VOL. 32, NO. 1

APRIL 1962

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

PUBLISHED BIMONTHLY BY THE BUREAU OF PUBLIC ROADS, U.S. DEPARTMENT OF COMMERCE, WASHINGTON

View of new location of Interstate Route 70 as it bypasses Idaho Springs, Colo., approximately 40 miles west of Denver.

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

Vol. 32, No. 1 *April 1962*

Published Bimonthly

Under the direction of E. A. Stromberg
Chief, Research Services Division

Muriel P. Worth, *Editor*

IN THIS ISSUE

Social Effects of Modern Highway Transportation, *by F. I. Thiel* 1

Estimated Travel by Motor Vehicles in 1960, *by T. S. Dickerson* 11

Advance Route-Turn Markers on City Streets, *by L. D. Powers* 12

A Preliminary Evaluation of Color Aerial Photography for Use in Materials Surveys, *by J. R. Chaves* 17

New Publications 10

TITLE SHEET, VOL. 31

The title sheet for vol. 31, Apr. 1960–Feb. 1962, of PUBLIC ROADS magazine is now available. This sheet contains a chronological list of article titles and an alphabetical list of authors' names. Copies of this title sheet can be obtained by a request to the editor of the magazine, Bureau of Public Roads, Washington 25, D.C.

U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

BUREAU OF PUBLIC ROADS
REX M. WHITTON, Administrator

THE BUREAU OF PUBLIC ROADS

WASHINGTON OFFICE
1717 H St. NW., Washington 25, D.C.

REGIONAL OFFICES

No. 1. 4 Normanskill Blvd., Delmar, N.Y.
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Puerto Rico.

No. 2. 74 West Washington St., Hagerstown, Md.
Delaware, District of Columbia, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia.

No. 3. 50 Seventh St. NE., Atlanta 23, Ga.
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee.

No. 4. South Chicago Post Office, Chicago 17, Ill.
Illinois, Indiana, Kentucky, Michigan, and Wisconsin.

No. 5. 4900 Oak St., Kansas City 12, Mo.
Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

No. 6. Post Office Box 12037, Ridglea Station, Fort Worth 16, Tex.
Arkansas, Louisiana, Oklahoma, and Texas.

No. 7. New Mint Bldg., San Francisco 2, Calif.
Arizona, California, Hawaii, and Nevada.

No. 8. 740 Morgan Bldg., Portland 5, Oreg.
Idaho, Montana, Oregon, and Washington.

No. 9. Denver Federal Center, Bldg. 40, Denver 25, Colo.
Colorado, New Mexico, Utah, and Wyoming.

No. 10. Post Office Box 1961, Juneau, Alaska.
Alaska.

No. 15. 450 W. Broad St., Falls Church, Va.
Eastern National Forests and Parks.

No. 19. Steinvorth Bldg., First Ave. and Calle 2, San Jose, Costa Rica.
Inter-American Highway: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

PUBLIC ROADS is sold by the Superintendent of Documents, Government Printing Office, Washington 25, D.C., at $1 per year (50 cents additional for foreign mailing) or 20 cents per single copy. Subscriptions are available for 1-, 2-, or 3-year periods. Free distribution is limited to public officials actually engaged in planning or constructing highways, and to instructors of highway engineering. There are no vacancies in the free list at present.

Use of funds for printing this publication has been approved by the Director of the Bureau of the Budget, March 6, 1961.

Social Effects of Modern Highway Transportation

BY THE HIGHWAY AND LAND ADMINISTRATION DIVISION
BUREAU OF PUBLIC ROADS

Reported [1] by FLOYD I. THIEL, Economist, Economic Impact Research Branch

This article focuses attention on some of the social effects and changes that have accrued from construction of modern highways. Knowledge of these social effects—both beneficial and undesirable—should be of assistance to those concerned with planning highways, especially during public hearings concerning the routes and the construction of the highways. It appears fundamental that the social effects attributed to previously constructed highways should be considered when a new highway or relocation of an existing highway is being planned.

The requirement for public hearings on route location is a recognition of the need for consideration of highway effects, social as well as economic. At such hearings, socio-economic questions may loom large; for example, the likely effect of a highway relocation on schools, local government services, and residential areas may be of great concern to those that will be affected.

This article contains a general discussion of the influences that modern highways and their construction have had upon life in the United States, including those on residences in urban and rural areas; population mobility and the resulting developments in education, recreation, public services, and certain voluntary associations; and the availability of services for a mobile public.

Introduction

THE WIDESPREAD social effects of highway transportation are everywhere apparent. In the United States there now are more automobiles than households, and more adults holding drivers' licenses than library cards (*1*).[2] But it is, of course, much easier to determine that highway transportation is having far-reaching social effects than it is to identify and measure these effects with any precision. Social effects may be regarded as those influences that change the relationship between people and social institutions such as the family, community, government, schools, churches, etc.

Information gathered during various highway impact studies and other pertinent material[3] has been used in this article to direct attention to certain social changes or trends that can be associated with, or attributed to, highway improvements. Although sociologists may attribute additional effects to highways, this article contains discussions primarily of the highways' effects on: (1) Suburban development, (2) population mobility, (3) residences, (4) relocation of residences, (5) employment conditions, (6) travel time, (7) public services, (8) certain voluntary associations, (9) rural areas, (10) recreation, and (11) drive-ins and mobile services. In some cases these changes or effects overlap.

Although information contained in this article is of a general nature and does not permit definite conclusions as to the effects of modern highways, it is believed that the pervasive role of modern highway transportation in urban, suburban, and rural living is undeniable. Though there may be some question as to whether improved highway transportation has been the cause or the effect of some of the changes referred to in this article, it is clear that life in the United States without modern highway transportation would be far different from what it is today.

Social Effects

An opportunity appears to exist for improvement of public relations for the highway builders through the development and dissemination of information concerning the social effects of highways. For a number of reasons, the public relations problems faced by highway builders are sometimes especially vexing. Those opposing or questioning highway projects are often more vocal than those supporting or indifferent to the projects. The negative effects of highway construction (dust, noise, inconvenience, etc.) may be apparent immediately, and the positive effects may be delayed so that the negative influence is often overemphasized. Furthermore, objective information as to the social and economic effects of highway projects often is not available or is not disseminated to the public. As a researcher in Kansas put it recently, costs are largely in the present, and they tend to be relatively definite and measurable, while benefits are only future anticipations and tend to be relatively diffuse and unmeasurable.

