specific ski areas, state parks or beaches, and the like. Movement to or within them may have characteristics that can be controlled or aided as much by the design of the area as by transportation facilities themselves. Local areas are defined as relatively large recreational or urbanized areas where considerable traffic of modest trip length, say 5 to 10 miles, may circulate for a variety of purposes such as shopping, visiting friends, or traveling from home to work. The city of South Lake Tahoe or urbanized portions of the north shore might serve as examples of local areas that generate considerable traffic that remains within their area. Regional travel is a term denoting longer trips that remain, however, entirely within the basin. Trips such as those from Tahoe City to South Lake Tahoe or entirely around the lake for sightseeing fall into this category. Travel to and from the region, such as from San Francisco or Carson City to South Lake Tahoe, or even traffic through the region on the way to points east and west falls in the last category.

Possible policies for dealing with both the shortest and the longest trips categorized above were treated at some length in the study. Examples of concepts useful for dealing with these traffic categories and treating them so that they do not interfere with local and regional travel are illustrated later.

The local and regional questions had to do with the mixed use of highway facilities by both short and long trips, a rather common phenomenon. The greatest need, both current and projected, was for local circulation, not high-speed regional travel. Yet the funding available for highway and street improvements was heavily biased toward regional highways, often in environmentally fragile areas; minimal funds were earmarked for urbanized portions of the region. Analysis showed a substantial need to reorient these priorities if even present levels of population were to be served well. Space limitations forbid inclusion of the details of the analysis leading to these conclusions.

Figure 2 shows an access intercept concept. If, for example, basin planners wanted to reduce visitors' dependence on the private automobile, large parking areas could be provided at several strategic entry points, with campgrounds and a variety of shopping and other facilities nearby. A transit system could be provided for access to most of the points of recreational interest at the north and south ends of the lake as shown by the cross-hatched areas. Casinos, ski areas, lakeshore, and hiking trails could all be made easily accessible by transit, which would reduce the need for parking at these recreational attractions and heavy automobile traffic between them. Residents, motel visitors, and those with less popular recreational destinations would not necessarily be limited in their travel.

Innovative, small vehicle transit systems that might lead to economical and enjoy-

Figure 2. Access intercept concept for reducing highway dependence.

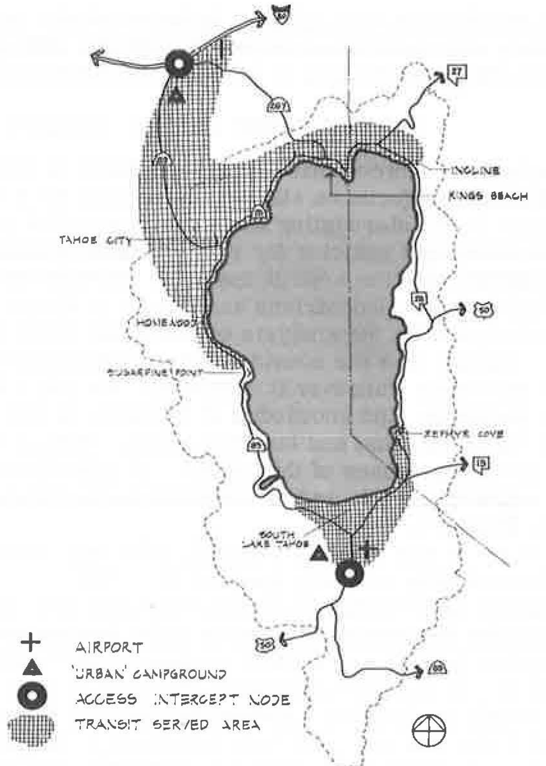
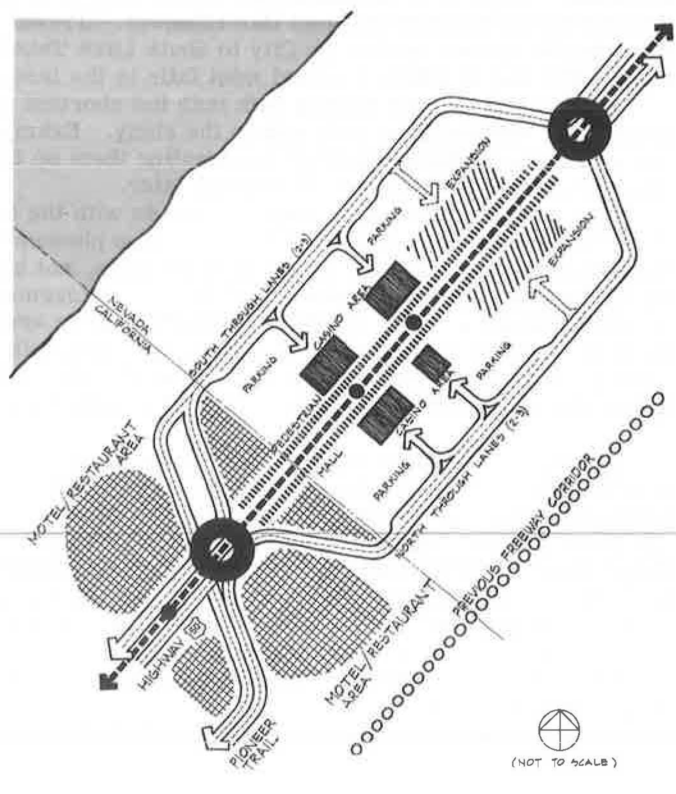


Figure 3. Circulation detail for Stateline area.



able public transport in an environmentally sensitive area such as the Tahoe basin are within the realm of possibility. The concept is of transit vehicles of eight to 20 passenger capacity operating automatically at frequent intervals on their own exclusive right-of-way. This is distinct from either rail rapid transit, which is likely to be too expensive, or buses, which are likely to lack the excitement and novelty to attract much patronage without strongly restrictive measures on automobile use. Although few such systems are yet in operation, and those mostly in airports, there are a number of installations planned within the next few years, and continuing programs of research and development exist in several countries (7). Even now, buses are being used extensively in Yosemite National Park for local transportation in conjunction with restrictions on automobile use to preserve the environment.

Another idea examined in the transportation planning study was the return of public boat service to Lake Tahoe. This had at one time been an important link between Tahoe City and the southern lakeshore areas.

The congestion problem might also be solved by means far short of new freeway construction involving the physical redesign of localized transportation facilities at Stateline on the south shore. Figure 3 shows how a new access route of modest size, together with redesign of existing US-50 around, rather than through, the casino area could eliminate a difficult bottleneck. Transit and pedestrian improvements, plus special parking lanes, would also be part of the remedy. To argue, instead, that a new freeway the entire length of South Lake Tahoe is needed to get traffic through this area is perhaps to fire a cannon at a mouse.

Virtually none of the actions suggested in the preceding discussion of innovative transportation-land use concepts could be taken by a federal, state, or local agency acting alone. Policy choices such as these would have to be taken in a cooperative spirit by numerous agencies, some of which may have only peripheral interests in transportation, or in land use planning for that matter. This is perhaps the most difficult problem of all. It is hard enough to break out of the conceptual limits that often block creative planning thought, but to break out of the institutional limits that impede the implementation of new ideas will be even harder.

OUTCOMES AND PROSPECTS

Although the aim of the transportation planning study discussed in this paper was not to make recommendations for or against specific transportation facilities, it bore heavily on a number of TRPA decisions related to the adoption of a regional plan for the basin. Perhaps the most significant of these was the deletion from the plan of most freeway mileage shown in the interim plan and other previous regional plans (8). Although the California highways will be included in the state freeway and expressway system until the legislature takes action to delete them, the local act of removing them from plans suggests that much more convincing evidence will be required from state agencies in the future to demonstrate that freeway construction is justified. As much as $200 million in state and federal construction funds would have been earmarked for these projects. It is hoped that a major portion of such funds can be used for other transportation facilities in the basin.

Recommendations in the transportation sections of the adopted regional plan for increased future reliance on local transit alternatives and for ferry service on the lake draw also from the general discussion of the transportation planning study. However, the details of such policies and the means for their implementation have not been spelled out as yet in work performed by either the TRPA or others responding to its guidance. Further studies and implementation strategies must be prepared in the next few years if anything other than an impasse in transport investment is to develop in the basin.

In a time of mobilized, articulate citizen protest and paralyzed, unresponsive state transportation agencies, it is becoming a relatively easy matter to stop a badly conceived highway project; but it is quite another matter to shift direction and move toward alternative solutions acceptable to all the parties involved. The transportation situation in the Tahoe region, past, present, and future, is a reflection of larger forces and dilemmas in transport policy and planning that have begun to paralyze the states and the nation. These dilemmas cannot be miraculously escaped at Tahoe alone, but must be resolved by legislative and administrative action in Sacramento, Carson City, and Washington, D.C. However, based on the Tahoe experience, some suggestions can be made on what those new legislative and administrative actions ought to look like to give more effective solutions a fair chance.

The release of state and federal funds for modes of travel other than highways is a fairly recent development. The proper amounts, sources, and administration of such funds pose questions that are unlikely to be resolved for perhaps another 3 to 10 years. But enough already has been done to indicate that even modest flexibility in the use of transportation money may greatly increase the range of choices available to local jurisdictions in the next decade. It is thus important that planners at Tahoe and elsewhere recognize that alternatives to freeway construction can become real prospects if perseverance and planning take these possibilities into account now.

A major transportation planning effort of several years' duration has been initiated by the TRPA with the cooperation of the Nevada and California highway agencies. Because the information and policy direction needed for a detailed assessment of transportation alternatives for the region were not available prior to adoption of the regional plan in late 1971, only the broadest outline of the transportation element of the regional plan, using inputs from both the study discussed here and other limited efforts by TRPA, had been prepared by TRPA. The new study will be a test of TRPA's ability to push toward an expanded set of policy and planning choices of the kind outlined.

However, problems may mar the near-term prospects for success in this endeavor and thus make it difficult to realize the more flexible and responsive transportation alternatives that should become available in future years. Although projects such as US-50 through South Lake Tahoe have been temporarily stopped and population levels for the basin may stay substantially below the high numbers originally feared in 1970-1971, the flexibility of providing alternative amounts and types of transport facilities for the region is still largely absent.

At the regional level of planning the transportation study now getting under way seems to focus on the same types of data inventories and computer models that have so obscured transportation policy issues in the past. Rather than break with a past, unsuccessful tradition of transportation planning in urban areas, the new study appears to continue it. Perhaps the traditions and institutional biases of the state highway agencies that helped to write the study work program are too strong to break. At the very least it is evident that TRPA planners and basin residents and visitors will have to exercise great care to see that policy questions are not again hidden by the flurry of new data collected and by the analyses performed as part of this new study.

The creation of the California Department of Transportation, as well as divisions of mass transportation and transportation planning, may help to ensure that regional transportation planning studies attain a more balanced outlook in the future. However, this reorganization should be viewed with cautious optimism inasmuch as the staff commitment to highways is on the order of 18,000 employees and that for public transportation is but 25. But the times will continue to change, and the realistic implementation of alternatives may become a reality before the 1980s. It will take strong action by state legislatures and the public in the next few years, however, to make it so.

The requirement that a new state transportation plan be written for California and its regions may provide additional leverage for ensuring that broader issues than road capacity and safety are addressed. This state plan and its regional elements must be prepared and approved by 1976, which is probably a useful target date for completion of the detailed TRPA transportation plan.

If major decisions on the policy thrust of the regional transportation plan and on specific projects within the basin are brought to focus between now and 1976, it is conceivable that the funds and implementing organizations necessary to translate plans into practice may have become sufficiently flexible to permit realization of at least some of the suggestions advanced in the study that the League to Save Lake Tahoe supported in 1970.

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A FRAMEWORK FOR INVESTING IN URBAN BICYCLE FACILITIES

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The bicycle as a transportation and recreation mode has explosively entered the public's consciousness. Accompanying this phenomenon has been a rash of problems including a sharp increase in accident rates and thievery. There is a need to provide facilities that will reduce these problems and accommodate the expected increase in bicycling popularity. This paper raises four basic questions, the answers to which will assist in planning urban bicycle facilities on a more organized basis with a minimum of misdirected effort and a maximum amount of coordination. How much money should be invested in bicycle facilities? What types of trips are the best candidates for bicycling? What type of bicycle facilities should be provided? Where should these bicycle facilities be placed? At this stage of urban bicycle facility planning, these questions are only beginning to be asked and are far from being resolved. Planning and engineering of bicycle facilities are essentially in a shakedown period in which many good and bad ideas will be tested before the best solutions surface and become the norm.

•ASSEMBLY-LINE techniques brought about a dramatic drop in the cost of the bicycle in the mid-1890s. With this, America's first "bicycle craze" was on, and, like today, bicycle advocates were clamoring for better conditions for bicycling. Albert Pope, a prominent bicycle manufacturer of the time, estimated that it cost an astronomical $1½ billion annually to feed the nation's horses and mules. He contended that the American farmer would save $700 million annually on fodder if $20 billion were invested in surfaced roads because they would eliminate the need for so much horsepower (4). His ulterior motive, however, was to improve conditions for bicycling.

The League of American Wheelmen took up the cause for better roads with such zeal that in 1902 it changed its name to the American Road Builders' Association to ensure the best possible bargaining posture. Joining the League and other bicycle advocates were supporters of the new rich man's toy, the automobile. It is ironic that the successful pioneering efforts of bicyclists to improve road surfaces helped spawn the automobile era. Today, the most serious deterrent to good bicycling conditions is conflicts between bicycles and automobiles due to their sharing the same road surface.

In spite of this deterrent to bicycling, the current U.S. bicycle boom is unprecedented in magnitude. It has been estimated that a maximum of 400,000 bicycles were sold annually during the peak of the first bicycle boom in the 1890s, as opposed to 13.7 million bicycles in 1972 (4, 5). If it is assumed that the average price of a new bicycle with accessories is $80, bicycle manufacturing has become a billion dollar a year industry.

The governmental response to this current popularity can be characterized as minimal, piecemeal, and uncoordinated. Even though annual bicycle sales currently average $5 for every man, woman, and child in the country, fewer than 10 percent of the nation's cities have provided any kind of facility to enhance the use of bicycles. Of those facilities that are provided, most are in the form of signed routes offering relatively little protection to the bicyclist. Fewer than 1 percent of all cities have ex-

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clusive bicycle lanes in operation (6). Where there are bicycling facilities, they frequently have been constructed with dramatically varying design standards and with little regard for their integration into a system covering the entire urban area. In many cities there appears to be a decided lack of coordination between advocates of bicycle systems and those in charge of providing other related transportation and recreational facilities.

To begin planning urban bicycle facilities on a more organized basis, with a minimum of misdirected effort, and with a maximum amount of coordination requires that at least four basic questions be resolved.

1. How much money should be invested in bicycle facilities?
2. What types of and how many trips are candidates for bicycling?
3. What types of bicycle facilities should be provided?
4. Where should these bicycle facilities be placed?

At this stage of urban bicycle facility planning, these questions are only beginning to be asked and are far from being resolved. Planning and engineering of bicycle facilities are in a shakedown period in which many ideas will be tested before the best solutions surface and become the norm. This paper adds one more perspective on the problem in hopes that the bicycle will finally receive a fair test of its considerable potential within the United States.

HOW MUCH MONEY SHOULD BE INVESTED IN BICYCLE FACILITIES?

A major deterrent to the commitment of substantial funds for bicycle facilities is the haunting question, Is the bicycle boom a fad? Most available evidence indicates that it is not.

Current Sales

The current rise in the popularity of bicycles has frequently been called a boom or explosion. This labeling of the phenomenon is inappropriate inasmuch as bicycle sales have approximated or exceeded 7 million annually for at least the past 5 years (Table 1) (5). Moreover, bicycle sales have increased or decreased on an annual basis similar to the more firmly established automobile. If the bicycle phenomenon were a fad, this sales pattern would not have been sustained over such a period of time.

Upward Long-Term Trend

Although sales of bicycles have been cyclic, every major bicycle sales boom has been larger than the previous one. For example, after the bicycle "dark ages" in the 1920s, when the American public adopted the automobile en masse as the primary means of transportation, the bicycle enjoyed a major revival. By 1935, bicycle factories were manufacturing more than 600,000 bicycles. In 1936, more than a million bicycles were sold. During World War II, the bicycle was seen as a partial solution to the problem of gasoline rationing; however, this idea was never carried out, for bicycle production nearly ceased in favor of more urgent war material production. Shortly after the war, another bicycle boom occurred; by 1948, it was estimated that over 12 million bicycles were in use (4). Again, in the 1950s, bicycling became popular partly on the advice of Dr. Paul Dudley White who became the evangelist of the "health-through-cycling" cause. At this time, however, only 15 percent of the nation's population were bicycling. By 1960, this figure rose to 20 percent and, by 1970, to approximately 37 percent (5). If the 1950 to 1970 trend continues, approximately half of the nation's population will be bicycle riders by 1980.

Market Saturation

Like all product sales, there is a point at which the bicycle market will be saturated. However, available evidence indicates that the market is nowhere near saturation in the United States. In the Netherlands, for example, where bicycling conditions are nearly ideal, 76 percent of the nation's population are bicyclists. A similar situation exists in frequently cited Davis, California, where three-fourths of the town's population are bicyclists (2). Whereas conditions in all American cities will not be so ideal, there is sufficient evidence to indicate that there still is a large, untapped bicycle sales market.

If the current popularity of bicycling is not a fad, there is a need to develop a means to justify reasonable levels of expenditures for bicycle facility development in urban areas. One point is clear: Traditional "pay-as-you-go" transportation economics will not work as a means for justifying expenditures on bicycle facilities. The bicycle does not produce revenue in its own right, either through the fare box as in mass transit or through gasoline taxation as in the case of the automobile. Even if the bicycle could produce revenue, an economic test would not be completely fair, given the currently underdeveloped state of bikeways. The potential of bicycle use will be unknown in the United States until safe systems are implemented to test bicycling in different situations. This is particularly true in the category of purposeful trip-making.

Given that traditional transportation economics will not work, what justifications are there for supporting long-term investments in bicycle facilities? Among those methods that might be considered are

1. A "quality of life" rationale,
2. Environmental quality and preservation,
3. Economic substitution for the automobile,
4. Relationship to other recreational expenditures,
5. Expenditures as a function of bicycle sales, and
6. Expenditures as a percentage of the total transportation budget.

A brief description of these approaches follows.

Quality of Life

Numerous experts have contended that bicycling is a pleasurable and effective form of exercise. Perhaps most overlooked under this rationale is the notion that variety is the spice of life. The mere opportunity to ride a bicycle because a person may feel like it has some value in our affluent society. Although all of these factors could be used to justify expenditures on bicycle facilities, they defy easy quantification and, consequently, have limited utility in the bicycle advocate's tool kit for obtaining bicycle facility development funds.

Environmental Quality and Preservation

Numerous environmental reasons such as reduction of air and noise pollution and economy of fuel resources have been advocated as a means for justifying expenditures on bikeways. However, these benefits would be extremely difficult to measure in the short run; and, given the long-term trend toward increased use of motor vehicles, there is considerable doubt whether even dramatically increased use of the bicycle would cause a reduction in pollution in the long run.

Economic Substitution for the Automobile

The cost of constructing bikeways could be compared to the cost of building additional streets, highways, and parking lots. If the number of person trips per dollar of investment on bicycle facilities were higher than the corresponding ratio of person-trips to dollars spent on streets and highways, it might be argued that bicycle expenditures on a large scale would be justified. In this vein, it is interesting to note that the British have concluded that the passenger-carrying capacity of a 12-ft (3.7-m) cycleway exceeds the capacity of a 24-ft (7.3-m) carriageway and that one cycleway accordingly saves one 12-ft (3.7-m) lane of carriageway (3). Added to this argument could be the less demanding parking requirements of the bicycle. However, there are so many factors to consider in this complicated bike-versus-automobile relationship that it would be difficult to deal with this type of economic analysis on a quantitative basis.

Relationship to Other Recreational Expenditures

A comparison could be made between participant hours of bicycling and participant hours in other sports such as golfing, tennis, or swimming. Based on this comparison, a determination could be made of the level of public expenditure versus recreational hours. The probable result of such an analysis would be that expenditures on bicycle facilities are comparatively deficient. As a rough measure of the need for bicycle facilities, the Bureau of Outdoor Recreation in 1970 recommended a minimum standard of 50 miles (80 km) of cycle paths for every 100,000 city dwellers (4). Translated to U.S. urban areas, this amounts to approximately 75,000 miles (121 000 km) of cycle paths.

Expenditures as a Function of Bicycle Sales

It could be argued that, for every bicycle sold, an increment of investment should be made on bicycle facilities. For example, if we assume a sales volume of 10 million bicycles per year at an average cost of $80 per bicycle including accessories, $800 million is spent annually on the purchase of bicycles. If this money were matched by expenditures for bicycle facilities (about the situation with the automobile) there would be approximately enough money to annually finance 80,000 miles (129 000 km) of paved bicycle paths (assuming a cost of $10,000 per mile) within the United States.

Expenditures as a Percentage of Total Transportation Budget

With Oregon leading the procession, there is increasing pressure to tap a specified percentage of Highway Trust Fund money generated by gas taxation to construct bicycle facilities. Currently, total state gas tax revenues amount to more than $7 billion annually (7). If 1 percent of this amount is tapped, there would be $70 million available annually for bicycle facilities.

WHAT TYPES OF AND HOW MANY PERSON-TRIPS ARE CANDIDATES FOR BICYCLING?

As is the case with all public investments, those organizations appropriating funds for bicycle facilities want to receive the greatest benefit per dollar spent. Accordingly, a preliminary attempt was made to determine which types and what volumes of trips were most likely to be made by bicyclists if safe and convenient facilities were provided. This investigation was limited exclusively to purposeful trip-making; it was assumed that recreational use of the bicycle would continue to be popular and that this use of the bicycle could be accommodated without extensive new facilities. It is important to recognize that the number of purposeful bicycle trips being made today is not a valid indication of the number of such trips that might ultimately be expected. Without a good system for bicyclists, the fear of having an accident caused by competing with the automobile for street space is probably the greatest deterrent to purposeful bicycle riding.

The definition of an adequate bicycle system is open to considerable debate. The spacing of bicycle facilities, their location within an urban area, and their design are all very important considerations. However, for the purposes of this analysis, it was assumed that the bicyclist could travel anywhere in an urban area with minimum concern for his personal safety.

Effect of Selected Factors on the Use of the Bicycle

There is no single indication of whether a person will use a bicycle to accommodate his or her travel desires. Furthermore, isolating one factor for a particular trip purpose becomes very difficult without an empirical data base. However, in an attempt to speculate on the kinds of travel desires that would most likely be accommodated by the bicycle, some preliminary criteria were analyzed. These criteria are given in Table 2 along with some subjective ratings of their impact by trip purpose.

Although criteria such as average trip length and age of trip-maker are obviously of

Table 1. Bicycle and automobile sales.

Year	Bicycle Sales (millions)	Automobile Sales (millions)
1967	7.5	10.0
1968	7.1	9.7
1970	6.9	8.1
1971	8.9	10.7
1972	13.7	11.0

Table 2. Effect of selected factors on the probability of bicycle use for functional trip purposes.

Factors Affecting Bicycle Use (typical conditions)	Work	Shopping	School		Personal Business	Recreation[a]	
			Grade	College		Outdoor	Indoor[b]
Flexibility of schedule	Considerable discouragement	Moderate encouragement	Considerable discouragement	Considerable discouragement	Considerable encouragement	Moderate encouragement	Moderate discouragement
Average trip length	Considerable discouragement	Considerable encouragement	Considerable encouragement	Moderate discouragement	Considerable encouragement	Moderate encouragement	Moderate encouragement
Age of trip maker	Limited effect	Limited effect	Considerable encouragement	Considerable encouragement	Moderate discouragement	Moderate encouragement	Limited effect
Availability and cost of automobile parking	Considerable encouragement	Considerable discouragement	Limited effect	Considerable encouragement	Moderate discouragement	Considerable discouragement	Limited effect
Cargo needs of trip	Limited effect	Moderate discouragement	Limited effect	Moderate discouragement	Limited effect	Moderate discouragement	Limited effect
Street congestion[c]	Considerable encouragement	Moderate discouragement	Limited effect	Moderate encouragement	Moderate discouragement	Moderate discouragement	Moderate discouragement
Quality of pedestrian system	Limited effect	Considerable encouragement	Moderate encouragement	Moderate encouragement	Considerable encouragement	Moderate encouragement	Moderate encouragement
Availability of transit	Moderate discouragement	Considerable encouragement	Moderate discouragement	Moderate encouragement	Moderate encouragement	Considerable encouragement	Moderate encouragement

[a]Trip to a recreational activity as opposed to a recreational bicycle trip.
[b]Social gathering, visiting friend, theater, etc.
[c]Assumed bicycle system would provide safe and uncongested route for the bicyclist.

Table 3. Daily home-based vehicular trips that could be attracted to the bicycle (9).

Trip Purpose	Number	Percentage Less Than 6 Min in Duration[a]	Percentage Less Than 6 Min in Duration That Could Be Made by Bicycle	Percentage Attracted to the Bicycle[a]	Number Attracted to Bicycle Use Given Proper Facilities
School	160,000	20.1	50.0	10.0	16,000
Recreation	917,000	35.0	35.0	12.0	100,000
Personal business	666,000	40.5	30.0	12.0	81,000
Shopping	566,000	48.6	20.0	9.7	55,000
Work	829,000	18.9	10.0	2.0	16,000
Medical	48,000	14.0	5.0	0.7	–[b]
Total	3,086,000				268,000

[a]Low percentages in this category are due to the high percentage of pedestrian trips, which are not counted.
[b]Less than 1,000 trips, not significant.

Table 4. Home-based vehicular trips by purpose and mode (9).

Trip Purpose	Assumed Percentage of Bicycle Trips	Estimated Percentage of Trips				Effect of Increased Bicycling on Present Travel Modes
		Automobile				
		Driver	Passenger	Transit	Other[a]	
Personal business	12.0	71.3	22.9	1.9	3.9	Reduce auto passengers and drivers
Recreation	12.0	39.1	57.1	0.9	2.9	Reduce auto passengers
School	10.0	15.7	20.5	4.6	59.2	Reduce school bus trips and auto passengers
Shopping	9.7	64.6	31.3	1.2	2.9	Reduce auto drivers
Work	2.0	75.7	14.3	5.4	4.6	Reduce auto passengers and transit
Medical	0.7	47.7	40.8	8.8	2.7	Negligible

[a]Includes trips by truck, motorcycle, and school bus.

considerable importance, perhaps one of the most underrated factors in determining the purposeful use of the bicycle is the degree of flexibility in trip scheduling. Trips that are most likely to be made by the bicyclist are those that are flexible on both an hourly and a daily basis. This is principally due to weather and traffic conditions, which are often cited as the greatest deterrents to bicycle use. The greater the chance of delaying a trip to avoid precipitation, temporarily unfavorable temperatures, or traffic congestion is, the greater the chance of completing it by means of a bicycle will be. Thus, work trips and school trips with rigid scheduling requirements (as opposed to shopping and personal business trips that might be delayed or postponed) are not particularly good candidates for bicycling based on this criterion. It is also important to consider that work and school trips involve a certain amount of routine. When a given mode of transportation frequently cannot deliver (such as a bicycle in inclement weather), the commuter is likely to switch to another mode of transportation on a permanent basis.

To determine a preliminary order of potential magnitude of purposeful bicycle trip-making, we analyzed travel characteristics in a typical large metropolitan area, the Minneapolis/St. Paul SMSA (Table 3). Only those vehicular trips that were 6 minutes or less in duration were considered to be candidates for bicycling. The 6-min trip was based on an assumed automobile operating speed of 20 mph (32 km/h); a corresponding bicycle trip would be 12 minutes at 10 mph (16 km/h) or 2 miles (3.2 km) in length. (This is the practical limit of heavy bicycle use based on analysis of bicycle user characteristics in other American and European cities.) Then, it was assumed that a percentage of these short trips could be accommodated by the bicycle based on the subjective criteria developed in Table 2. Not surprisingly, recreational trips were most likely to be attracted to the bicycle mode on a given day. The next largest trip categories were shopping and personal business trips. Somewhat surprisingly, work and school trips, which are receiving a lot of attention from bicycle planners, ranked relatively low in bicycle travel magnitudes based on this analysis.

Although the data developed in this exercise were based on a very empirical base, it should be recognized that the potential for purposeful bike riding is considerable in relation to current levels of transit use. For example, the 268,000 daily bicycle trips estimated would be 65 percent more than the 163,000 daily transit trips in the Twin Cities area in 1970. This observation might receive serious consideration by those who are looking for low-cost alternatives to moving people other than by automobile. Whereas transit is extremely useful for moving large volumes of people, especially to concentrated points, bicycles could serve as a supplemental mode of transportation for moving people to dispersed points within a 2-mile (3.2-km) radius.

Impact on Modal Split

Increased use of the bicycle may generate new trips, but certain trips that are currently made by the automobile, transit, or pedestrian mode will be made by the bicycle. An overwhelming percentage of all vehicular trips in the Minneapolis-St. Paul metropolitan area are by the automobile (Table 4). This is, of course, a typical situation in most metropolitan areas in this country. From the pool of automobile users, it is expected that the automobile passenger is the most likely potential convert to the bicycle. In many cases, the automobile passenger is a captive rider, for he may not have ready access to an automobile or may not consider the transit alternative sufficiently convenient. The attraction of a sizable number of automobile passengers to bicycles could have an effect on the transportation system, for in many instances as many as 10 percent of the total automobile trips are solely for the convenience of the passenger.

A much smaller number of bicycle trips might be attracted from transit inasmuch as a relatively small percentage of total trip-making in the metropolitan area is by transit. However, the percentage of trips that might be diverted from transit to the bicycle might be considerably greater than those diverted from the automobile. Transit trips are typically shorter than automobile trips and often involve a substantial amount of time in waiting and transferring. Under these conditions, transit trips are particularly vulnerable to diversion to the bicycle mode.

WHAT TYPES OF BICYCLE FACILITIES SHOULD BE PROVIDED?

Now that we have investigated which types of trips could be accommodated by bicycling, attention is directed toward selecting those facilities that would yield the most benefit per unit of investment. At least four criteria should be considered in the selection of facilities.

1. Safety—Provision of bicycle facilities should be based on the degree of safety offered to bicyclists, principally protection from motor vehicles.
2. Environmental attractiveness—The bicycle is a means of transportation and of recreation and enjoyment; for this reason environmentally pleasant routes are much more important in bicycle planning than in planning for the more utilitarian and higher speed motor vehicles.
3. System continuity—Bikeways should be a continuous system with a minimum of interruptions. Although some types of facilities may be safer or more attractive than others, there are situations in which the most desirable solution is impractical. In those cases, the goal of system continuity should take precedence.
4. Cost—The costs of bicycle facilities must be weighed against the estimated benefits of safety, environmental attractiveness, and system continuity.

Given the criteria for evaluating bicycle facilities, discussion turns to the alternatives. While a wide variety of specific applications are possible, bikeways can be classified into the following five categories (Fig. 1):

1. Bike route—a road signed for bicycling but with bicyclists sharing the road surface with other vehicles.
2. Unprotected bike lane—a lane on street pavement separated from motor vehicle traffic only by a stripe marking the lane.
3. Protected bike lane—a lane on street pavement separated from motor vehicle traffic by a physical barrier.
4. Bike track—a path within a transportation right-of-way separated from the street by an intervening strip of land.
5. Bike path—a bicycle facility completely separated from a street or highway right-of-way.

The cost of these facilities varies considerably; bike routes and unprotected lanes cost far less than the other alternatives (Table 5). Therefore, it is not surprising that bike routes and unprotected bike lanes constitute the dominant proportion of all bikeways within urban areas.

Although it would be desirable to build systems that provide bicyclists with a maximum amount of physical protection from motorists, this desire must be balanced against the amount of funds that might become available for biking facilities. One way of measuring the effect of this restriction is to estimate the number of system-miles that would be desirable in an urban area and then to assess the potential cost of such a system for each of the five types of biking facilities. Such an analysis was undertaken for Atlanta. Hypothetical bikeways laid out in grids with ½-, 1-, 2-, and 4-mile (0.8-, 1.6-, 3.2-, and 6.4-km) spacings were evaluated within the 500-square-mile (1300-km^2) urban area. The costs varied dramatically (Table 6) from $200,000 for signed routes on a 4-mile spacing to a conservatively estimated $20 million for bicycle tracks or bike paths on a ½-mile spacing (8).

In regard to facility spacing, generally bicycle facilities should be spaced no more than ¼ to ½ mile (0.4 to 0.8 km) apart if a useful bicycle system is to be provided in all parts of an urban area. This rather close spacing is required since most bicycle trips are no longer than 2 miles (3.2 km) (Fig. 2).

Given this spacing, the smallest bike route system for the Atlanta area was estimated to cost $900,000. Although this cost is considerable, higher level treatments on a systemwide basis appear to be unattainable in the short run even with currently proposed financing. For example, even if 1 percent of all federal and state highway and street funds were diverted for biking facilities, it would take at least 20 years to finance a system of bike tracks or bike paths in the Atlanta metropolitan area on the desired ½-

Figure 1. Bicycle facility alternatives.