Benefits

Not all the social effects of highways are beneficial. Certain developments that have been associated with highways—for example, noisy or littered drive-in facilities, poorly planned or administered parks for mobile homes, or ribbon developments—obviously have harmful effects. However, these developments may be economically beneficial to certain people, at least temporarily. While it must be recognized that highways have some harmful effects, no suggestion is intended that the harmful effects equal or approach the beneficial effects, even if quantitative measures were available for precise comparison. Any investment of the magnitude of that for the highway system of the United States is expected to provide substantial net benefits, both social and economic.

A good deal of the attention that has been focused on economic effects of highways has been useful in indicating what the social effects are. It seems safe to assume that increased residential land values, which are often associated with highway improvements, are a

---

[1] Presented at the 41st annual meeting, Highway Research Board, Washington, D.C., January 1962.

[2] References indicated by italic numbers in parentheses are listed on p. 10.

[3] In the preparation of this paper, particularly the portion dealing with church activities, information gathered and summarized by Mr. Robert Daiute, an employee of the Bureau of Public Roads during the summer of 1961, was of considerable assistance.

reflection of certain social benefits—perhaps easier access to libraries, schools, government buildings, churches, friends' residences, and social contacts. For fairly small communities, 1,200 population or less, it is possible that bypass routes may be located in such a way that residential and commercial development may be somewhat restricted.

Selected Indicators of Highway Effects

All social changes have multiple causes and those occurring in areas of highway improvement cannot all be attributed to the effect of the highway, as might be suggested by the title of this article. In addition to the effect of the highway, the social and economic changes occurring along Massachusetts Route 128 have been attributed to a variety of causes: a pent-up need for suburban expansion, the abundant supply of technically trained personnel, and aggressive banking. Furthermore, the causes and effects of social trends interact so that generally it is difficult to distinguish between them. Highways may have important influences on family living, such as broadening employment opportunities and facilitating school and church consolidations. At the same time, changes in family composition—more children per family or more working wives—have certain social effects that should be considered in relation to highway building.

Nothing new on the use of quantitative terms to describe the social effects of highways is presented in this article. But as Professor Hennes has pointed out, the lack of precise instruments for measuring changes does not excuse highway people from exercising some measure of intuitive judgment in the determination of social benefits. To ignore realities because numbers cannot be found to put into formulas would be most unfortunate (*2*).

In the absence of summary quantitative indicators, perhaps some of the social effects of highways can be detected by careful observation and analysis of certain social changes or trends that appear to have been strongly influenced by highway transportation. Some indication of the highway's influence can be gathered by noting the timing of certain trends. In commenting on the adjustment that farmers make to a loss of land for highway right-of-way, Professor McKain has pointed out that highways may simply accelerate and smooth the way for changes that are inevitable, such as the consolidation of farm properties (*3*). It seems entirely possible that improved highways also may hasten other changes that would have occurred later without the highway. Changes or trends of this nature appear to include the whole suburban movement, population mobility, school and church consolidations, and generally expanded community boundaries, upgrading of residential property, improved public services, larger farms, fewer farm buildings, and more off-farm employment. Other possible indicators of highway effect include residential development, changes in employment conditions and in recreational activities, and the development of drive-ins and mobile services.

Suburban Development

The phenomenal increase in population of the United States metropolitan areas is well known. Since 1950, about 90 percent of the growth in population has occurred in metropolitan areas. Within metropolitan areas, the suburban fringes are experiencing the fastest growth rates—approximately seven times as fast as the rate of growth for central cities. By 1980, three-fourths of the Nation's 245 million people are expected to be urbanites.

The drift of population to metropolitan areas was underway in this country well before the advent of motor vehicular transportation and can hardly be attributed to improved highways. But the influence which improved highways are having on the current acceleration of the movement of people to the edges of metropolitan areas is undeniable. Of all the influences responsible for the phenomenal growth of the suburbs—mass-produced homes, shorter working hours, easy mortgage financing, septic tanks, and driven wells—improved highway transportation has surely been one of the most important. This highway influence on suburban development is quite similar to other effects that highways exert and is caused primarily by the increased accessibility of suburban areas and the easier driving that modern highways permit.

A good indication of the important role highways play in suburban growth is provided by Richardson, Tex., a community from which travel time to downtown Dallas was cut from more than 30 minutes to about 17 minutes, when the North Central Expressway was completed in 1955. Richardson's subsequent growth in terms of population increase and manufacturing activity was greater than that of comparable towns that were not influenced by the Expressway.

It often has been pointed out that the growth of a metropolitan organization has resulted from the conquest of distance, a barrier to community size. With modern highway transportation, it has become possible for almost any worker, regardless of economic or social level, to commute some distance to work. Reduction of the limiting effects of distance has permitted an extension of community boundaries of up to 35 miles or more from the center, approximately one hour's travel time.

Modern highway transportation has been instrumental in filling in many of the vacant areas near urban centers, as well as in extending the limits of settled areas. These underdeveloped areas had resulted from the pattern of development prior to the 1930's when, in most cities, development was feasible only if the site could be conveniently reached by public transportation. This emphasis on public transportation in major cities frequently resulted in a starlike growth pattern. The present tendency, for urban development to spread out more evenly and to fill in the gaps between public transportation arteries, has certain advantages—for example, the resultant improvement in the availability of utilities or public services. Thus, modern highways have the effect of increasing the supply of land available for urban development.

Population Mobility

It is obvious that the modern highway system has had an effect on the mobility of the American people. This mobility, of course, cannot be attributed solely to the effects of highway transportation. In any one year, about 7 percent of the American people move their place of residence across county lines. Disproportionately large numbers of these people are attracted to those areas without public transportation, which makes it necessary for them to depend on automobiles and highways for transportation (*4*). This tendency for people to move is a response to social and economic opportunities; it is purposeful at least from the viewpoint of those moving. Migration apparently occurs primarily for economic reasons. This mobility may have certain harmful effects in that family and community ties may be broken or weakened; but at the same time, opportunities for additional and desirable contacts may be opened up. In addition, mobility of people geographically usually speeds and eases their social mobility and reduces provincialism.