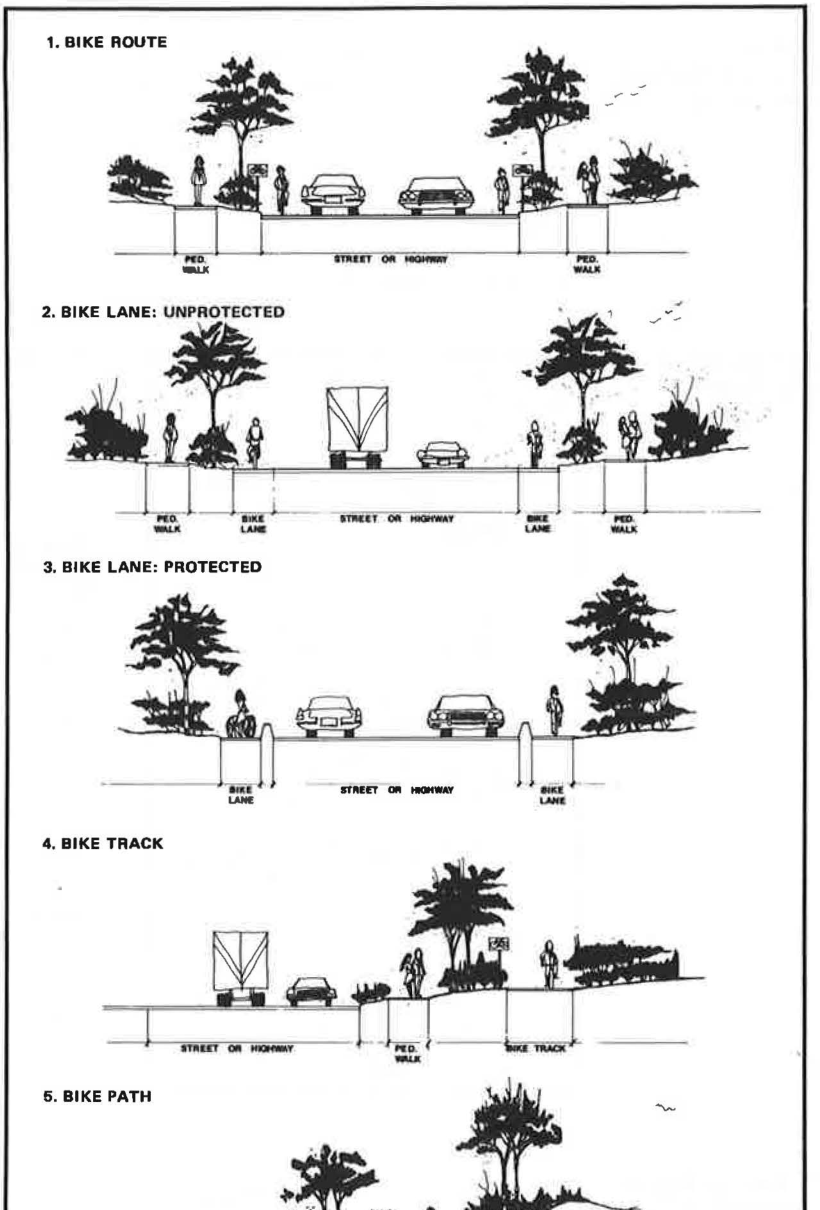

Table 5. Sample costs (in dollars) of alternative bicycle facilities.

Bicycle Facility	Signing	Striping	Barrier	Pavement and Base	Right-of-Way	Total
Signed route	500	0	0	0	0	500
Unprotected bicycle lane	500	500	0	0	0	1,000
Protected bicycle lane	400	0	2,650	0	0	3,050
Bicycle track	400	0	0	10,560	–*	10,960
Bike path	200	0	0	10,560	–*	10,760

*Right-of-way cost for a 10-ft-wide (3-m) strip at a land value of $10,000 per acre (4.05 km^2) would be $12,100 per mile (1.6 km).

Table 6. Costs of hypothetical biking systems within Atlanta area.

Type	Cost of Bicycle Facilities (millions of dollars)			
	½-Mile	1-Mile	2-Mile	4-Mile
Signed route	0.9	0.5	0.3	0.2
Unprotected bicycle lane	1.8	1.0	0.6	0.4
Protected bicycle lane	5.6	3.1	1.8	1.2
Bicycle track[a]	19.6	10.9	6.6	4.4
Bike path[a]	19.4	10.8	6.4	4.3

Note: Costs in this table were based on system component estimates as established in Table 3.

[a]These estimates do not include land costs.

Figure 2. Hypothetical bicycle facility grid.

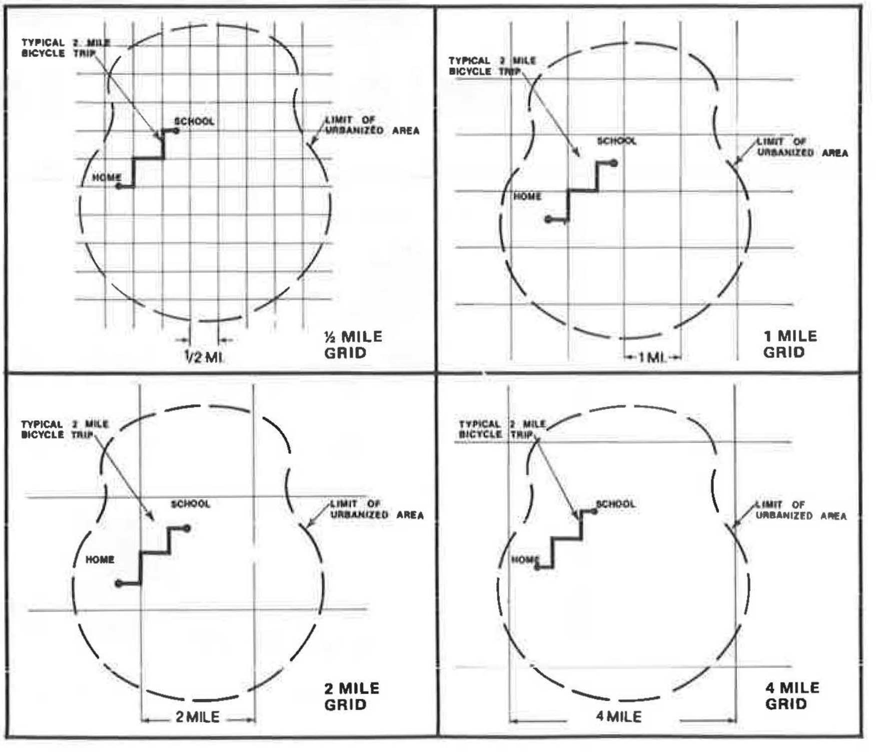

Table 7. Potential locations for urban bicycle facilities.

General Category	Best Location Opportunities
Barrier removal	Freeways and major arterials, rail lines, gorges or rough topography
Storage facilities	All high-use areas
Penetrator systems	Schools (especially universities), central business districts, large employment concentrations, shopping centers, transit stations and express bus stops, heavily used parks
Internal systems	Colleges and universities, large city parks
Environmental corridors	Stream valleys, utility rights-of-way, ridge lines
Transportation linear corridors	Street and highway rights-of-way, adjacent to public transit lines, adjacent to operational rail lines
New land developments	Residential subdivisions, large-scale planned unit developments

mile (0.8-km) grid spacing. (This is based on the assumption that current expenditures for streets and highways will remain constant.)

At this stage of bicycle facility development within urban areas it is risky to advocate one type of bicycle facility over the others. Too little is known about the safety and performance characteristics of the alternatives under operating conditions. Nevertheless, the following tentative recommendations on the selection of alternative bicycle facilities are presented for consideration.

1. Bike route signing should be used primarily as a route identification technique. Although statistical evidence is not available, there is enough preliminary evidence from operational bike routes to seriously question the degree of safety gained by merely signing streets. Whereas signing warns the motorist, there is a danger that it may create a false sense of security on the part of the bicyclist. The principal advantage of signing appears to be its usefulness in directing the bicyclist to the safest roads in a given area. However, signing in conjunction with other related actions such as reducing traffic volumes and speeds on streets designated for priority bicycle treatment may have a significant impact.

2. The unprotected bike lane is a marked improvement over the signed bike route. When traffic volumes and speeds are low, these lanes substantially protect the bicyclist from passing motor vehicles. When traffic volumes become heavy, the motorist is especially prone to encroach into a bike lane. Under normal operating conditions, right-turning vehicles and the opening of parked car doors present the greatest dangers.

3. Protected bike lanes and bike tracks have similar performance characteristics. Both bike lanes and bike tracks offer considerable protection from the automobile. Of the two, the bike track generally is preferred for two reasons. First, the bicyclist is protected to a greater degree from noise and exhaust fumes by being separated by a greater distance from motor vehicles. Second, a slightly greater degree of protection is provided at intersections, especially with regard to right-turning vehicles.

4. The bike path is preferred to all solutions. A bike path system totally divorced from roads carrying motorized traffic offers a more pleasing environment for the bicyclist and reduces the potential number of bicycle-automobile conflicts. A bike path system can also be effectively combined with pedestrian and equestrian routes as evidenced in many of the American and British new town developments (3). This preference, of course, must be weighed against costs. There is a great potential for constructing such systems on the fringes of urbanized areas as new land developments are undertaken. By aggressive public action supported by good development ordinances, these facilities could be largely provided by private developers at a minimum of public expense.

WHERE SHOULD BICYCLE FACILITIES BE PLACED?

Determining where investments in bicycle facilities should be directed must be based on an investigation into the potential purposes of bicycling. Because the bicycle is being used for a variety of recreational and purposeful trips, investments in bicycle facilities should reflect these diverse interests. Currently not enough is known about the specific interests of bicyclists to make this determination.

Use of the bicycle will be strongly influenced by the type and location of systems constructed. For example, if safe and direct commuter routes are provided into areas of high employment, probably commuter biking would increase substantially. The same, of course, would probably be true for bicycle touring, if pleasant environmental corridors of some continuity are provided. Based on this observation, it is recommended that investments in bicycle facilities in urban areas be initially directed toward serving a wide variety of trip purposes.

So that public investments will be channeled into opportunities having the greatest potential payoff, the following specific opportunities (Table 7) are offered for consideration.

Barrier Removal

Opportunities for bicycling within urban areas will be maximized if selected barriers to continuous travel are removed. In particular, construction of underpasses and bridges will accommodate movement across obstacles such as freeways and principal railway lines. Although these may appear costly, a few such improvements might significantly increase the use of the biking system.

Storage Facilities

The provision of adequate numbers of well-placed and relatively inexpensive storage facilities might increase bicycle travel more than any other type of immediate biking improvement. Placing these facilities close to points of origins and destinations will enhance a major potential advantage of the bicycle—portal to portal service. Bicycle storage facilities should be required at most major trip attractors such as shopping centers, schools, selected public buildings, and office and employment locations. Many of these facilities could be provided by building owners. Inasmuch as mandatory inclusion at the time of construction is the most effective means of ensuring that such facilities are provided, such a requirement might be part of local zoning ordinances.

Penetrator Systems

If the bicycle is to be used to make purposeful trips, bikeways that lead into concentrations of high employment or other high-use areas such as shopping centers and universities must be provided. Unfortunately, intense motor vehicle traffic in and around these high-activity areas often precludes safe bicycling. Bicycle facilities penetrating into these areas are bound to be costly or unfeasible in many situations. Nevertheless, where opportunities do occur, expenditures higher than the average might be justified when high usage can be anticipated.

Internal Systems

In portions of urban areas an appropriately designed bicycle system could result in the bicycle becoming a primary means of transportation. This opportunity appears to be particularly good on college campuses where a well-developed bicycle system could provide an efficient, low-cost transportation alternative with low storage-area requirements.

Environmental and Aesthetic Corridors

Although the rush has been to provide bicycle facilities adjacent to streets and highways, providing environmentally pleasing routes totally separated from motorized transportation facilities is getting less attention than is deserved. Particularly appealing are stream valleys with flat gradients that are highly conducive to bicycle riding.

Transportation Linear Corridors

There is a great opportunity to provide bike tracks adjacent to major transportation corridors such as freeways, toll roads, major arterials, and public transit lines at the time of construction or reconstruction. Once construction is completed, the cost of bike tracks escalates sharply because of the number of structures that must be removed or redesigned.

New Land Development

To a certain extent, the battle for high-quality bicycle facilities has already been lost in developed portions of urbanized areas. Particular attention should be paid to the possibility of providing bicycle facilities separated from transportation corridors within new land developments. Development incentives could be included in local ordinances to encourage developers to provide bike paths as part of their subdivisions.

CONCLUSIONS AND RECOMMENDATIONS

The following principal conclusions are offered to serve as guidelines for future bicycle facility development in urban areas:

1. Considerably more expenditures for bicycle facilities are justified. Although traditional transportation economics cannot be used to justify greater expenditures for bicycle facilities, there is ample evidence through other evaluation measures. Without substantially greater investments to provide safe and convenient facilities for the bicyclist, it is very possible that the true potential of the bicycle may never be realized in the United States, especially for purposeful trip-making.

2. Investment in commuter biking facilities may not produce benefits so significant as similar investments in "convenience" biking. The commuter trip is typically the longest of all urban trips, must be performed on a rigid schedule, and has the best transit options. All of these factors, in combination, pose a serious question on whether first priority bicycle facility investments should be directed toward accommodating the commuter. It appears that considerably more convenience trips such as shopping and personal business trips might be readily accommodated at less expense. However, bicycle commuting shows promise.

3. Bicycle ridership for purposeful trip-making could exceed public transit ridership in many U.S. cities. Given a safe and convenient bicycle system, the use of the bicycle could outstrip public transit use even if all purposeful bicycle trips are restricted to a distance of less than 2 miles. Consequently, as transportation funding for modes other than the automobile increases, the bicycle should receive serious consideration. Whereas the bicycle and public transit modes are primarily "middle distance" forms of urban transportation, they are largely complimentary. Public transit is most useful in carrying large numbers of people to concentrated points, whereas the bicycle is better suited to moving smaller numbers of people to dispersed points.

4. Proportionately more should be spent on bicycle facilities other than signed bike routes. The principal advantage of signing routes appears to be to direct bicyclists to safer streets rather than to provide protection on these streets. As more funds become available for bicycle facility development, it is recommended that a much greater proportion be spent on those facilities that separate the bicycle from motor vehicles.

5. Greater emphasis should be placed on developing bike paths within environmental areas. To date, the majority of attention on biking facilities has been directed toward locations within or adjacent to street and highway rights-of-way. At this formative stage of accommodating the bicycle within urban areas, it should be recognized that the "ideal" solution is not adjacent to corridors accommodating motor vehicles but rather in the interior of developed blocks.

6. Barriers to safe bicycle travel should be removed. Instead of building long stretches of expensive bicycle facilities, it may be more useful to concentrate on removing barriers to travel (such as a bridge over a freeway) where the greatest dangers to bicyclists occur. The number of miles of bicycle facilities provided is not an accurate indicator of the adequacy of the system; the amount of safety provided is.

7. Warrants for alternative bicycle facilities should be developed. There is considerable uncertainty surrounding the selection of an appropriate type of bikeway for each type of traffic, parking, and pavement width condition. Much more data regarding accident propensities must be gathered before the decision among bicycle facility alternatives can be made with authority. An important first step would be the systematic reporting of bicycle accidents and the routine inclusion of bicycle traffic volumes in traffic surveys.

8. Local bicycle facility plans should be a prerequisite for governmental grants. If substantial funds become available from state and federal sources for the purpose of constructing bicycle facilities, it seems only natural that guarantees should be made that these funds are spent wisely. Investigations of existing bicycle facilities indicate that many of the solutions are piecemeal and not suited to long-term development. In many cases, this situation could be corrected by advance system planning.

9. Municipal ordinances should encourage or require provision of bicycle facilities. It is a common practice to require provision of streets, open spaces, and automobile parking spaces as a precondition for zoning and subdivision approvals. The same type of requirement should be adopted where the provision of bicycle facilities would be in the public interest.

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STUDY OF THE IMPACT OF THE LANCASHIRE-YORKSHIRE (M62) MOTORWAY

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A study of the effect of the Lancashire-Yorkshire (M62) Motorway was initiated in late 1968 at Leeds University under the sponsorship of the Department of the Environment. This paper describes the background of the study and discusses some specific aspects of it. Inasmuch as the motorway is not yet fully open, the paper is an interim report. The main issues addressed are (a) whether there are indirect benefits of road investment that should be incorporated in appraisals, (b) what account should be taken of regional effects, and (c) the nature of and the allowance made for traffic that at present is not included except on an ad hoc basis. "Before" traffic and household surveys were carried out, and interim surveys were taken on newly completed sections. The relationship between transport costs and subregional employment growth has been analyzed. Interim results suggest that the M62 will cause marginal employment growth in Yorkshire and Lancashire. No empirical work has been done on the benefits, but theoretical examination suggests that existing procedures are not inappropriate. New traffic generation on the 27-mile trans-Pennine section is lower than expected. These interim results suggest that transport investment is not among the best regional policy tools for the United Kingdom and also that the current treatment of generated traffic by the Department of the Environment seems appropriate. Much analysis and further data collection still remain that may modify these interim conclusions.

•THE M62 MOTORWAY is a dual, three-lane, limited-access highway that will traverse northern England from near Hull on the east coast to Liverpool on the west coast, a distance of about 130 miles. It provides, via the sections already open, an important link between the economies of West Yorkshire and Lancashire and between the parallel lines of the national motorway network, separated by the Pennine Mountains. This range of hills has in the past constituted a significant barrier to east-west movement, and, although existing trans-Pennine roads are of high quality, they are susceptible to closure during periods of bad winter weather and of inadequate capacity to cope with the increasing volumes of traffic. The M62 Motorway is thus the first all-weather road across the Pennines. Extension of the motorway east to Hull in about 1975 will help to connect the heretofore isolated Humberside region to the national motorway network.

The areas the M62 passes through are the U. K. Standard Planning Regions (SPR) of Yorkshire and Humberside and the North West Region. These areas and other SPRs are shown in Figure 1, which also maps the main road system and cities of Great Britain. The Yorkshire, Humberside, and North West SPRs are shown in greater detail in Figure 2. The two regions are among the older industrial regions of the United Kingdom and have shared to varying degrees in the reduced prosperity, compared to the country as a whole, that has affected these regions since World War I. Table 1 gives a few statistics of these regions along with the corresponding U.K. figures. These statistics point out the net outmigration, higher-than-average unemployment, and lower-than-average activity rates and earnings in the regions. Both regions for the most part are

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Figure 1. Main road system and SPRs of the United Kingdom.