Residences

The suburban upsurge has depended greatly on the large-scale conversion of land to residential purposes. Single-family residences have become the largest consumer of land in urban areas, from 50 to 75 pecent of the total urbanized area. Thus, the extent of the expansion of urbanized areas—more than a million acres a year—is governed largely by the quantities of land converted to residential use.

Effects that modern highways have had on residential development are quite obvious. By shortening travel time, and in effect bringing more land close to employment and shopping centers, modern highway facilities make it feasible to develop land that formerly was too remote for residential development. The attraction that sites located near modern highways have for residential developers is so obvious and generally recognized that it hardly seems necessary to cite specific instances where new residential developments have been associated with highway improvements. The effect of modern highways on residential areas perhaps can be discerned more clearly by considering other aspects on which there is less general agreement. Some of these aspects are (1) the opinion of residents toward nearby highways, (2) whether highways attract a particular type of resident, and (3) how highways affect community blight.

Opinions of Residents

While attitudes are no objective measure of benefits or disadvantages, the opinions of residents about a nearby highway facility are an important indication of the social impact that the highway has on the local community. A highway must not only facilitate the transport of goods and people; it must be generally acceptable to the residents of the area through which it passes.

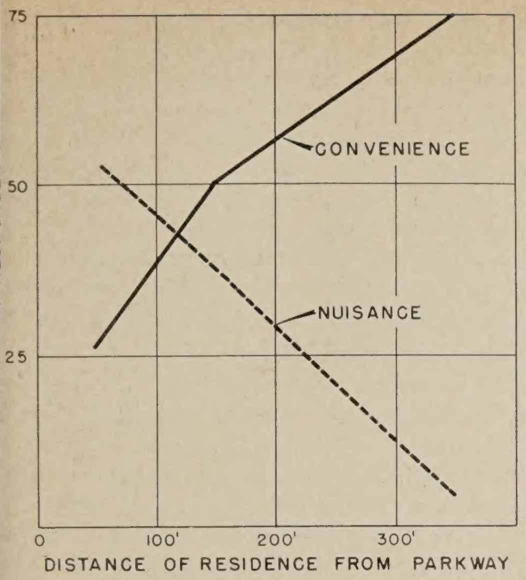

Figure 1.—Residents' opinions of Hutchison River and Bronx River Parkways (New York) by distance from parkway.

Without this acceptance, a highway can generate such harmful effects as lowered land values—land values to a great extent depend on how people feel about property and the surrounding area—and general community blight.

In the determination of attitudes toward highway improvements, careful attention must be given to the highway's stage of development. Typically, the degree of acceptance of a highway facility increases with time; perhaps because the positive effects from highway improvement sometimes are not immediately appreciated, and the apprehensions about possible negative highway effects often are not confirmed. In spite of this tendency for many residents to be initially suspicious of nearby highway improvements, modern highways appear to be quite acceptable to the major portion of the residents of areas served by these facilities. This acceptance is based, not only on the attitude that the highway is good for the community generally but, in many instances, on the individual's feeling that the highway provides benefits to him personally or to his property. There is also some evidence that certain community leaders display a more favorable attitude toward highway facilities than average citizens (*5*). A few of the findings from attitude surveys are referred to in the following paragraphs.

Favorable reaction

In Texas, about 80 percent of the residents questioned along the Dallas Central Expressway felt that the highway made their property more attractive and increased its value. Along a portion of one San Antonio expressway, about 60 percent of the owners said the attractiveness of their property had been enhanced as a result of the highway improvement, while about 40 percent felt that their property had not been affected. Along another section of a San Antonio expressway—Loop 13—the nearby residents, by a 2-to-1 ratio, believed the highway's effect to be beneficial.

In Baltimore, Md., residents near the Beltway who were questioned also considered their highway locations to be generally satisfactory, with the exception of those located near a particular interchange handling a considerable volume of truck traffic.

Attitude surveys in New York State also indicated that residents generally have found important traffic arteries in their neighborhoods to be acceptable, though the acceptance of a highway facility was found to depend largely on the highway's proximity. As might be expected, there is a relationship between the proximity of a person's residence to the highway and his attitude toward that highway. In Westchester County, for example, the percentage of residents with a favorable opinion of the nearby highway varied from about 33 percent in the first 100-foot zone to more than 75 percent in the 300- to 400-foot zone. About 50 percent of the residents in the first 100-foot zone regarded the highway facility as a nuisance, but only about 5 percent in the 300- to 400-foot zone regarded it so. This relationship is illustrated in figure 1.

The tendency for residents near, but not abutting, a highway facility to have a higher opinion of the facility than residents whose property abuts the highway has been noted in other studies, such as those made in Texas and California. Another finding from the New York studies, which agrees generally with results obtained from Texas opinion surveys, is that residents with children tend to object more to a nearby highway than residents without children, presumably because of the traffic hazard.

In addition to the general improvement in access to employment and shopping that highways provide, the general acceptance of highway facilities was sometimes based on an interesting combination of reasons. In San Antonio, benefits mentioned were the assistance the lighted highway provided in keeping prowlers away, the easier circulation of cooling breezes along the right-of-way, and the entertainment value provided by passing cars. Several of these advantages have been mentioned in studies in other States; for example, in Illinois advantages mentioned included the interest and activity along the highway, assured light and air, and the parklike environment pro-

Figure 2.—Varying uses of land near a highway, illustrated by the Gulf Freeway, Houston, Tex.

vided by the broad right-of-way. In New York, residents referred to the special advantage a highway location provides when they are directing friends and relatives to their homes.

While there appears to be a general acceptance of highway facilities by nearby residents, opposition is sometimes raised, particularly when a highway cuts through a residential community. For example, those opposing a particular highway location in Rhode Island stated their objections thusly: A 4-acre playground will be taken entirely for an interchange. Police and fire protection will be more costly because travel distances will be greater. Of 443 houses, 114 will be taken and 40 will be isolated, leaving the community one-third smaller. New friendships may develop, but more of the social life will have to be carried on by car. Many children, instead of having 15-minute walks, will have to ride a bus to school (*6*).