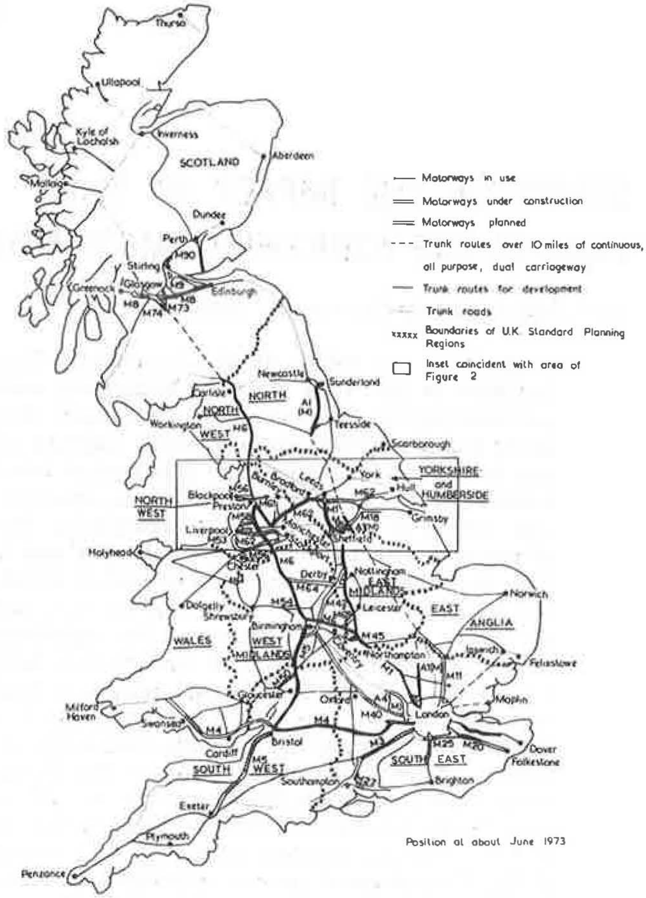
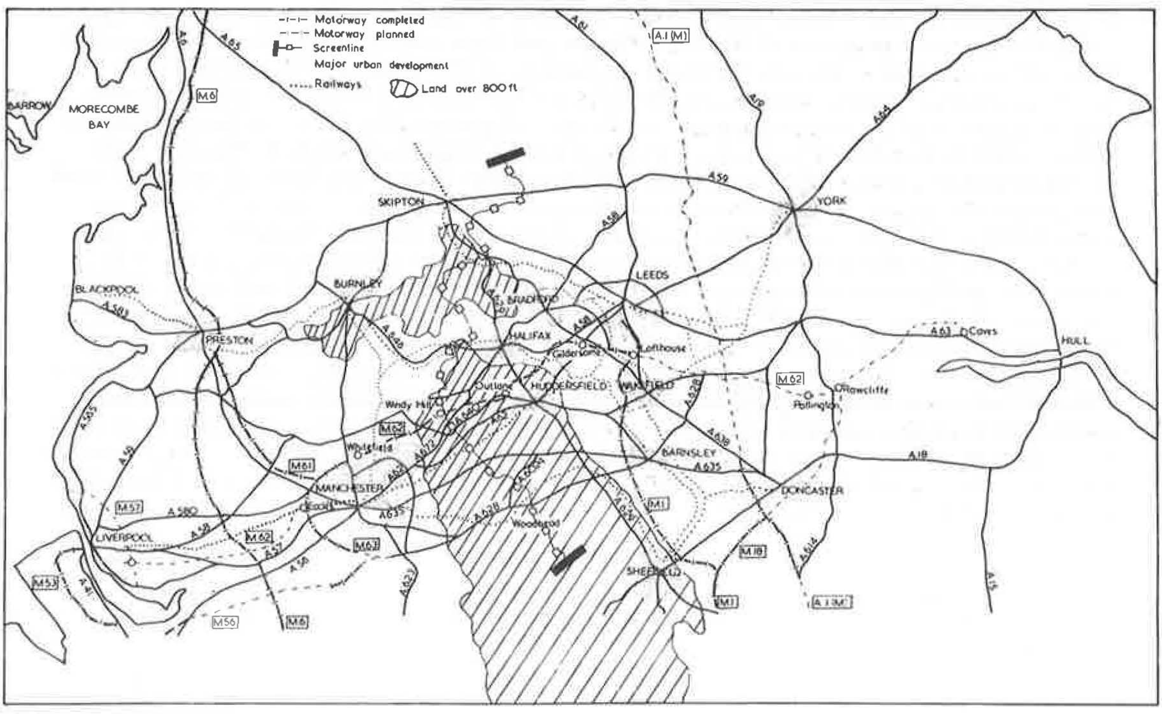


Figure 2. Road network in vicinity of M62 Motorway.



categorized as intermediate areas under which they are eligible for preferential treatment within the framework of current government regional policy. This is, however, less favorable than the treatment accorded to the worst affected regions—development areas.

The decision to build the Lancashire-Yorkshire Motorway was not, however, based on regional development grounds but on the need for network improvement. The need for such a new east-west link has long been recognized and was first proposed before World War II. In 1961 the Minister of Transport invited the county councils of Lancashire and Yorkshire to carry out route feasibility studies to determine the alignment of the motorway. These studies were completed in 1963, and the alignment chosen is shown in Figure 2. (The populations of the main urban centers along the route are given in Table 2.) Construction started in 1966 and has been a topic of considerable interest in itself (1). The first sections opened in 1970; phasing of completed and planned sections of the motorway is given in Table 3.

The effect of the motorway on travel times will be substantial, and, as an illustration of the magnitude of the change, some comparisons for private vehicles are given in Table 4. Although the travel times are derived by multiplying average speeds by the specified mileages, they are, nevertheless, reasonably comparable to observed travel times. As can be seen, the time savings are very significant—up to 40 percent for the longer journeys.

AIMS AND THEORETICAL BACKGROUND

The study of the effects of the M62 Motorway was described as an "impact study." In some ways this is a misnomer because the primary purpose of the study was not to build up a generalized view of the effects of the facility per se or to attempt to predict its effects so that these forecasts could be used by government agencies in their general planning activities. This is very often the case with what are conventionally termed impact studies, of which there have been numerous American examples (2) and some British ones (3).

Although such aspects were not excluded from the M62 study its objectives were related more specifically to a number of problem areas in the procedures used by the Department of the Environment (DOE) for evaluating interurban road investments. The economic evaluation of road investments in the United Kingdom is of fairly recent origin and began with the retrospective evaluation of the M1 Motorway from London to Birmingham (4). Following the experience gained here, procedures were outlined for the economic evaluation of road investments (5) and later updated and improved (6). At the same time DOE laid down general procedures specifying the format in which all road schemes submitted to it were to be evaluated (7); subsequently these procedures were computerized (8, 9). Hence, a large proportion of all interurban road schemes in the United Kingdom are evaluated in a fairly sophisticated and uniform way. Larger schemes are evaluated on a case-by-case basis using modeling approaches specific to each scheme, though there are similarities of philosophy and technique with the standardized procedures. The most important similarity is that all appraisals are direct user cost-benefit appraisals, and there is no explicit procedure for incorporating indirect effects on the economy into the appraisal. Such effects are sometimes quoted to justify more road construction in absolute terms or preference for road construction in some places rather than others.

In the past, recognition that road improvements benefit other than existing users was allowed in the treatment of generated traffic. The Transport and Road Research Laboratory (TRRL) suggested (6) that "to obtain an estimate of the total traffic (i.e., including generated traffic) the predicted traffic should be multiplied by $(C_1/C_2)^n$ where C_2 and C_1 refer respectively to the total costs of the journey with and without the improvement," and n is an impedance exponent from an unconstrained gravity model. Such a procedure has been criticized (10), and, in fact, DOE has not adopted this formulation as a general rule. At the present time the standard procedure (8, 9) incorporates no allowance for generated traffic, though in the past up to 30 percent had been allowed where specific justification was offered. For example, "Generated traffic on large

Table 1. Statistical data for 1971.

Item	United Kingdom	North West Planning Region	Yorkshire and Humberside Planning Region
1. Population (thousands)	55,515	6,743	4,799
2. Migration per 1,000 population	-0.6	-1.7	-1.5
3. Total persons employed (thousands)	23,987	2,923	2,039
4. Total persons unemployed (thousands)	724	102	70
5. Unemployment as percentage of total labor force	3.5	3.9	3.9
6. Economic activity rate[a], percent	72.0	73.3	71.6
7. Wage rate[b], £	29.8	28.2	29.8

[a]Percentage of population in age group 15 to 64 economically active.
[b]Average weekly earnings in April 1971 of males aged 21 and over.

Table 2. 1971 population for main urban centers.

Region	City	Population
Lancashire	Barrow	64,032
	Blackpool	151,860
	Burnley	76,513
	Liverpool	610,113
	Manchester	543,650
	Preston	98,088
Yorkshire	Barnsley	75,395
	Bradford	294,177
	Doncaster	82,668
	Halifax	91,272
	Huddersfield	131,190
	Hull	285,970
	Leeds	496,009
	Sheffield	520,327
	York	104,782
	Wakefield	59,590

Table 3. Construction schedule for M62 Motorway.

Section	Approximate Length (miles)	Opening Date
1. M57 junction (near Liverpool) to Tarbock	3	Autumn 1975
2. Tarbock to Risley	13	Spring 1974
3. Risley to Eccles	7	Summer 1974
4. Eccles to Whitefield	6	October 1970
5. Whitefield to county boundary	13	August 1971
6. County boundary to Outlane	8	December 1970
7. Outlane to Ainley Top	1	December 1972
8. Ainley Top to Chain Bar	7	July 1973
9. Chain Bar to Gildersome	4	October 1972
10. Gildersome to Lofthouse	6	December 1970
11. Lofthouse to Pollington	20	Summer 1974
12. Pollington to Rawcliffe	6	Spring 1975
13. Rawcliffe to Caves (near Hull)	13	Summer 1975

Note: Opening dates are not necessarily synonymous with completion of construction, and opening dates for uncompleted sections are tentative.

Table 4. Estimated journey times by private car with and without M62 Motorway.

Origin-Destination Pair	Distance on Existing Roads (miles)	Journey Time on Existing Roads (minutes)	Journey Time With M62 Motorway (minutes)			Percentage Reduction in Travel Time
			Distance on M62	Distance on Other Roads	Total Journey Time	
Leeds-Manchester	40	80	32	9	50	38
Leeds-Liverpool	73	146	58	13	84	42
Halifax-Manchester	24	48	21	10	41	14
Halifax-Liverpool	57	114	47	14	75	34
Hull-Manchester	93	186	78	16	110	40
Hull-Liverpool	123	246	104	20	144	41

Note: Approximate and measured distances to nearest mile. Times derived by computing an average speed of 30 mph for ordinary roads and 60 mph for motorways. Data include no allowance for improved running times on existing roads after reassignment of traffic to M62 nor for improvements to access roads to the motorway.

schemes has often amounted to between 5 percent and 25 percent over and above the normal forecast traffic level" (11). Hence, DOE takes a cautious stance on this point, and one of its interests in sponsoring this study of the effects of the M62 Motorway was to see whether more light could be thrown on the nature and magnitude of generated traffic.

The more general question of indirect effects of transport investment on the structure of the economy still remains. This has three aspects:

1. It is often argued that transport investment has an effect on the structure of an economy that is not reflected fully in the direct user benefit, so that, even if traffic patterns and benefits are correctly predicted, the total benefit to the economy is underestimated.
2. Related to 1 above, but not dependent on it, is the argument that road investment can alter the relative economic positions of different regions and can therefore be used as a tool of regional policy.
3. Existing structural changes in the economy generated by the transport investment may themselves generate further traffic, which then invalidates the forecasts used in the normal appraisal procedures (which may or may not include allowances for generated traffic based on straightforward price effects). This point, of course, relates back to the initially stated interest in evaluating the conventions used to estimate generated traffic.

Each of these points may be discussed in a little more detail. The general line of argument on externalities and secondary benefits in road investment is discussed extensively elsewhere (12, 13), and only the elements need be presented here. Regarding the external effects, it would appear that the possibilities for technological externalities are somewhat limited, though there is a range of intangible technological external diseconomies of an "environmental" nature that may be significant. The argument on pecuniary externalities, mainly relating to the effect of transport investment on land values, has been shown to be mainly a double-counting problem, though there are possibly relevant distributional issues involved.

Secondary benefits, discussed by Bos and Koyck (14), Tinbergen (15), and Friedlaender (16), in which an initial investment sets off a chain of effects throughout the economy leading to an increase in national income, have, however, seemed to carry more weight. Bos and Koyck and Tinbergen, using arithmetical examples, show that, in an imaginary economy with various assumed supply and demand functions for the products considered, the change in national income due to a transport investment would be greater than the conventional measure of benefits to existing and generated road traffic, as measured by the area under the demand curve for transport between old and new transport costs. Although this may be so, it does not follow, for various reasons, that the magnitude of the welfare change that results from the transport change can be deduced correctly from the change in national income. Once this is recognized, we are thrown back from the general to the partial equilibrium level in order to measure welfare changes via consumers' surplus. Because it has been shown by arithmetic examples that the demand for freight transport is derived in a perfectly competitive world, we can measure the net level of benefits of a road investment to the community as a whole by accurately measuring the benefits to both existing and generated freight and passenger road users. This brings the argument back to the question of how we forecast generated traffic.

Even if one does not subscribe to the secondary benefits argument at the whole economy level, it is possible to hypothesize that a reduction in transport costs at a regional level effects an improvement in the growth rates of the regions most directly affected by the highway investment to the disadvantage of the regions less directly affected. The idea that a region's accessibility affects its growth rate has had some popularity (17) and has been voiced in official policy statements advocating road construction as an aid to regional development (18, 19, 20). Analysis at the SPR level by Brown (22) does not support this proposition; an attempt to discover such an effect at a more disaggregated level is described later.

Given the low significance ascribed to generated traffic with current procedures, the question of whether road improvements cause structural changes that then cause new traffic generation has perhaps less practical importance. However, even when more importance was attached to generated traffic in appraisals it was not totally explicit where this new traffic came from. The former TRRL procedure (6) would suggest that a price effect produced these new trips, inasmuch as there was no allowance for loss of benefit on other links or modes. Equally well, the former DOE procedure of allowing up to 30 percent new traffic generation made no such allowances but, at the same time, was not explicit on whether a structural effect might be operating along with the price effect, though one would presume only a price effect. At a practical level one might ask whether the observed new traffic generation is due to redistribution of the existing trip levels or merely reassignment of traffic across a wider area than that covered by the pre-appraisal survey. This would be equivalent to saying that the price-structural effects were negligible. Of course any intermediate combination of the two propositions is possible.

The net effect of current procedures is to make interurban appraisals more consistent with urban transportation study procedures where a fixed trip matrix is assumed and there is no interaction between transport networks and the total level of trip generation. This is not to say that no such interaction exists, but until now there has been no satisfactory method for establishing the nature of the effect and the way in which it can be incorporated into forecasting procedures. Hence, research into this question is proceeding on a number of fronts, one of which is the present study.

The general area of interest in the study has been discussed at some length. Whereas it was not realistic to expect results on all the questions raised, work is in progress on a number of them. Topics singled out for study have been, first, the effect of the M62 on subregional employment growth; second, its effect on crude traffic generation; and, last, its effect on total traffic generation. Clearly, because the motorway will not be fully open for up to 2 years, much of the work is of necessity focused at a cross-sectional level. However, some time series work is being done and is described at length in the next section.

EMPIRICAL WORK

M62 Motorway and Subregional Employment Growth

Dodgson (23) has conducted a cross-sectional analysis of the impact of the motorway on employment growth; this analysis is used to provide a forecast of the impact. The analysis consists of three parts:

1. Development of measures of industrial transport costs for each of 30 zones at varying distances from the motorway;
2. Development of a relationship between employment growth in these zones and the transport costs from each zone; and
3. Use of this relationship to predict what employment increase will result from the transport cost reduction brought about by the motorway.

The development of a transport cost measure consists basically of an accessibility calculation in which the expected cost of transporting a given quantity of freight from (or to) each origin (or destination) is computed. The effect of the M62 is readily calculated and indicates that the likely fall in transport costs is not great, varying from less than 4 percent in Huddersfield near the center of the motorway to less than 1 percent in Preston and Blackpool, some distance from the motorway. In addition, the disparity in transport costs between areas is not very great; all but three are within about 15 percent of the lowest (Manchester). Edwards (24) has calculated that transport costs represent about 9 percent of the value of net manufacturing output; therefore, a cost reduction of less than 4 percent of 9 percent for Huddersfield is not a large effect. Clearly some haulers will benefit more than others, especially, for instance, if most of their traffic is, say, Huddersfield-Manchester, but the average effect must as indicated be smaller.

The second stage of relating regional growth to transport costs involved a regression analysis to include the effect of other variables on areal employment growth, namely, the interaction of demand for and supply of labor, variations in industrial structure, and the effect of congestion in large urban areas. The analysis indicates a relationship between employment growth and these variables, which is consistent with theoretical expectations in terms of parameter signs, but the relationship as a whole is weak. (The corrected multiple correlation coefficient is 0.26.) All the parameters are, however, significant at the 97.5 percent level. However, most of the influence of access cost in the model is due to a smaller number of areas on the periphery of the industrial North of England (around the Barrow peninsula), which had the highest transport costs. This effect is reflected in the statement by Brown (22): "as between the existing major industrial concentrations of Great Britain, differences in the average extent to which an establishment in them is accessible to the industry and population of the country as a whole are not very important in promoting or hindering growth, other things being equal. Small and remote areas may be at a disadvantage but so far as the major ones are concerned, the extra growth at the centre of the United Kingdom economy as compared with its periphery is to be explained largely by differences of structure."

The third stage of using the derived relationship to predict the employment-generating effect of the M62 is based tentatively on the weak relationship and the poor-quality data, but the actual predictions may, as Dodgson (23) states, "suggest the most probable maximum orders of magnitude of employment change on the basis of present knowledge." The predicted total employment change is 2,900 per annum in an area with a total employed population of 3,400,000. This is not a large effect and constitutes what is due solely to the M62 and may in fact be counter-balanced by the effects of motorway construction in other areas. (Also, it needs to be emphasized again that this is a predicted effect and has not been observed.)

Whereas Dodgson is cautious about the results derived from his model and points out that his conclusions are not directly testable, they are nevertheless consistent with other work for the United Kingdom (21, 22) and do help to temper somewhat the enthusiastic claims that have been made about the likely effects of the motorway. Indeed, when the large size of the regional economies concerned and the fact that the M62 is a very marginal addition to the existing capital stock are considered, such a conclusion is hardly surprising. Thus, in a developed economy, the effect of transport investment on regional growth may be limited as compared with other regional policy measures. In an underdeveloped economy with inadequate transport facilities, transport investment may clear away bottlenecks with apparently quite dramatic effects, but even here, as Wilson et al. suggest (25), "There are, in fact, few magical properties in transport investment that warrant the excessive attention frequently paid to them." Nevertheless, further research would be useful to amplify and support these initial tentative conclusions.

M62 Motorway and Generated Traffic

Previous discussion has indicated that more information is required on the magnitude and nature of generated traffic so that it may be more satisfactorily taken account of in appraisals. However, from a practical point of view, planners have not been in a position to check their forecasts against results because of the long intervals between appraisal and construction, a problem compounded by the intervention of numerous other unforecast developments. This difficulty can be reduced to some extent by reducing the time interval involved, i.e., by providing a data base on travel patterns shortly before the new facility is operational and then comparing forecasts derived from this data base with new data collected shortly after the facility opens. The commissioning of a new link like the Lancashire-Yorkshire Motorway was such an opportunity to attempt to clarify some of these problems.

The term "generated traffic" may be used to describe the extra road traffic that is observed in a corridor after a network improvement (over and above secular growth). Alternatively, and more precisely, the term may describe those new trips observed in a corridor once account is taken of trip redistribution, modal-split changes, and secular changes. The task is to investigate the nature and magnitude, initially of the first type of "generated traffic" and then of the second type.

A good start has been made on monitoring the effect of the M62 Motorway with these objectives in mind. Surveys were carried out on traffic movements and household trip generation before the M62 Motorway was open, and monitoring surveys have been carried out in the intervening period. It will be some time before a complete data bank is assembled on the effects of the M62 Motorway on traffic patterns in northern England. Apart from the data collection effort mounted by the study team, various public bodies are, or will be, generously supplying relevant data collected in the course of their own work, including traffic and household surveys carried out after the opening of some main sections of the motorway in 1973. Hence, much work remains before full results can be reported. Nevertheless, a brief summary can be given of the initial effects of the motorway, pending a complete analysis carried out with the aid of a transport planning computer program, which has been commissioned.

Because of the very large area involved, data on traffic flows have only been collected on one screen line (Fig. 2). This was a line running along the Pennines for about 40 miles from Skipton in the north to Woodhead in the south. It would have been valuable to monitor effects within the Yorkshire and Lancashire urban areas, but this would have involved an enormous data collection effort. The "before" traffic survey in spring 1970 involved interview surveys for four 16-hour days (Thursday to Sunday) on each of the 11 roads. In addition, interurban bus passengers across the screen line were surveyed and almost all the 11,000 passengers were interviewed. At the same time, British Rail carried out one of its periodical passenger surveys on routes across the Pennines and the results of this, covering interviews of about 20,000 passengers, were made available. Further data have subsequently been collected on the effects of the M62 over the sections opened to traffic up to spring 1972. In addition, monitoring counts and full traffic surveys for 1973 have been carried out, and a further survey is planned for 1974; however, no results for the 1973 surveys are yet available. The results up to 1972, which are presented in more detail elsewhere (26), may be summarized briefly.

The situation in 1970 before a few short sections of the motorway opened is given in Table 5. This table indicates the relative importance of the various trans-Pennine roads for east-west movement. About three-quarters of the flow passes on the A65, A629, A646, A58, A62, and A628, whereas some roads stand out as particularly important commercial vehicle routes (A628, A62, A646, A629).

Intermodal comparisons are available for passenger flows; almost all freight moves by road across the Pennines except for certain bulk movements, like coal, that constitute a small percentage of the total. The aggregate results for the screen line indicate that 91.2 percent of the 346,261 passengers crossing the line during the survey went by private car. However, this share is an overestimate of the true share, inasmuch as public transport modes were surveyed differently from road traffic. On some origin-destination pairs, the road share is as low as 70 percent, and, hence, there is clearly room for some significant diversionary effects.

When the 1970 survey was carried out no part of the M62 was open. In the period up to spring 1972, for which data are available, a number of sections were opened:

Date	Section
December 1970	Lofthouse-Gildersome
	Outlane-Windy Hill
August 1971	Whitefield-Windy Hill

Follow-up surveys that monitored secular trends and the initial effects of the sections then commissioned were carried out in spring 1971 and spring 1972. The monitoring surveys were generally carried out by automatic traffic counts, although some manual counts were also taken in 1972. The results of the automatic counts for 1970, 1971, and 1972 are summarized in Table 6, giving figures for the weekdays Thursday and Friday and for the full survey period of Thursday to Sunday.

The table indicates the marked effect that the M62 has had on traffic patterns across the screen line. Between 1970 and 1972 the roads on either side of the M62 lost substantial amounts of traffic. It is, however, instructive to group the results for the

Table 5. Trans-Pennine traffic flows during spring 1970.

Road	Two-Way Traffic Flow Private	Commercial	Total	Buses and Coaches
A59	9,088	3,050	12,138	132
A65	14,299	3,885	18,184	303
A629	45,839	12,842	58,681	1,322
A646	21,020	7,614	28,634	738
A58	12,195	4,990	17,185	262
A672	8,282	2,119	10,401	201
A640	10,739	3,366	14,105	90
A62	14,966	11,960	26,926	416
A635	7,487	1,628	9,115	71
A6024	3,582	352	3,934	19
A628	9,769	8,198	17,967	304
Total	157,266	60,004	217,270	3,838
Total east			108,109	
Total west			109,161	

Table 6. Summary of automatic traffic counts on trans-Pennine screen line.

	Thursday and Friday			Thursday to Sunday		
Road	1970	1971	1972	1970	1971	1972
A59	7,196[a]	7,060[a]	9,400[a]	13,953[a]	13,991[a]	17,407
A65	8,861[a]	13,489	10,247	19,718[a]	26,405	21,755
A629	30,861	30,931	31,493	68,231	59,550	64,390
A646	17,228	16,378[a]	13,064	35,162	30,608[a]	26,902
A58	10,805[a]	9,155	4,094	21,123	15,965	8,074
A672	5,544	4,469[a]	3,946[a]	11,925	8,198	7,239
A672/M62	—	—	3,435[a]	—	—	6,871
M62	—	13,560	54,301	—	24,679	85,170
A640	8,947	2,851	1,480[a]	15,928	6,315	3,427[a]
A62	19,450	19,653	10,443	34,959	33,981	18,758
A635	4,200	5,209	3,230[a]	9,186	10,696[a]	6,636[a]
A6024	2,181	2,102	1,478	3,953	4,062	2,850
A628	15,651	14,118[a]	12,157	25,229	24,383[a]	21,244
Total	130,924	138,975	158,768	259,367	258,833	290,723

[a]Total partly derived by estimation (usually due to counter deficiency).

Table 7. Analysis of screen-line traffic growth.

	Thursday and Friday			Thursday to Sunday		
		1972			1972	
Corridor	1970 Flow	Flow	Index of Growth (1970 = 100)	1970 Flow	Flow	Index of Growth (1970 = 100)
1. Northern	46,918	51,140	109.0	101,902	103,552	101.6
2. Motorway	61,974	90,763	116.5	119,097	156,441	131.4
3. Southern	22,032	16,865	76.5	38,368	30,730	80.1
4. 2 + 3	84,006	107,628	128.1	157,465	187,171	118.9
5. All (1 + 2 + 3)	130,924	158,768	121.3	259,367	290,723	112.1

Table 8. Secular growth across screen line.

Days	Corridor	1971 Flow	Ratio 1971/1970	Predicted 1972 Flow	Generation or Degeneration	Percentage Generation
Thursday and Friday	1. Northern	51,480	109.7	56,474	-5,334	-9.4
	2. Motorway	66,066	106.6	70,426	+20,337	+28.9
	3. Southern	21,429	97.3	20,850	-3,985	-19.1
	4. 2 + 3	87,495	104.2	91,170	+16,458	+18.1
	5. All (1 + 2 + 3)	138,975	106.1	147,453	+11,315	+7.7
Thursday to Sunday	1. Northern	108,697	106.7	115,980	-12,428	-10.7
	2. Motorway	119,746	100.5	120,345	+36,096	+30.0
	3. Southern	39,141	102.0	39,924	-9,194	-23.0
	4. 2 + 3	158,887	100.9	160,317	+26,854	+16.8
	5. All (1 + 2 + 3)	267,584	103.2	276,147	+14,576	+5.3

whole screen line into a number of corridors. The roads seem to fall naturally into the following groups:

1. Northern corridor—A59, A65, A629;
2. M62 corridor—A646, A58, A672, M62, A640, A62; and
3. Southern corridor—A635, A6024, A628.

The results for this breakdown are given in Table 7, which shows that traffic growth in the immediate motorway corridor has been quite dramatic, namely an increase of over 30 percent between 1970 and 1972 for the whole survey period and an increase of over 45 percent on weekdays. Such results would appear at first to support the expectation of 30 percent for generated traffic. The roads covered by the original appraisal (as far as the trans-Pennine section is concerned) consisted of the motorway and southern corridors, and here the increases are not so substantial, the full survey period showing an increase of 18.9 percent and the weekday period an increase of 28.1 percent between 1970 and 1972. However, the corresponding figures for the screen line as a whole are 12.1 and 21.3. This would suggest that the overall impact of the M62 Motorway so far has been significant in abstracting traffic from along the length of the screen line, but not very significant in generating new traffic once secular growth is allowed for. The impact seems to be greater proportionately for weekdays than for the full survey period, perhaps suggesting that commercial vehicle and work or business trips may have been more affected than nonwork trips, 76 percent of which occur on Saturday and Sunday.

By making allowance for secular growth, we can arrive at a crude estimate of completely new traffic generation. In Table 8 an attempt is made to use the traffic growth rates estimated between 1970 and 1971 (with some necessary adjustments) to predict 1972 flows without the M62 and, hence, to obtain a crude estimate of new generation. The results should, of course, be treated with reserve, since it would be preferable to estimate the secular growth rate in the area over a longer period. Nevertheless, the results are interesting as a preliminary indication. The estimate of generation is greatly affected by whether the northern corridor is included, though the results are broadly consistent between the weekday period and the full survey period. Thus, if the northern corridor is included, new generation is 5.3 and 7.7 percent, whereas, if it is excluded, new generation is 16.8 and 18.1 percent. Given the nature of the traffic in the northern corridor, it is reasonable to assume that there has been significant reassignment because of the M62 (this should emerge in more detailed traffic assignment work in progress), whereas exclusion of the northern corridor leaves secular growth in the other corridors at less than 1 percent. Although the 50-point census results for 1971 and 1972 are not yet available, the last results published in 1970 (27) indicate a growth rate of 7 percent per annum for nonurban roads over the previous decade. Although this high rate of growth eased off at the end of the decade, present conditions would suggest that a current growth rate of 3 to 4 percent is not unreasonable and is, moreover, consistent with the results for the screen line as a whole. Hence, the upper generation estimate is likely to be optimistic for both the reasons suggested, and a figure of around the lower estimate is preferable.

The above analysis is, of course, tentative and preliminary. The M62 has still to open completely while the effect of sections opened since spring 1972 is not included in the figures quoted. Data are being collated to monitor the changes between 1972 and 1973, and further data collection is scheduled from 1974 onward. Thus the results given may be subject to modification, both in light of further data collection and in the light of more refined and disaggregated analysis using the computer models mentioned. Nevertheless, the results gained so far provide the first consistent and complete picture of what is happening on the trans-Pennine screen line with the opening of the major link. The results indicate a moderate increase in traffic due to the M62, but on the other hand a substantial effect on the routing of existing traffic. Also they suggest that the present cautious treatment of generated traffic by the DOE is not inappropriate. Finally, the wide spatial extent of the observed effect strongly indicates the need to take a large survey area when the future impact of a proposed new link is assessed.

CONCLUSIONS

The area of interest in looking at the impact of the M62 Motorway has been discussed and some of the empirical work in progress has been reported. The amount of work still to be done is substantial and hence we are still to some extent in the early stages. Nevertheless, it is felt that some useful work has been completed.

The main priorities for future work are to carry through the cross-sectional investigation of the effect of accessibility on trip generation, and to analyze the nature of the changes in traffic patterns between 1970 and 1973, the latter year being the first for which a full "after" origin-destination study is available. In the meantime, the annual monitoring counts in the interim period 1970-1973 and thereafter provide and will provide a useful indication of year-to-year changes.

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GROWTH MANAGEMENT: A NEW FRAMEWORK FOR LAND USE AND TRANSPORTATION PLANNING

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This paper examines the role of the "growth management" framework being built at the local level and its effect on land use and transportation planning. Two considerations, fiscal and environmental, are basic to the position of local leaders who advocate managing or controlling growth along some rational lines. The key elements of growth management presented in this paper include tight controls over capital expenditures for water and sewer facilities and for transportation (both highways and transit); innovative revisions of zoning and subdivision regulations; coordinated administration of open space and park development programs; and initiation of new public mechanisms for joint public-private efforts in land development. Beyond these basic considerations, there are two other trends of particular significance. One is that the role of land use planning is taking on increasing significance as an integral part of the movement to manage growth. The other is that highway planning, which has dominated the transportation field, is losing its prominence in the local arena. This paper identifies three implications for transportation planning: Highway planning, as such, will come to have a new relationship to the local land use planning process; highway planning will be more fully integrated into a broader discipline of transportation planning based on multimodal movement of people and goods within growing urban areas; the linkage between transportation and land use planning will become a great deal closer in the future, with a set of relationships and feedbacks that will substantially cement the two disciplines.

•WE ARE in a period of profound transition on public policies affecting physical development in the United States. At all levels of government it is a time of groping and reappraisal.

In many respects, this reappraisal has been going on for several years. With the relative ineffectiveness of top-down approaches to the mounting problems of urban growth, a bipartisan effort was initiated in behalf of a "new federalism" pledged to shift responsibility and power for land use and development controls to the state and local levels. Before the guidelines for a new modus operandi could be fully worked out, however, crises in the environmental and energy fields have further complicated an already complex matrix of intergovernmental relationships.

This paper focuses on the functions of land use and transportation planning and on the new directions and imperatives posed for these functions by the events that are taking place. The basic theme of this paper is that a new "growth management" framework is being built at the local level that is decisively affecting both of these planning functions and their relationships to each other. New strategies are being called for in both land use and transportation planning, including strategies that can link them in a much closer liaison than existed before.

Following 3 decades of pell-mell growth, we are now witnessing a nationwide countermovement of public pressure that would check if not reverse past trends. It is no fly-by-night countermovement, although it has its share of kooks. At the middle of the spectrum of voices in the countermovement (and the middle is increasingly attracting

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the real leadership of the community) is an insistence on managing or controlling growth along some rational lines.

Fiscal and environmental considerations are basic to the position of the hard-core middle. The continued horizontal growth in suburban jurisdictions has put immense financial pressures on local governments and their constituents, e.g., overextended utility systems, overextended transportation networks, duplication of services and facilities, excess capacities in close-in neighborhoods, bypassing of developable and potentially taxable land, rising service costs and taxes, and other forms of public and private inefficiencies. From an environmental standpoint, the negative forces have been building up in terms of mounting traffic congestion, physical blight, overcrowding in some neighborhoods and abandonment in others, and pollution (or degradation) of land, air, and water resources.

It has been the latter factor, damage to the resource base, that has finally triggered the clamor for control and management. Planners with their warnings and even public administrators with their rising tax bills had not provided the public with enough incentives for change in development policy. It took the issue of environmental protection and the mechanisms afforded by the conservation effort to provide the necessary muscle.

The evidence of this new insistence on doing something about the growth problem is a good deal more fundamental even than indicated by the dozens of highway projects that have been stopped by citizen action through the courts. There is a widespread movement to fashion new master plans calling for ceilings on future growth and prescribing precise definitions of settlement patterns. The first outlines of judicial review are just becoming visible. It is clear that capricious and arbitrary no-growth policies will not stand up in the courts; however, long-range development plans that limit and control growth within the framework of reasonable use, conservation, and protection of resources (both fiscal and physical) will be supported. There is little doubt that some form of growth management will dominate public policy thinking in the decade ahead.

If indeed there is any question about this following the introduction of environmental considerations and controls, the energy crisis should dispel it. No one fully knows the implications of fuel shortages for patterns of physical development and human settlement, but the pressures can only be toward different growth and development patterns in the future. The caveats are beginning to surface: Both time and distance factors in transportation must be shortened; compactness in development patterns must be sought in place of sprawl; higher densities must be given higher priorities in urban design; and the long-deferred issue of public transit versus highways must be settled, despite what Detroit does in mass producing smaller automobiles. These at least are some preliminary indications. Energy shortages coupled with environmental, entrepreneurial, public finance, and quality-of-life considerations can only mean growing interest in new patterns of land development.