Highways and Community Development

A highway can have a significant influence on the general character of a community development—either to uplift it or to depress it, according to the type of residents it attracts. Analysis of results of several investigations suggests that the type of residential development and the residents that are being attracted to highway locations are tending to upgrade the communities involved. In Blairsville, Pa., residents arriving after completion of a new bypass route generally had more formal education, higher incomes, more interest in community affairs, and more upward occupational mobility than was the case for people with a longer period of residence (*5*). In Monroeville, Pa., where rapid development has been experienced along with greatly improved highway access, recent residential construction has been predominantly for white-collar employees, in contrast to the character of its earlier residential development. A similar upgrading in residential development has been noted in association with the Atlanta Expressway in Georgia. Caution obviously should be exercised against overstating the highway influence. Some increase in the proportion of technical and professional people attracted to any new development, with or without highways, is of course to be expected in view of the increasingly higher educational and training standards for the work force.

Highway effect on blight

Highways can exert either a beneficial influence on a community or can contribute to its blight. The noise and accident hazard associated with some highways, especially those with free access, can have a blighting influence on nearby residences. Even controlled-access highways can have such a blighting effect if residences are too close or are poorly oriented to the right-of-way.

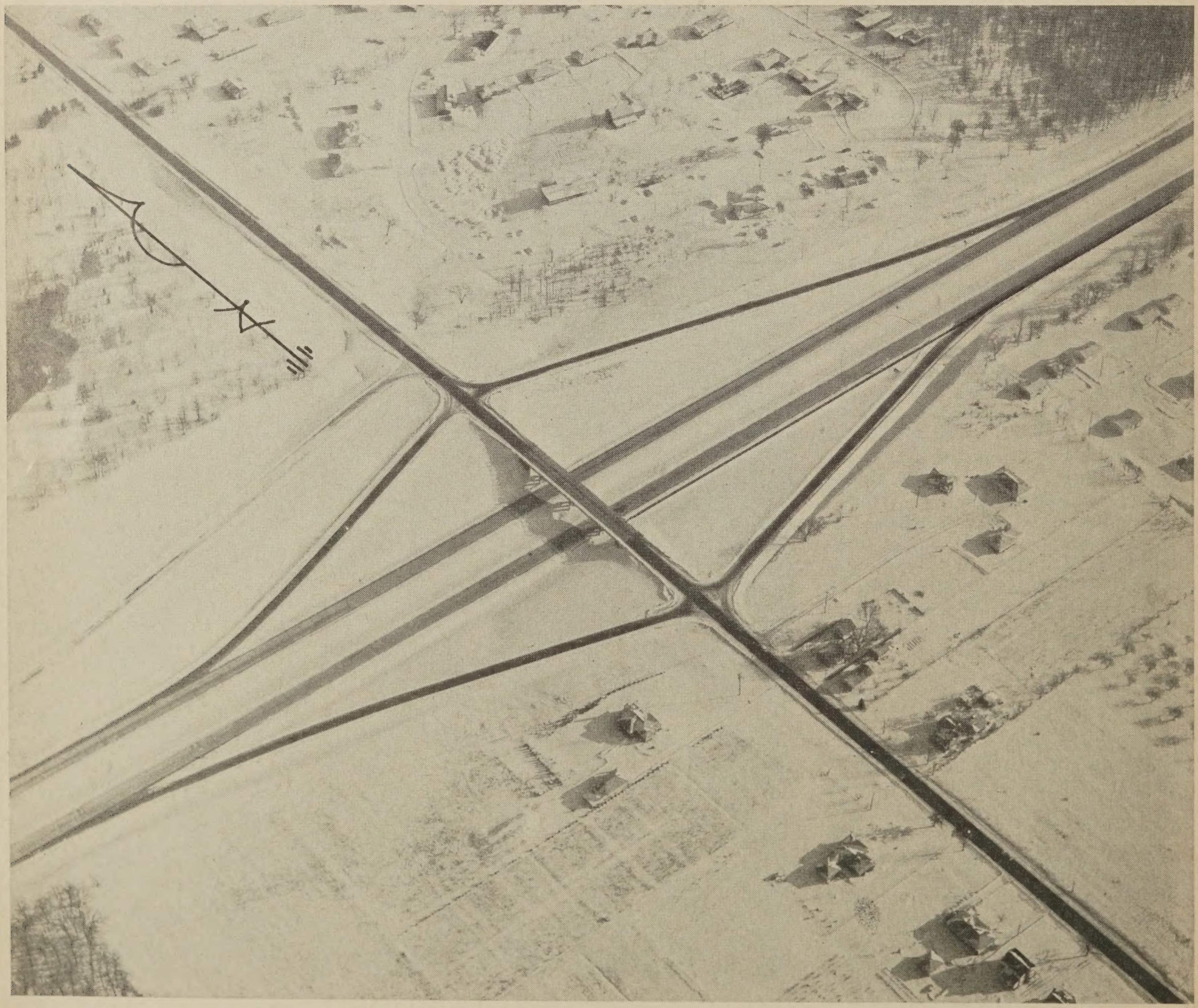

Figure 3.—Residential lots oriented to a modern highway, illustrated by Interstate Route 94, south of Kalamazoo, Mich.

But highways often exert a beneficial influence as evidenced by the reclaiming of blighted areas and the prevention of blight by the removal of substandard structures for a highway improvement. Because of the low prices paid for right-of-way property that is in a rundown condition, construction of the Interstate System has been an incentive for urban renewal efforts in a number of cities. It has been estimated that 50 percent of the Boston, Mass., households displaced for the inner beltway, between Memorial Drive and Massachusetts Avenue, would have been removed eventually during urban renewal projects (*7*). In addition to providing an impetus for clearing slum areas, the payment provided for the direct cost of property taken for the highway can assist localities in clearing out these areas. The Federal Reserve Bank of Boston has referred thus to the effect of highway construction on urban development: "A web of new highways across the land is eating out slums . . . and generally changing the faces of our cities."

Highways can also help prevent blight by providing boundaries between differing uses of land. Since modern freeways are ordinarily broad, well-landscaped, and quite permanent, with relatively few cross-overs, they can be made to serve as effective barriers between areas, such as between residential and industrial areas. James Rouse and Wilfred Owen have compared the Waverly and Hampden areas in Baltimore, Md., stating that Hampden has been able to keep its identity and avoid blight because of its surrounding barriers—including highways (*8*). The Gulf Freeway demonstrates an effective use of a highway facility to separate industrial and commercial uses of land from residential areas, as shown in figure 2.

However, geographical separations caused by highways can sometimes be undesirable; for example, the division of an elementary school district. Obviously, coordination of highway planning with land-use planning is required. As Ellis Armstrong has said, "A highway resembles a hallway with the same need for a blueprint to show what is to be on either side—living rooms, office space, bedrooms, etc." (*9*). Enough experience has been gained with residential areas adjacent to modern highways to demonstrate that the two can be compatible, if they are properly coordinated. Figure 3 illustrates a successful way of locating residential areas near a highway, with deep backyards abutting the highway. More than four-fifths of the 1,239 urban places of 10,000 population and over (the number out of 1,749 that have responded to a Public Roads survey) reported the existence of either a comprehensive, a transportation, or an arterial highway plan.

Relocation of Residents

While more detailed information is needed to show what happens to the people displaced from land taken for highway right-of-way, enough has been learned to suggest that certain adjustments may be typical. Investigations in several different locations have indicated that displaced residents often improve their living conditions, either by upgrading houses that are moved to new lots, or by purchasing better quality houses. In fact, there is sometimes such an upgrading in housing that total assessed valuation for people relocating in the same community is greater than the total assessed valuations for all those who were displaced. However, it is easy to overestimate the highway influence when upgrading accompanies relocation; the highway may in some cases merely hasten an upgrading that would have come later without the highway. The possibility also exists that some people improve their housing conditions because more moderately priced housing is unobtainable, though such cases are believed to be few.

Employment

Modern highway transportation affects employment and employees in several important ways. Improved highway transportation has the effect of bringing additional employment opportunities within commuting distance. Highway improvements also commonly result in a saving to employees, in time or money, or both. For employees working in locations served by a modern highway, such as industrial parks, a further benefit of easy and economical parking ordinarily results.

The reliance placed on highways for commuting to work is shown by the results of a recent survey in 20 States—almost 70 percent of all workers commuted to and from work by automobile (*10*). The importance of bringing additional employment opportunities within commuting distance can hardly be overestimated. Increased employment opportunities increase the likelihood that individuals will be able to find suitable employment—jobs that more nearly correspond to their full capabilities. As the Baltimore Regional Planning Council has stated, ". . . an important goal to be considered is the desirability of maintaining a variety of employment opportunities accessible from any given residential area so that a change of job will not necessitate a change of residence away from established social ties."

Travel Time

That workers are traveling increased distances to work on modern highways appears undeniable; work travel is thought of in terms of travel time rather than distance. Of workers using automobiles for the trip to work, over 10 percent have a one-way travel distance of more than 15 miles, and about two-fifths of them travel 25 miles or more. In Detroit, one out of five workmen has been reported to travel more than 10 miles to work. In Atlanta, Ga., 15 percent of the labor force crosses county lines to employment, and these commuters typically travel about 33 miles on public highways. A number of workers have been found who travel as far as 60 miles to work; and around Boston, Mass., commuters on the modern design Route 128 spend about the same amount of time in going approximately 15 miles to work as others spend in going an average of 8.5 miles on other routes (*11*). This apparent advantage of a modern highway system may of course result in part from other causes such as less settlement or

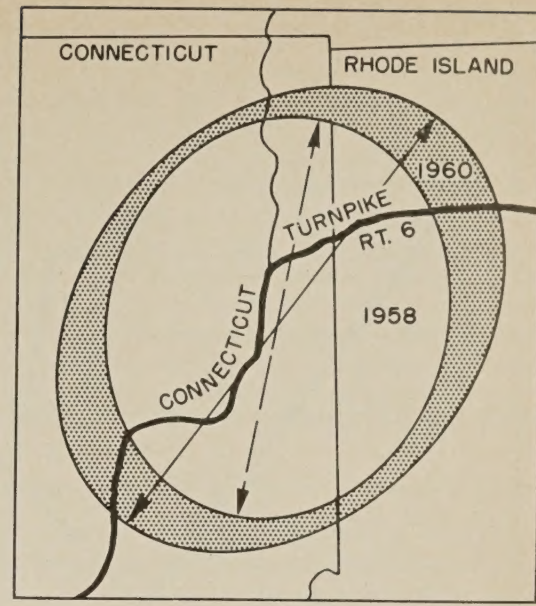

Figure 4.—Extension (1958–60) of labor market for one manufacturing firm that followed construction of the Connecticut Turnpike. Note how this expansion was greatest near the axis of the Turnpike.

congestion in the area served by Route 128. Figure 4 illustrates the effects that a modern highway apparently had on the commuting pattern of one firm's employees.

Highway Effects on Public Services

Highway effects on public services resemble their effects on many other aspects of American life; some appear to be harmful, others beneficial. In some instances, areas subject to the influence of a modern highway have been associated with increased demands and higher costs for education and other public services, as well as with increased tax rolls to help pay for these increases in public service. Perhaps the most important and beneficial effect of improved highway transportation on public services is that public service facilities are made available more generally and more economically.

Protection services

Protection services such as fire and police are clearly dependent on the availability of efficient highways. The fairly elaborate systems that firefighting organizations employ for mutual aid in case of catastrophic fires provide an example of this important reliance on efficient highway transportation. Police protection can be improved by the highway's effect in making police officers more mobile, by increasing coordination between State and local police, and by permitting use of more centralized headquarters.