The stage is already set for new growth management policies, however chaotic the lines of policy-making and implementation now are. Federal land use and urban growth legislation is in the making in Washington; even as these bills are being debated, EPA directives are already prescribing new development controls, and there will soon be others from the Federal Energy Office that could have even more drastic effects. Practically every state is in the process of developing land use plans; many already have them in effect, and some with very tight development restrictions. (This puts the states in the land use business for the first time on any broad scale.) And, as indicated earlier, many local jurisdictions are putting together plans and fashioning implementation programs on management of growth.

THE GROWTH MANAGEMENT CONCEPT

It would appear that a new discipline of growth management is emerging in response to an accumulation of forces: the fiscal and environmental problems of sprawl so familiar to planners, the rising public concern about both the quality of life and the cost of living, and the new double-barreled crises of a mistreated ecology and a fuel shortage. The fact is that strong public efforts are being directed, primarily at the local level, toward pulling together the available tools of government to manage the level and distribution of physical growth.

For purposes of this paper, these efforts are called "growth management." These widespread efforts are mostly positive rather than negative (although going to court to stop expressways or getting injunctions against new private subdivisions seems to get the most publicity).

The trend is toward the kind of coordination between planning and public service delivery (i.e., implementation) that land use planners have been preaching for years. It is primarily a phenomenom affecting and related to local government, because that is where most of the implementation devices are and where there are pressure points that will respond to public opinion. There are currently few examples of a fully articulated growth management program, but two things are clear: that efforts to move in that direction are widespread and that attitudes toward planning and management of physical growth are changing rapidly.

What we are seeing in many situations is the promulgation of new master plans representing community growth objectives and the translation of these growth objectives into immediate implementation devices such as capital improvement budgets, street and highway construction plans, and zoning regulations. There is nothing new or unconventional about this approach except that it is finally being used. The more sophisticated efforts are moving toward an across-the-board integration of the key elements of growth management, which include

1. Tight controls (through PPBS techniques) over capital expenditures for water and sewer facilities and for transportation (both highways and transit),
2. Innovative revisions of zoning and subdivision regulations,
3. Coordinated administration of open space and park development programs, and
4. Initiation of new public mechanisms for joint public-private efforts in land development.

At whatever level of sophistication, these mounting waves of interest in growth management focus on the same thing: more effective control of settlement patterns. They want either to keep things the way they are or to control future growth in a way different from how it has been controlled. These efforts have another element in common; they work primarily within the framework of individual governmental jurisdictions where there are powers of implementation. This fact poses many problems, of course. It means competition and tension between different jurisdictions within any metropolitan region. It sets into motion forces that run counter to past efforts that have properly dealt with many of the basic problems on a regional basis, which is particularly true of transportation.

The potential intergovernmental confusion at the local level is compounded by developments at other levels of government. Through revenue sharing and other measures to improve local government capabilities, federal policy was directed toward a major shift in responsibility and power, but both the environmental and the energy crises have prompted new initiatives for direct federal action. Where the states' new head of steam in matters of land use and environmental control will carry them, nobody knows. And if the local jurisdictions decide on total and individual growth management, the role of regional bodies, both planning and operational, will be doubtful.

The fact remains, however, that the local trust toward growth management is under way. For both land use and transportation planning, and particularly for the relationship between the two, it is a new ball game, regardless of how the cookie crumbles.

At the risk of exaggeration and oversimplicity, a historical note might put the current situation in a clearer perspective. For nearly 3 decades, both land use and transportation planning have been concerned primarily with accommodating the suburban growth overspill that has taken place in America. Although both planning disciplines attempted to influence development along rational lines—with due regard for design, environmental, and efficiency considerations—the essential achievement was one of accommodating the torrent of growth that was generated. The most decisive policies of federal, state, and local governments were those that generated and supported the momentum of growth. One result was that most regional transportation and land use plans looked alike, with different types of growth neatly accommodated and tucked within a circular highway framework. This was only a minor product of the growth syndrome, however (although it suggests that planning did little to solve the real problem that the patterns of sprawl created). The real problems created by growth patterns are at the base of today's countermovement of public opinion and public policy: large-scale despoiling of physical resources, overextension of local government capabilities, economic and social decline of the central city, and threats to quality of life, which are now widely perceived.

Growth Management and Planning

Beyond these basic considerations, there are two other trends of particular significance. One is that the role of land use planning is taking on increasing significance as an integral part of the movement to manage growth. The other is that highway planning, which has dominated the transportation planning field, is losing its support in the local arena. These two countertrends will determine the kinds of relationships between land use and transportation planning in the days ahead.

The heightened role of land use planning has already been alluded to. After decades of only peripheral success in influencing settlement patterns, it appears that planning is being thrust into a key position within the growth management context. Regardless of how effective one feels that planning has been in the past, its new role can greatly increase its relevance to measures of implementation.

There are two reasons for this strengthened role. One is that the exercise of governmental powers to manage the level or distribution of growth, through capital expenditures, delivery of public services, control of land use, and so on, calls for a planning framework if it is to be effectively coordinated. As local governments respond to public opinion and to environmental and energy considerations (including federal directives), they are turning to the planners for guidelines on the basis of which public programs might be timed, budgeted, and administered to meet growth management objectives. The evidence that this is happening throughout the country is widespread.

The other reason, as noted earlier, is that the courts are holding that growth management must proceed on the basis of a reasonable plan. It is not within the power of local governments to peremptorily prohibit the inflow of people, goods, or investments. They can, however, take measures to manage and control growth in such a way that their environments are protected, their resources are conserved, their financial capacities are matched, and their character is preserved. Again, basic to such management efforts is a plan that relates goals and objectives to the resources at hand.

Changes in Planning

Even as land use plans take on greater importance in public policy-making, they will be subject to important changes. Long-range master plans must be recast to have direct relevance and usefulness to short-range programming and budgeting. In some jurisdictions, new staging plans are being devised to translate long-range objectives into short-range program recommendations. Regardless of the methods used, land use planning will be thrust much more actively into the governmental process.

A different situation is emerging for highway planning. For many years highway planning has enjoyed a high degree of independence and has exercised a high degree of initiative in providing the transportation response to urban growth. The large-scale availability of federal and state funds and the use of state personnel in major highway planning efforts have supported a largely independent approach to transportation planning in most urban areas. This is not to say, of course, that highway planning has not been integrated into local and regional land use planning processes; both legally and as a matter of practical cooperation, highway and land use planning have been closely interrelated. The fact remains, however, that the land use patterns of most urban areas (particularly the suburbs) have reflected the strong influence of highway patterns, which in turn have often reflected transportation rather than land use objectives.

In most cases, land use and transportation objectives have not been incompatible. Both sets of plans have had as their primary goal the accommodation of growth, and it has been the responsibility of the land use planner to be aware of the implications of the highways that are proposed. Again, however, joint plans have been predominantly highway-oriented for the obvious reason that highways have been the backbone of physical settlement patterns.

The strong influence of highway planning on development patterns, however, may now be waning. Dozens of highway projects have been stopped in the courts following citizen actions relating to environmental impact. There are uncompleted urban segments of the Interstate Highway System and other primary road networks throughout the country. Questions are now being raised by responsible citizens and public officials about the preponderant influence that highway planning may have played in the development process in the past. The new concept of growth management puts primary emphasis on determining optimum patterns as well as levels of growth; then transportation planning can provide one of the major tools for achieving the land use objectives. Highway plans that have been projected in many urban areas are no longer being accepted as givens but are being subjected to reexamination in light of new values and priorities of public policy.

In theory, of course, this has always been the joint approach of land use and transportation planning. It has rarely been brought into sharp focus, however, because of the overwhelming momentum of growth pressures that forced primary attention on accommodating the growth syndrome. The turn now is toward managing and controlling growth, not simply accommodating it. The efforts of local governments to rethink the development process is being matched by innovative approaches at the state level that point in the same direction—in some cases involving direct intervention in the local development process. Environmental and energy imperatives are also interjecting the federal government into the process, as already noted.

There are three obvious implications for transportation planning:

1. Highway planning, as such, will come to have a new relationship to the local land use planning process;
2. Highway planning will be more fully integrated into a broader discipline of transportation planning that relates to multimodal movement of people and goods within the growing urban areas; and
3. The linkage between transportation and land use planning will become a great deal closer in the future, with relationships and feedbacks that will substantially cement the two disciplines.

It is only through the effective wedding of these two disciplines that the objectives of growth management can be achieved, of course. Along with the availability of water and sewerage, transportation is the most decisive determinant of the human settlement pattern. If new and more efficient patterns of development are sought, their realization will depend on how well transportation facilities accommodate their requirements. New definitions of economic viability might have to be applied to the transportation systems under consideration; new technologies might have to be explored more vigorously if transportation systems are to serve new patterns of development. In any event, effective land use planning cannot proceed without effective transportation planning involving rapid transit, bus systems and other movers of people and goods in addition to automobiles.

Problems and Issues Ahead

The foregoing has dealt primarily with political and institutional changes that are taking place in response to changing problems and conditions. The transition taking place in public policy has been a long time in the making, but it also reflects crises that have triggered governmental responses not foreseen a few years ago.

There should be no doubt that urban America faces continued heavy growth pressures over the next 2 decades, despite all of the talk about zero population growth and the facts about the falling birthrate. There will be continued pressures to develop or redevelop lands. These pressures will reflect shifts in the location of people, businesses, functions, activities, and institutions and responses of government to meet the demands generated thereby.

Even at today's relatively low birthrate, the momentum of growth will call for substantial population increases for another 30 or 40 years. The household formation rate is still close to its all-time peak. Although rural-urban migration is off sharply from what it was in the first two postwar decades, it is still under way; there are also continued shifts of population and plants between and among metropolitan areas.

DEVELOPMENT OF CRITERIA FOR SCENIC ROADS

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This paper discusses the development of criteria used to determine highway improvement programs for three corridors through the Upper Great Lakes region of Michigan, Minnesota, and Wisconsin. These improvements would provide safe, efficient travel and foster new economic growth. One objective of the study was that the findings be applicable to future planning and development of comparable highway corridors in the region. Inasmuch as the tourism and recreation industry and scenic quality of the area held the greatest potentials for such growth, it was necessary to develop a procedure for comparative evaluation of scenic values. The aspects of the study included definition of operating speed as related to functional and scenic criteria; development of new design-hour and traffic service level criteria for planning highway improvements in rural recreation regions; and development of a method for comparing scenic values in the planning and design of scenic routes. The scenic evaluation feature uses a point system to assist in selecting an alignment that takes advantage of the best scenic potential. A table relating to traffic service function and to scenic viewing is presented. The route selection procedure is outlined in a flow chart indicating the elements of scenic inventory and evaluation plus the other considerations normally used in highway planning.

• THE Public Works and Economic Development Act of 1965 directed the formulation of plans and programs to revitalize the lagging economy of the northern portions of Michigan, Minnesota, and Wisconsin and, toward that end, established the Upper Great Lakes Regional Commission.

The Commission, proceeding in joint agreement with the highway departments of Minnesota and Michigan and the transportation department of Wisconsin, decided that the greatest potential for developing and expanding the economy lay in making the region more accessible. Consequently, further studies were centered around the common theme of fostering economic growth within the Upper Great Lakes region through an expanded and improved highway program. The tourism and recreation industry and the scenic quality of the region were immediately seen as the most promising sources of economic growth.

In July 1970, we began a multidisciplinary study to determine the most suitable types of highway improvements to safely and efficiently carry traffic and stimulate new economic activity within the region.

SELECTION OF CORRIDOR LOCATIONS

Three highway corridors, one in each state, were selected by the Joint Highway Planning Staff as case studies because of their immediate need for improvement and because they were representative of corridors throughout the region. An important objective was that the findings and recommendations be applicable to the planning and development of comparable highway corridors throughout the Upper Great Lakes region.

Locations of the three highway corridors selected for study were as follows (Fig. 1).

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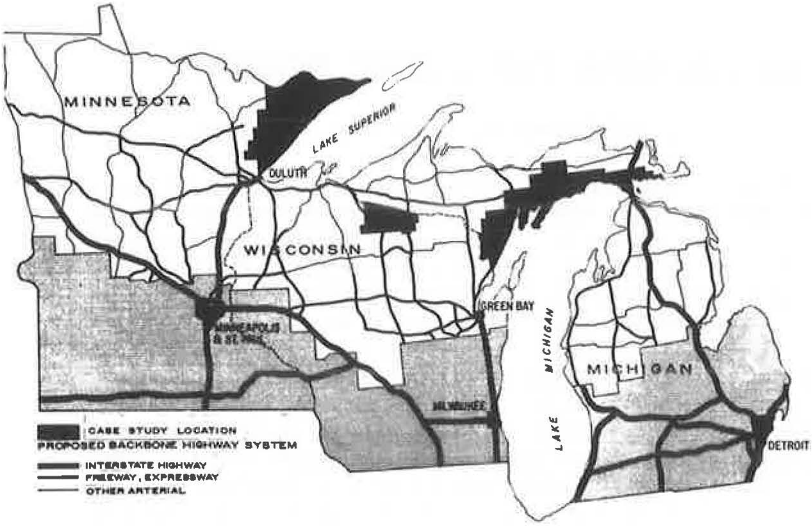
Figure 1. Upper Great Lakes region.



Wisconsin—A Scenic Road Planning and Design Study

The 50-mile corridor formed by Vilas County trunk highways extending between US-51 near Woodruff and US-45 at Land O'Lakes was selected as a typical scenic route through an area of intensive recreational activity. This corridor is purely a scenic, pleasurable route of collector-level status and has no high-mobility traffic demands. Moreover, it is a scenic route to a major regional attraction—the Sylvania recreation area in Ottawa National Forest.

Study of this route demonstrates the application of scenic route planning and design standards, guidelines, and criteria developed under the overall planning program. Specific recommendations were made for an optimum scenic route through the corridor.

Minnesota—Compatibility of Leisure and High-Mobility Traffic in a Scenic Corridor

The US-61 northshore corridor from Duluth to the Canadian border was selected as representative of a high-mobility "backbone" highway through an area of outstanding scenic quality (along Lake Superior).

This study involved an assessment of the compatibility of casual pleasure or scenic driving with high-mobility travel and a determination of the types of improvements required to serve both types of traffic demand.

Michigan—Implications of Improved Backbone Highway Service on a Developed Corridor

The corridor formed by US-2 and Mich-35 extending along Lake Michigan from the Mackinac Bridge to Menominee on the Upper Peninsula was selected as representative of a high-mobility "backbone" highway serving medium-sized urban concentrations and having a well-developed local tourist economy.

This study concentrated on the types of improvements required to serve high-mobility demands and promote economic growth.

CHARACTERISTICS OF THE SCENIC ROUTE

Every road should take maximum advantage, consistent with traffic and safety needs, of the scenic qualities of its environment. Every road serves a function of point-to-point travel; roads passing through corridors containing outstanding scenic features (mountain or desert scenes, sweeping vistas, bodies of water, forests) are primarily scenic. The significant features of scenic roads relating to quality, variety, compatibility and other elements are as follows:

1. Quality—the scenic, historic, or cultural character of the highway corridor should have a quality that merits state or national recognition or should be of sufficient interest to be a destination for recreational purposes;
2. Variety—the terrain and land use along the highway should be varying and differ from those along other routes in the state so that a balance in scenic route types is provided; and
3. Compatibility—the highway should have a geometric design that fosters graceful, ground-fitting horizontal or vertical alignment, appropriate curves, and striking vistas and should accommodate the anticipated volume of traffic without undue hazard to highway users.

Any route, regardless of functional level, can be scenic. High-mobility routes can meet the criteria for scenic routes, e.g., the Minnesota US-61 corridor. Moreover, all highways should be developed along scenic road design principles to maximize the potential for a pleasant driving experience, even though the areas through which they pass may be quite average in visual quality.

Areas of attractive scenery normally exist in random patterns, which makes it difficult to predict whether a loop or linear road system is more appropriate in a given situation. Most of the roads proposed by the states for inclusion in a scenic highway system are parts of existing highway networks, making combinations of linear and loop routes possible in certain instances. This is particularly true in the Wisconsin area, where numerous intersecting routes form a linear-loop system. In the Minnesota study area, however, proposed scenic routes are primarily linear as a result of development patterns and topography.

If the distribution of scenic features or obstacles in the terrain does not permit the development of a scenic loop system or if the scenery is more suited to viewing at higher speeds, then a linear route, possibly combined with a high collector- or arterial-level traffic service, could be developed. If roads of this category pass near areas with high scenic appeal to tourists, it may be desirable to develop a lower speed loop to permit access to those areas. The two large peninsulas that form Big Bay de Noc and Little Bay de Noc on the southern shore of Michigan's Upper Peninsula provide excellent examples of areas in which a looped route might be used to advantage.

The lengths of a scenic drive are limited only by the availability of scenery and the amount of interest it evokes from the traveler. The interest varies with the individual and is the result of such factors as subject matter, age, weather conditions, physical limitations, and the mental attitude of the viewer.

It is probably not important to be concerned about an ideal length when linear roads are being considered. Such roads normally are parts of longer routes. Developing the scenic appeal of sections of such routes would not be detrimental to overall function, since the recommended design procedures ensure compatibility.