Education

Education has undergone several marked changes that appear to be quite directly related to highway improvements. Some of these changes are shown in figure 5. The number of rural one-room schools has declined from about 190,000 to 25,000 during the past 40 years. During this same period, the number of pupils transported in schoolbuses has

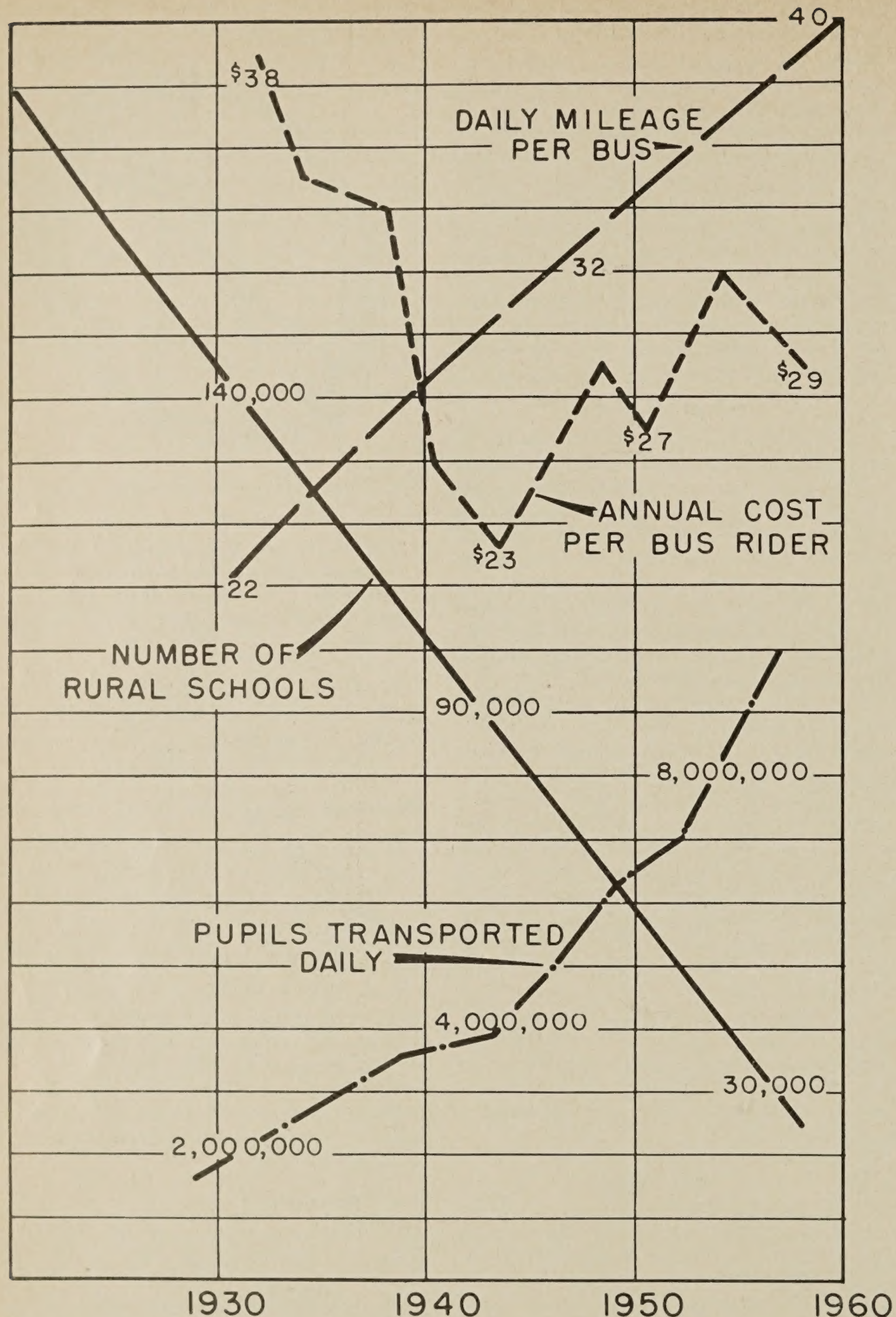

Figure 5.—Relation of new highways to changes affecting rural schools.

increased; and the unit cost of transporting pupils has declined. This lower cost appears to be the result, at least in part, of the improvement of available highways. During the past 30 years, the daily mileage traveled by each schoolbus has nearly doubled—from 22 to 40 miles—and the number of pupils carried by each bus has increased. Other improvements related to education, which appear to be at least partly associated with improved highway transportation, are the gains made in school enrollment—both in absolute numbers and in the proportion of the school age population enrolled—and gains made in the average attendance of enrolled pupils. The absentee rate in public schools in 1900, for example, averaged more than 33 percent of the enrollment compared with an absentee rate of only 12 percent in 1958.

The increasing feasibility of daily highway travel to educational establishments has special significance for higher education. The burgeoning United States population, combined with higher and higher expectations for education, would place an intolerable burden on colleges and universities if these institutions had to provide living facilities for all those attending college. In addition to offering colleges and universities some relief from the necessity for providing dormitory space, commuting from home to college often permits the young people who cannot afford to pay room and board to attend college. Such commuting by auto obviously may aggravate parking problems on campuses and in nearby areas. Figure 6 shows typical changes that have occurred during the past 20 years in the pattern of commuting to an institution of higher learning. The increased volume and greater distances involved are quite noticeable. At many colleges and universities, nearly half of the students arrive by automobile (*12*).

Postal service

Postal service changes also reflect certain highway effects. Improved highway transportation appears to be at least partially responsible for the trend to longer rural delivery routes, fewer post offices, and an increase in the portion of mail being hauled by highway. Changes made in rural mail delivery routes show a remarkable improvement in productivity. The average length of rural mail delivery routes had increased from 27 miles in 1920 to 56 miles by 1959. Table 1 provides additional information about the development of rural delivery routes. In addition to improved highway transportation, the increased distances that rural carriers travel have no doubt depended on the more lenient requirements approved for establishment of rural delivery routes, such as the change from the requirement for four families per mile traveled prior to 1953, to two families in 1959.

Increasing reliance placed on highways through mobility apparently has been a contributing factor in making it possible for the Post Office Department to close a substantial number of smaller post offices without impairing postal service. Thus, from nearly 77,000 post offices in 1900, the number has declined to less than half, approximately 36,000. Many new post offices have been established during this same period to serve areas with increasing populations. While the number of post offices has declined, the volume of mail has increased manyfold; in recent years, the percentage increase in mail volumes has been about twice that of the population.

Health services

Health services also have been affected in important ways by improved mobility made possible because of better highways. This improved mobility obviously benefits many phases of health service—patients, physicians, visiting nurses, health inspectors, health testing units, etc. Medical doctors were among the first users of the automobile. Automobiles permitted them to increase the number of patients they could call on from 5 to 7 a day to, perhaps, 8 to 10 a day. Gradually, however, the practice of doctors to make home visits has changed until now the practice is for patients to visit doctors' offices. The increase in productivity of doctors resulting from this change in mode of operation has been quite spectacular: from 15 to 35 patients now can be seen daily. An American Medical

Table 1.—Rural free delivery routes, 1900–59[1]

Rural free delivery routes				Total annual travel
Year	Number	Total length	Average length	
		1,000 miles	*1,000 miles*	*1,000 miles*
1900	1,259	29	23	--------
1910	41,079	993	24	303,007
1920	43,445	1,152	27	348,627
1930	43,278	1,335	31	404,738
1940	32,646	1,402	43	424,704
1950	32,619	1,493	46	453,260
1959	31,377	1,753	56	532,677

[1] Source: *Statistical Abstract of the United States, 1959,* U.S. Bureau of the Census, and *Annual Report of the Postmaster General, 1959,* U.S. Post Office Department.

Association study notes that in a rural county in Illinois, 16 physicians in 1950 had provided more service for more people than 42 physicians had provided in 1920.

The effectiveness of such health facilities as hospitals often depends largely on how accessible they are. Travel time to the facility may be all-important. In some instances, as many as 75 percent of all hospital patients arrive by motor vehicle.

Location criteria

Location criteria for public service facilities provide some indication of the effect highways have on public services. In general, service areas are expanding and accessibility is being recognized as a more important factor than that of being near the geographic center of the area served. Thus, police stations may be established on an accessible site with space for parking. Schools may be located away from main thoroughfares to avoid grade-crossing problems. Some public service facilities, such as senior high schools and hospitals whose activities might annoy nearby residents, need locations removed or isolated from residential areas but accessible to arterial highways. Physicians are locating more and more in suburban areas, many of them in medical centers oriented to high-capacity highway facilities. Libraries, especially downtown libraries, need to be accessible to both pedestrian and motor vehicular traffic. Figure 7 shows a dramatic example of the emphasis that has been given to accessibility in locating a library building; this library building in Hartford, Conn., spans the highway.

Highway Influence on Voluntary Associations

The role that improved highway transportation has played in creating opportunities for new associations and in changing many local neighborhood ties is fairly obvious. According to Professor Hawley, highway transportation, ". . . more than any other single factor, has revolutionized the pattern of local relations." With the expanded community made possible with modern highway transportation, ". . . the traditional support of local government, the church, the family, the neighborhood group, is weakened." The services formerly derived from such units, if sought at all, are found in better equipped and more widely scattered units (*13*).

Like many other highway effects, then, it appears that the influence that highways have exerted on participation in voluntary organizations has been both beneficial and harmful in some aspects. The easier participation in church, fraternal, social, civic, or other voluntary organizations, which improved highways permit, is suggested by the results of a Connecticut study. This survey of more than 1,800 suburban families revealed that those families located on hard-surfaced roads had an average per family of nearly two memberships in voluntary organizations compared with an average of only about one-half a membership for those families not located on hard-surfaced roads (*14*).

Churches

Variations in church experience and activity provide some indication of the effect of highway transportation; church activities provide a fairly close reflection of population movements. Thus, suburban churches generally are growing and prospering while churches in downtown areas of large cities and in rural locations are having difficulty in continuing to exist. Much of the general increase in total church membership, now about 113 million, and in the percentage of the population associated with a church, 60 percent now versus 40 percent in 1910, has occurred in suburban areas. A survey of 4,600 Protestant churches, in 23 metropolitan districts and 3 suburban counties, shows that 70 percent of the churches in suburban areas have been growing (*15*). The Catholic church has experienced a similar growth in