Length criteria are more applicable to the loop type of road, where more control can be exercised. Even with loop roads, however, the length often will be affected by such things as the distance from a particular site or area to the nearest point of access, the topographic limitations of the area, or the need to provide for limited land service in addition to scenic viewing.

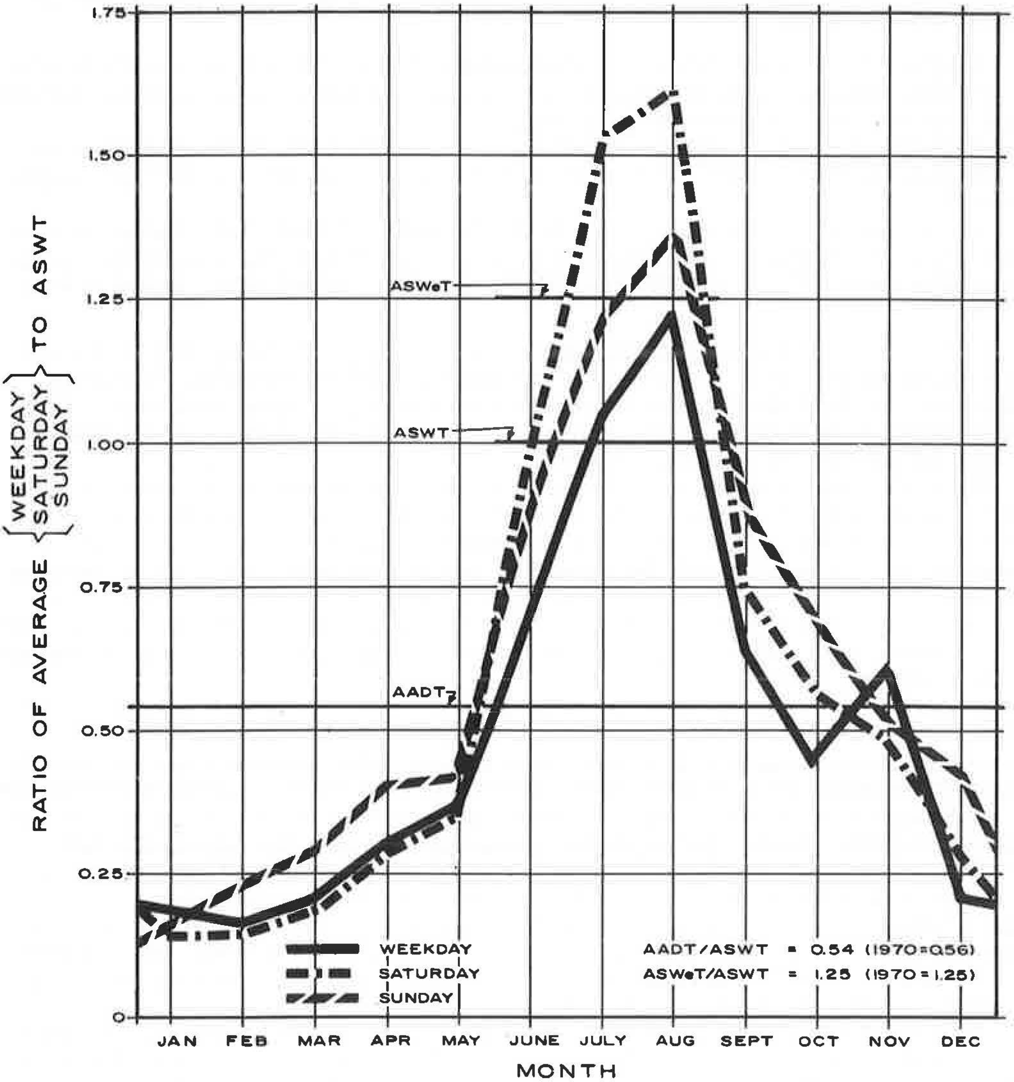
Although it is not uncommon for a person to travel hundreds of miles on a pleasure ride, figures from a national study indicate that 61 percent of all pleasure rides range from 5 to 30 miles in length. This suggests that a loop road provided solely for scenic viewing should average about 20 miles in length or should have exits to arterial highways at about 20-mile intervals.

TRAFFIC EVALUATION

Demand Analysis

Activity and travel patterns in any study area generally are investigated in terms of

Figure 2. 1968 monthly traffic distribution for US-2 near Brevort, Michigan.



average conditions, including trip generation for the functional planning of highway facilities. The common unit of measure for identifying and projecting the demand for highway facilities is annual average daily traffic volume. Average daily traffic characteristics provide the basis for relating existing and projected land use activities to the demand for the basic highway network. Average daily traffic volumes also provide the economic justification for the facility.

In the three study areas, average traffic conditions during the summer tourist season were considered a more suitable indicator of basic highway needs; therefore, average summer weekday traffic (ASWT) was used as the basic measure of demand. Where activity conditions vary, alternative measures may be appropriate. For example, average summer weekend traffic may be more suitable for highway studies in tourist or scenic areas close to metropolitan centers.

Design Service Levels

Level of service, a concept developed to provide a qualitative measure of operating conditions, is based on travel speed characteristics and volume-capacity relations associated with specified operating conditions. Speed and volume provide an indication of overall performance on a roadway, whereas capacity and operating conditions provide an indication of traffic densities and freedom to maneuver.

Design criteria appropriate to most rural arterials and generally accepted for design by the three states and the Federal Highway Administration provide operating conditions at level of service B during the 30th highest hourly volume of the year.

Level of service B, as defined in the Highway Capacity Manual (6), represents freedom for the driver to maneuver and to maintain desired travel speeds. For two-lane and multilane rural arterials, service level B is associated with minimum operating speeds of 50 and 55 mph respectively under design-hour flow conditions.

Investigations have led to the general acceptance of the 30th highest hour as the critical period for design; however, high seasonal fluctuations, as shown by the monthly traffic distribution for US-2 near Brevort, Michigan (Fig. 2), require special attention in areas of heavy recreational travel. Summer volumes and, in particular, peak-hour conditions far exceed off-season demands.

A review of this monthly traffic distribution chart indicates that a facility design under conventional procedures would be significantly underutilized during most of the year. For these studies, however, considerable thought was given to selection of design criteria that would reflect the objective of promoting recreational development by ensuring suitable operating conditions during periods of sustained tourist demand. Otherwise, tourism-recreation travel will be discouraged.

Combined recreational development objectives and investigation of traffic fluctuations led to the selection of dual design criteria for the highway planning studies in the Michigan and Minnesota "backbone" corridors. Instead of selecting a single design-hour volume (e.g., 30HV) as one design criterion, we chose a criterion based on a peak period to represent the critical tourist demand.

Summer weekday traffic patterns (Fig. 3) for the three survey locations along the Minnesota corridor provided a basis for selecting this additional criterion. Peak demands remain relatively stable for 4 to 6 hours during the midday and afternoon, with 8 to 9 percent of the daily demand occurring during each of the hours. This sustained demand condition was repeated on the average for nearly 400 weekday hours of the summer tourist season. Therefore, maintaining desirable operating levels during these hours, including level of service B for rural arterial highways, was considered essential to the economic well-being of the specific communities and to the region in general. The design must ensure that reduced, yet tolerable, operating conditions are maintained during the highest overall peak periods occurring on summer weekends or in special periods of peak off-season activity, such as the opening days of the hunting and fishing seasons. Therefore, 30HV demands were analyzed on the basis of a tolerable operating condition at service level C for rural arterial highways and found adequate.

Projected operating conditions can thus be identified and compared with selected minimum levels, both for the hours of highest overall demand and for those of the pe-

Figure 3. Hourly distribution of summer weekday traffic for the Minnesota study corridor.

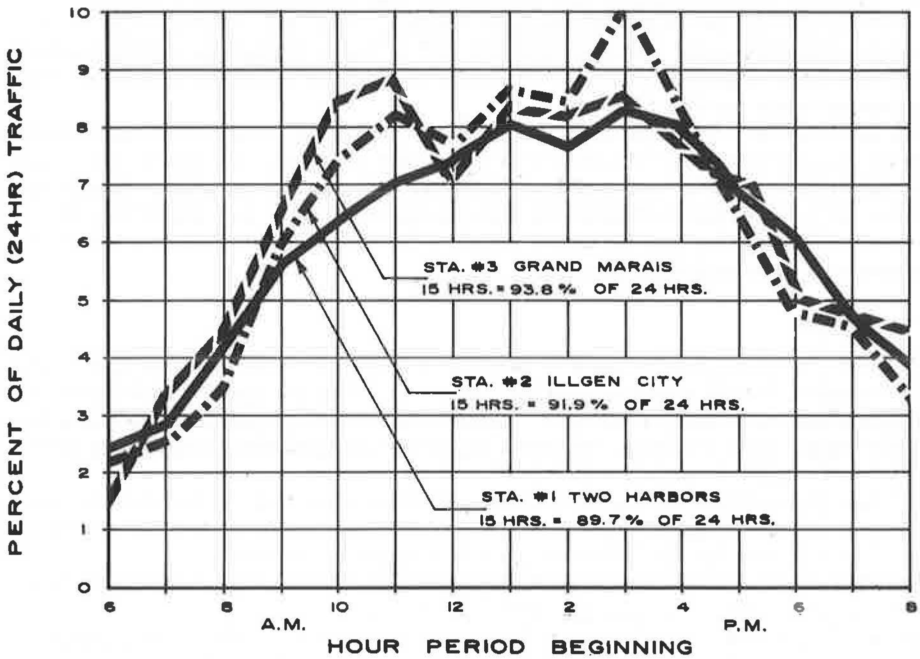
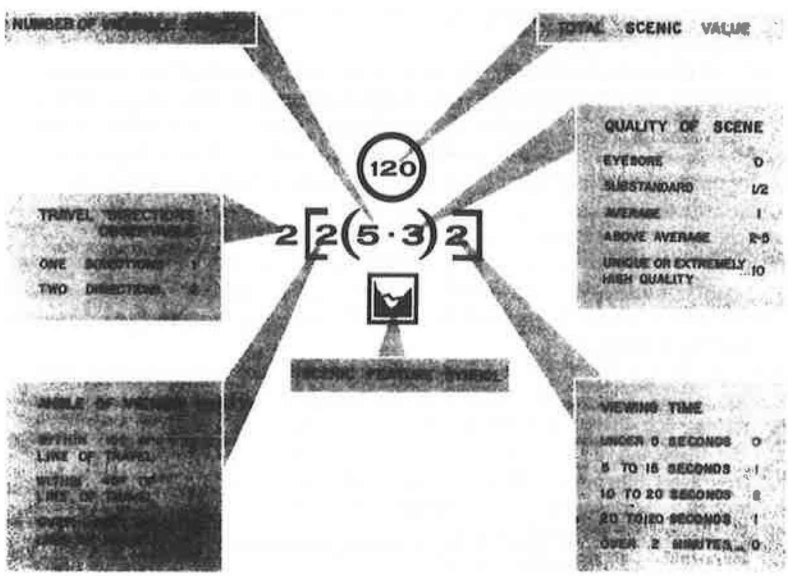


Figure 4. Scenic feature evaluation.



riod critical to the area involved. In addition, the necessary traffic data inputs are normally readily available or easily collected, and the basic analytic procedures familiar to highway and traffic engineers are maintained.

The same dual-criterion principle can be applied easily to areas characterized by heavy weekend recreation or scenic use, such as a Saturday or Sunday afternoon peak period of significance.

On urban connecting links of the rural arterials, where level of service C is commonly accepted as appropriate for 30HV operating conditions, this level was used to evaluate the sustained ASWT peak, with level of service D accepted as appropriate for 30HV operation. For example, where expressway design standards were considered necessary in rural areas, extension of the expressway design to the connecting link through or around urban areas was considered essential, even though minimum operating service level criteria could be met under requirements for an urban arterial of nonexpressway standards.

IDENTIFICATION AND EVALUATION OF SCENIC FEATURES

The technique for evaluation of scenic features was developed in response to the needs of the Minnesota and Wisconsin studies but has universal application in scenic route planning. All scenes must be compared to that that is typical of the region, whether natural or man-made, rather than to an arbitrary subjective standard. This technique assists the designer in locating the roads by indicating how he may take maximum advantage of the scenic values determined.

Initially, we conducted field and map reconnaissance of the study areas to determine their major scenic features. This macroscale analysis was used to determine alternative route locations. Scenic features of the area were then evaluated in greater detail in terms of a number of factors expressing the visual quality of the feature in itself and as viewed from alternative alignments.

Scenic Inventory Procedure

Once the most promising routes were determined, an inventory of scenic features within these corridors was made. The ideal procedure is to locate and evaluate all scenic features in the field. Unfortunately, conditions such as topography, tree cover, legal restrictions, project budget, and the like restrict the amount of information that can be obtained in this manner. But much information can be gathered through other means. Many topographic features—hills, streams, lakes, buildings—can be identified from detailed maps and vertical or oblique aerial photographs. An on-site inspection supplements the map information.

Evaluation Technique

Each scene is evaluated initially according to a set of established criteria. The method or technique of representing this evaluation is shown in Figure 4. A relative rating of all scenes in a particular corridor is established. An alignment that makes use of the best scenes available is then selected. The alignment scoring the highest points on a per-mile basis is generally considered the most appropriate scenic route through the corridor.

Factors to be considered in the evaluation of scenic quality are number of objects, quality of scene, angle of viewing, time in view, and travel directions.

All scenery is composed of recognizable objects or compositions that occur either singly or in groups. A single object is one that can be assimilated visually without a change in eye position. A picturesque tree in an open field, a solitary mountain, or a tall building are examples.

A more complex scene, such as a lake with cliffs and wooded hills in the background, a sandy beach, and groups of lakeside cottages, contains three to five objects, depending on their visual relations as seen from the viewing position. A complex scene such as this is usually considered by the average viewer to be more attractive, which leads to the conclusion that, the greater the number is of interesting objects that can be viewed, the greater the value of the scene is.

A second factor to be considered is the visual quality of scene. To evaluate this, the designer must be capable of determining how attractive an object is through its conformance to basic art principles (form, balance, harmony, etc.) and how well an object, as compared to other objects located within the region, satisfies these principles. Also to be considered in judging the quality of a scene is the frequency with which a given type of object occurs within the region. If it occurs occasionally, it is of more interest to the viewer than if it occurs frequently. When either the object is an outstanding example of its kind or its occurrence is so seldom that it is unique, it is of even higher scenic value.

Upon completion of this inventory and evaluation, the information is coded and the visual quality of scene is measured according to the numerical values shown in Figure 4. If the rating of the number of viewable objects in a scene and the quality of that scene are low, then it is discarded.

Factors other than the intrinsic features of a scene that enter into the scenic evaluation of a route are (a) direction from which it can be observed, (b) angle of viewing relative to the direction of travel, and (c) time in view. Such evaluation is made for each scenic feature relative to each alternative route. During the process, typical views of the area's dominant scenery are dropped from consideration but are noted as scenic augmentation of the road.

Many valuable scenes, such as panoramas, are viewable from one direction only. The design of the road, however, frequently determines whether other objects such as lakes, a village, or even a single tree may be observed from one or both directions. If the scenic rhythm and pattern permit, twice the scenic value may be obtained for a given route by adjusting the alignment to permit views of its scenic features from both directions of travel.

The angle of viewing factor represents the opportunity the average traveler will have to observe a scene under normal conditions and is based on the lateral field of vision. The highest value is given to those scenes that can be viewed without distracting the driver's vision from the road. The next lower rating is given to scenes that require the driver to turn his line of vision but still allow him to be aware of road conditions through peripheral vision.

When the viewing angle is so great that the driver's attention is completely diverted from the road, a value of zero is assigned, the scene is no longer considered in the roadway alignment, and it is considered, if suitable, as a scenic stop.

The values shown in Figure 3 are suitable for use at travel speeds of 40 to 60 mph. These should be adjusted for use at other speeds. Viewing time in Figure 4 indicates the period during which the scene might be viewed and the effect it might have on the viewer's attitude toward the scene. Unfortunately, little research has been conducted to determine how long a person will view scenic features, which depends on differences in the subject and quality of scenes and on the individual's reactions to varying light levels, atmospheric conditions, interests, etc.

Some laboratory tests have indicated that under controlled conditions the average person will view a design for slightly less than 5 seconds. Other observations indicate that the length of scenes in television and movie productions generally ranges from 2 to 10 seconds. Although these are not conclusive, they do indicate that the average person will view a scene for only a limited period of time before shifting his attention. Based on these conditions, values have been assigned to the average traveler's viewing time. The evaluator is required to exercise judgment when applying the factors to compensate for the scene's complexity and the frequency with which the scene occurs in the region.

The highest rating was given to a 10- to 20-second period. This time will permit the typical traveler to locate the scene, to view its various components to his satisfaction, and to have it leave his field of vision before becoming monotonous. Lower values were assigned to periods of 5 to 15 seconds and 20 to 120 seconds, thereby recognizing that insufficient time could cause the viewer to miss a portion of the scene or that excessive time could cause boredom or deprive him of interest created by other scenes. No values were assigned to periods of under 5 seconds because the viewer probably would be unable to locate or assimilate any but the most simple scenes. Also, it was

Figure 5. Route study plan for Wisconsin.

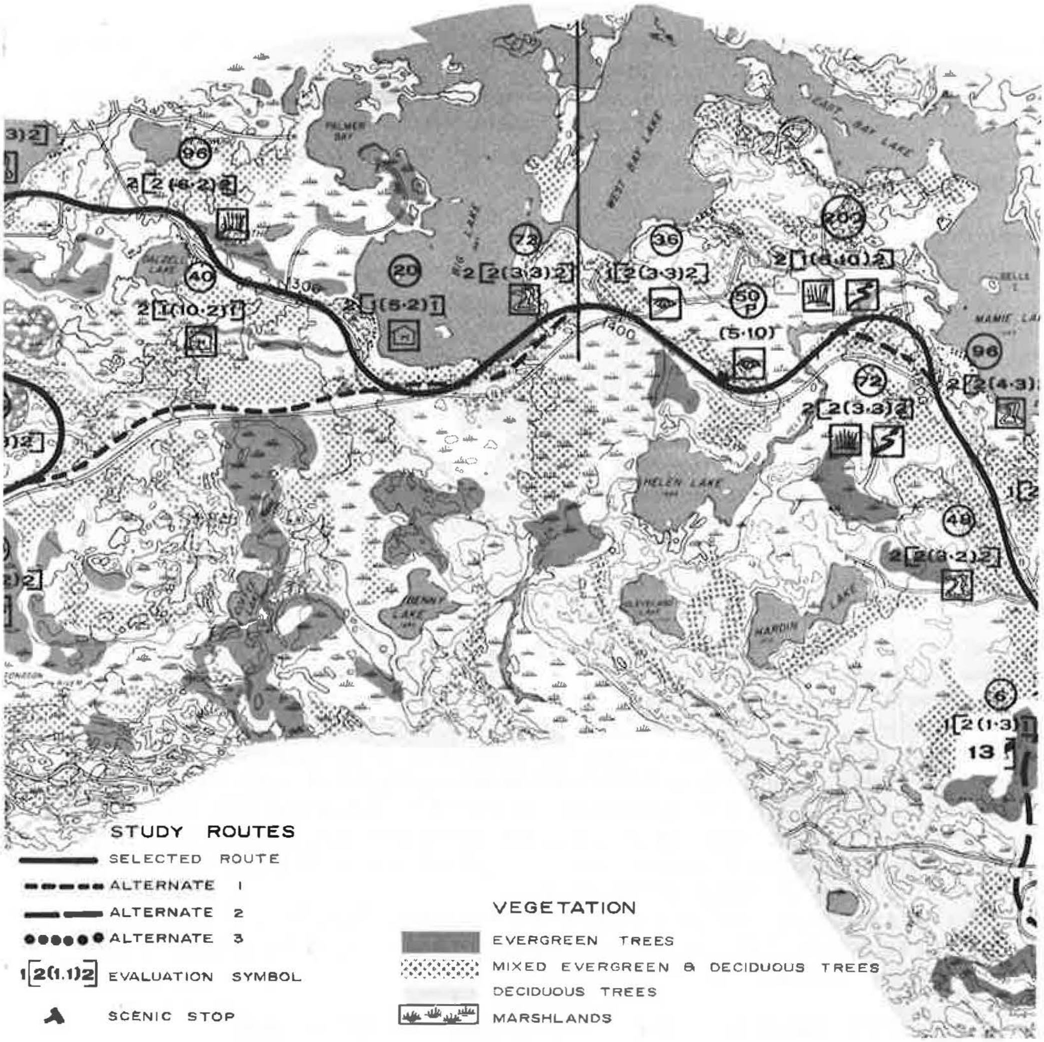
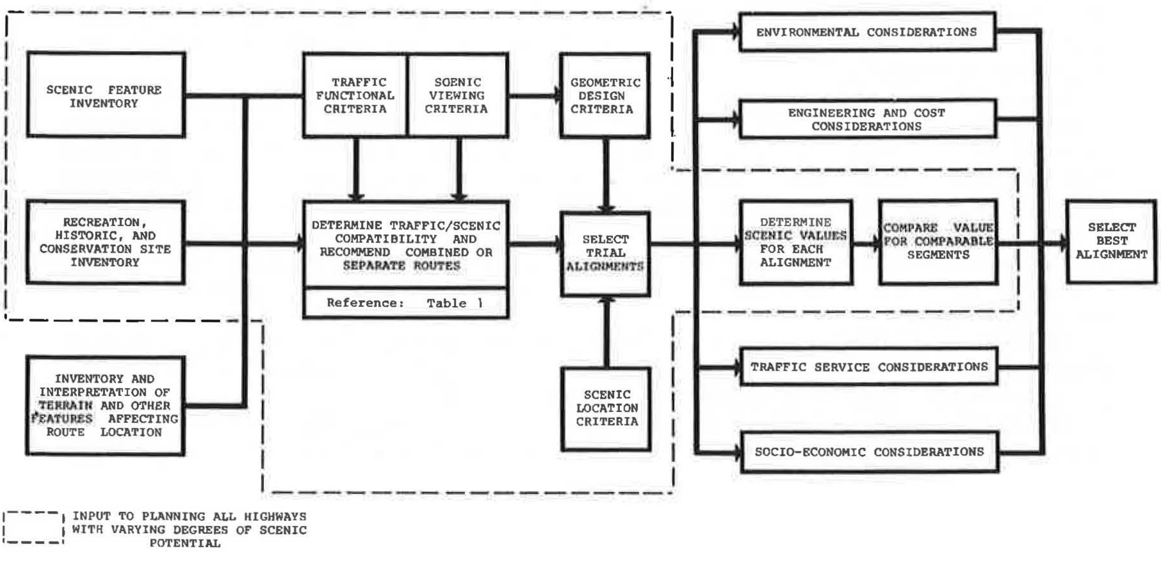


Figure 6. Selection procedure for scenic route.



felt that periods in excess of 2 minutes would produce reactions similar to those resulting from the typical scenery of the region.

Numerical ratings established for each of these factors are added to the identification and evaluation symbol previously plotted on the study map. All factors are then multiplied together to determine the total numerical rating for each scene, referred to as the total scenic value.

Stop Scene Determination

Stop scenes are those scenic features that cannot be viewed safely while the traveler is in motion because of (a) engineering or other considerations that prevent proper relation to the line of sight, (b) screening by an object that cannot be removed, or (c) insufficient viewing time. Where there is no practical solution to make views of features of above-average or unique quality available to vehicles in motion, stationary viewing locations (overlooks, rest areas, and the like) should be provided. Such scenic stops will bring out the full value of a scene. Features of lesser quality should be screened from view to prevent possible driver distraction.

In evaluation of stop scenes, the factors applying to motion scenes drop out, and the scene is evaluated only on its basic indexes, i.e., number of viewable objects and rated quality.

FINAL ROUTE EVALUATION

After scenic features were evaluated for each trial alignment, including motion and stop scenes, corresponding route segments were compared on a per-mile, point value basis. The final alignments should normally follow the highest averages as determined and developed within the context of engineering and traffic service feasibility.

The Wisconsin study (Fig. 5) illustrates the application of the procedure and shows alternative alignments, scenic feature evaluations associated with each, and a selected composite route resulting from the technique. It should be noted that this scenic route evaluation and selection procedure is designed for evaluating alternative routes within one corridor. The technique, however, can be adapted to evaluating alternative scenic corridors with the same or comparable termini.

Figure 6 shows the scenic inventory and evaluation described, the inputs affecting the function and selection of purely scenic routes, and the input of the scenic evaluation process to other highways having scenic potential.

SCENIC VIEWING-OPERATING SPEED RELATIONSHIPS

Highway travel speed determines the type of scenery that can be viewed. Thus, in the initial stages of route planning there is a need to determine whether scenic qualities of a route corridor can be viewed effectively at the desired level of traffic service. Frequently, there is no conflict, but occasionally the level of service desired is such that the scenic features will be barely viewable or even not seen when the necessary alignment is provided.

Functional criteria and scenic criteria are given in Tables 1 and 2; together, these tables provide a rapid means for determining the basic compatibility or incompatibility of these two elements in a given corridor. For example, a scenic inventory revealing that the predominant scenery within the corridor consists of small forms containing integral detail and traffic service requirements demanding a major arterial improvement are two basically incompatible elements. This does not mean, however, that a road using the scenic features of the area is out of the question; rather, it indicates that certain measures will have to be taken during the planning and design process to create compatibility.

Of course, we realize that, when the required service level lies below the level of dominant scenery, the scenic features theoretically can be developed to their fullest potential without adversely affecting the traffic function.

The first use of the table, then, is to determine the compatibility of basic traffic service and scenic viewing needs. If initial evaluations reveal a basic incompatibility

Table 1. Functional traffic criteria.

Functional Designation	Service Description	Average Trip Length (miles)	AADT	Desirable Minimum Rural Operating Speed (mph)
Major arterials	Interstate, interregional, and intraregional travel corridors generally connecting urban areas and forming a continuous system network	>50	>2,000	55[a] 50[b]
Minor arterials	Interarea travel corridors generally connecting cities and villages to supplement the major arterial system	15 to 100	1,000 to 3,500	50
High collectors	Provides intraarea travel, access to local areas, and feeders to the arterial system connecting communities generally in the 200 to 500 population range	10 to 75	<2,500	45
Low collectors	Provides intraarea travel, with an emphasis on land access; connects communities not otherwise served by high-level route	<30	<500	20
Local	Provides land access and local traffic service	<15	<500	20
Waysides and scenic stops	Provides access to rest area and picnic facilities, historic sites, overlooks, and so on	—	—	—

[a]Freeway expressway. [b]Other.

Table 2. Scenic viewing criteria.

Functional Designation	Desirable Operating Speed (mph)	View Angle From Line of Travel (deg) Desired	View Angle From Line of Travel (deg) Maximum	Minimum Attracting Distance (ft)	Time Interval Between Scenes (min)	Scene Characteristics	Examples
Major arterials	>60	10	20	900	2 to 5	Large mass forms, depend on outline shape	Lakes, rivers, tree groups, mountains, panoramas, large architecture
Minor arterials, High collectors, Low collectors	40 to 60	15	25	750	2 to 5	Smaller mass forms, may contain simple integral detail	Brooks, streams, specimen trees
Local	20 to 40	25	50	450	1 to 3	Forms of minor complexity whose attractiveness rely on surface texture, variations in outline; complex, contained detail	Residential properties, commemorative sculpture, roadside features
Waysides and scenic stops	—[a]	180[b]		Any distance	—[a]	High-quality views: insufficient viewing time or incomprehensible detail at any travel speed; alignment cannot be adjusted to permit proper viewing angle; view obstructed by immovable object	Large panoramas to detailed roadside features
						Special views: unique features whose setting would be destroyed by extensive construction	Wildlife, wild flowers, geologic or historic areas
						Activity areas not familiar to average visitor	Manufacturing, canal locks

[a]Not applicable. [b]If attention is directed to scene, 360 deg possible.

Table 3. Scenic improvements.

Viewing Time Description	Viewing Time Seconds	Method of Improvement
Less than ideal	<5	Above-average and high-quality scenes: Increase viewing time where possible by removing obstructions or modifying alignment; screen if scene is distracting and above steps are unfeasible; provide roadside scenic stop
		Typical or frequently occurring scenes: Generally no action; screen if distracting
Ideal	5 to 20	Provide acceptable viewing angle[a]; investigate use of quality improvements such as frame or background or an interruption to view; determine desirability of providing subsequent scenic stop
Greater than desirable	20 to 120[b]	Screen portion of scene to create additional views from varying viewing points; adjust alignments to reduce viewing time; alter shape of tree line; emphasize visual rhythm
	>120[c]	Consider alignment variations to alter viewing angles in addition to actions outlined above

[a]<40 mph, 0 to 25 deg desirable, 50 deg maximum; 40 to 60 mph, 0 to 15 deg desirable, 25 deg maximum; >60 mph, 0 to 10 deg desirable, 20 deg maximum.
[b]Or segments of neutral mass scenery.
[c]Or neutral mass scenery.

between functional and scenic requirements, several courses of action are open. One alternative, and the least desirable, is to ignore either the scenic or the functional requirements. A second option is to provide separate routes for each function; but, unless one route already exists, preferably the route with the greater scenic qualities, this may be an expensive solution and is justified only in locations of many complex or detailed scenes.

The most practical alternative is to design a road that satisfies the traffic requirements and at the same time offers to its travelers scenes that are compatible with the traffic function, i.e., providing scenic stops for viewing those scenes that are otherwise too complex to view at the desired travel speeds.

The selection of an alternative must be based on an in-depth study of all factors pertinent to the specific case under consideration, including (a) the potential economic impact of each of the alternatives, (b) topographic constraints that may favor or preclude one or more of the alternatives, (c) the general scenic quality of the particular route and its importance to an overall state scenic highways program, and (d) the availability of funds and the effect that each of the alternatives may have on eligibility for such funds.

The Minnesota case study illustrates how such factors were analyzed. Even though traffic and scenic requirements were found to be compatible along the US-61 corridor, the method of analysis used was applicable as well to the situation in which a basic incompatibility exists.

Once a decision has been made, a three-step approach is followed to develop the scenic potentials of the selected corridor:

1. Develop those individual scenic attractions compatible with operating speed criteria through alignment location, clearing, and so on to obtain desirable viewing time, angle, and distance from the roadway.
2. Develop those scenic attractions that require provision of loop, spur, or overlook facilities, as appropriate.
3. Provide screening for those scenic features in step 2 that would remain viewable from the roadway.

Table 1 indicates the desirable operating speed, viewing angle, attracting distance, and time interval between views as applicable to specific types of scenery. These criteria are used in selecting an alignment that will take maximum advantage of the available scenery. This represents the second use of the table.

Vision Factors in Scenic Viewing

The level of scenic viewing is a function of the eye's ability to perceive the details of scenes and objects coming into view and passing by at various travel speeds. Several basic factors govern this function.

1. Horizontal field of vision narrows and the point of focus moves further ahead as travel speed increases.

Speed (mph)	Focal Point (ft)	Horizontal Field (deg)
25	600	100
45	1,200	65
60	1,800	40

2. Rapidly moving objects cannot be seen readily. Foreground objects begin to blur when travel speed is approximately numerically equal to distance between the object and vehicle, and foreground detail is lost when travel speed is approximately one-half the distance.
3. Line of sight seldom varies more than a few degrees from the direction of travel; therefore, features must fall within a horizontal field of vision centered on this line of sight if they are to be noticed.

In addition, the period of attention of the viewer will vary. Thus, different scenic characteristics become important as travel speeds vary. For a traveler to notice a scene, he must have sufficient time to become aware of its existence and to view it long enough to be satisfied with his reaction to its content. In general, as the complexity and detail of a scene increase, a longer period of time is required to fully assimilate the scene.

Scenic Viewing Criteria

Viewing angles given in Table 1 describe the desirable relationship between the object and the line of sight. If the object lies within the limits shown, then it can be observed within a normal horizontal field of vision at the given speed of travel.

The minimum attracting distance is the distance from the viewer to the object and should provide approximately 10 seconds of viewing time within the specified viewing angle at the given speed of travel. In practice, this must be checked carefully against possible viewing interference, particularly along curves of minimum design radius in areas where there may be visual obstructions such as embankments, buildings, and woodlands. Conversely, because the normal point of focus is approximately twice the minimum attracting distance and normal eye movements extend this even further, objects frequently can be seen for a much longer time in open areas and along less restrictive alignments. Under these circumstances there may be a need to limit the viewing time to avoid monotony.

The purpose of the time interval is to establish a suitable frequency that will prevent boredom and at the same time discourage the driver's tendency to slow down for frequent high-interest scenes. The mind must have an opportunity to rest between periods of high interest or excitement. The spacing or time interval between scenic features pertains only to those relatively high-quality scenes that can be observed while driving. Views from roadside turnouts and more typical examples of roadside rhythms, while still important in the overall design, should not be considered in spacing the main scenic views.

The desirable spacing of scenes varies with their quality level. As the scene generates more excitement, the spacing should increase if the travel speed is to be maintained. If the frequency of quality scenes exceeds that shown in the table, then either the level of traffic service should be modified or some of the scenes should be removed from the field of vision. This can be accomplished by modifying the alignment to change the viewing direction and by screening certain features to obtain proper spacing.

SCENE TREATMENT AND VARIATIONS

An important consideration in the visual design of the road is the relationship between objects of visual interest and the line of sight. The eye is known to move constantly in an elliptical pattern when observing most scenes. When traveling as either driver or passenger in an automobile, most people concentrate approximately two-thirds of their sightings on nearby objects that are located along the axis of travel. Other sightings are normally within 6 degrees of this axis and consist of more distant stationary scenes. The problem thus becomes one of permitting the traveler to become aware of a scene and to enjoy it without distracting him from his primary task of vehicle control or without allowing him to lose interest through overexposure.

To accomplish this, the view must be pointed toward the scene, or its value will be diminished or completely lost. Sweeping curves or straight segments wherein the scene is located very near the line of sight are most commonly used for this purpose.

The scene should be terminated within the specified time interval to prevent boredom and to provide a period of mental relaxation. Several techniques are available for accomplishing this: properly located screens of buildings, trees, or earth. The most useful method, however, is to turn the roadway to direct attention away from the scene. Table 3 gives methods of exploiting scenes at various viewing times.

When a scene is of high enough quality to distract the driver, viewing must be concluded before the driver enters a minimum curve. If the scene is located slightly to one side of the travel direction, the driver can view it and still divert his attention to the road before he enters the curve.

CONCLUSION

This initial development of criteria for scenic roads is a vital step in the planning and design of such roads. These techniques are a fresh approach that will supplement normal planning and design procedures.

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