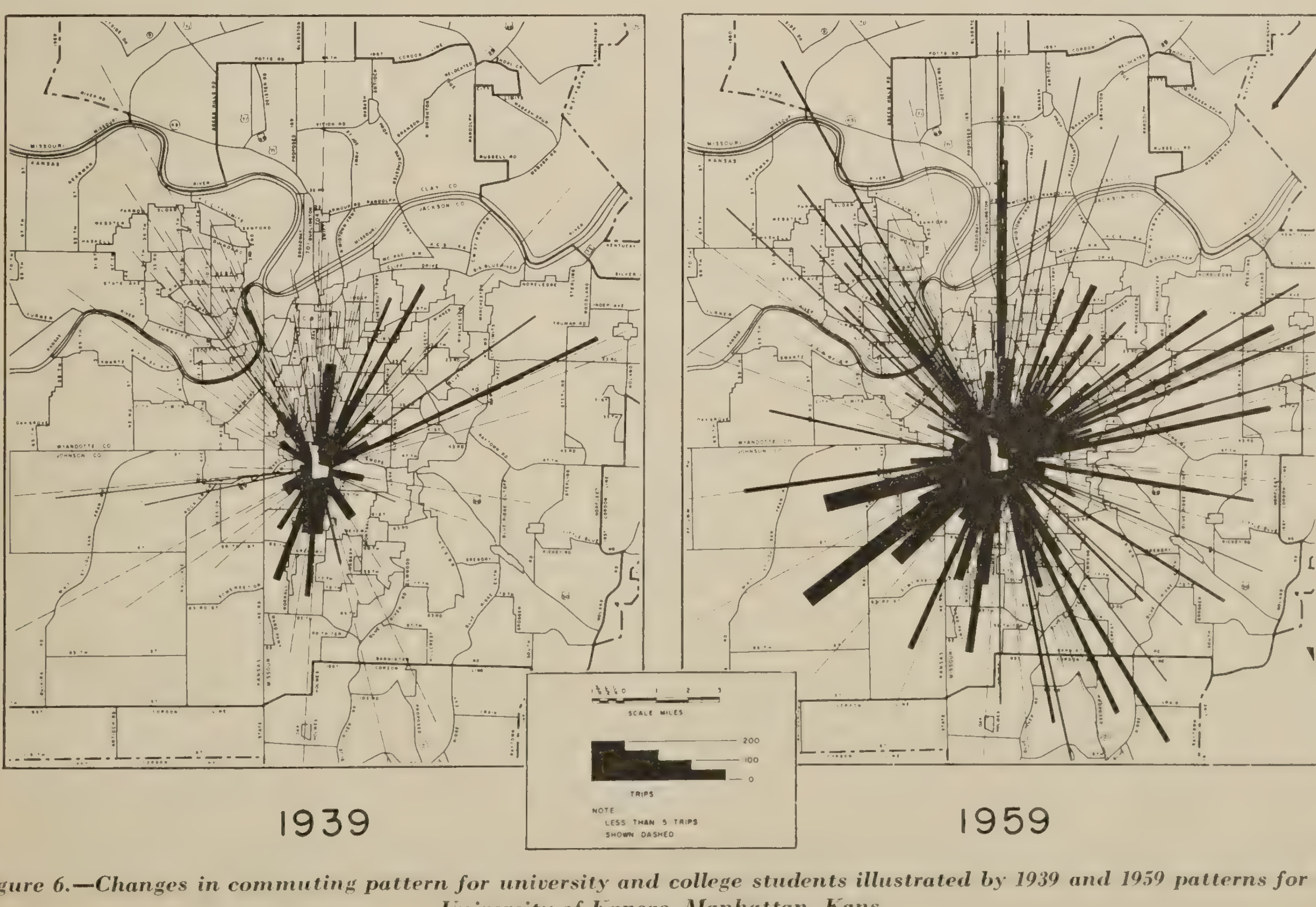

Figure 6.—Changes in commuting pattern for university and college students illustrated by 1939 and 1959 patterns for the University of Kansas, Manhattan, Kans.

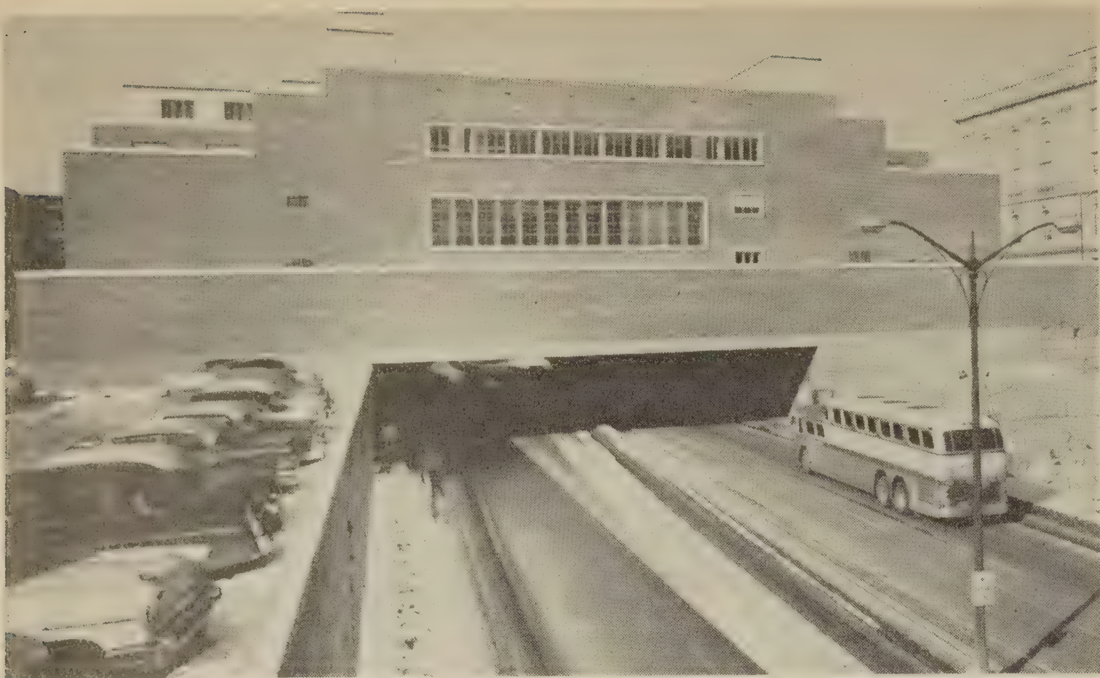

Figure 7.—Public library in Hartford Conn., spans the highway. The windowless section at the base houses the supporting girders and the library's basement bookstack area.

the suburbs; in recent years some 55,000 members have been added each year in the newer sections of Los Angeles alone (*16*). The survey of Protestant churches also revealed that a decline in church activity was experienced by 23 percent of the metropolitan churches, a disproportionate number of which were in downtown locations. In rural areas, Protestant churches closed at the rate of 1,000 per year between 1946 and 1956 (*17*).

Several of these changes in church experience are clearly related to improved highway transportation. It seems reasonable to infer that trips for church attendance are becoming longer. This follows from the fact that the average number of members per congregation has increased from 235 in 1926 to 357 in 1959, even though an increasing portion of those attending church reside in suburban areas, where population may be quite scattered (*18*). In helping to make it feasible for people to congregate in larger groups, highways no doubt have been at least partially responsible for the closing of many rural churches. Rural church difficulties may come about because former members travel farther to attend larger churches and/or because of the " . . . intensified competition for the time of nominal adherents . . ." (*13*). The beneficial effects that highways have in making pastors more mobile for calls on parishioners and, in many cases, for dual preaching assignments seems especially important in view of the growing shortage of clergymen.

The wisdom of locating suburban churches near highways of modern design seems undeniable. The advantage of going on display along a heavily traveled highway may be even greater for churches than for other establishments. Unlike school, work, shopping, and family associations, church affiliation is sometimes so tenuous that many people new to an area will make little effort to locate a church to attend. In the shift of population from rural and central city areas to the suburbs, many people delay affiliating with a church in the new area. In one suburban area in Connecticut, 25 percent of the new residents were found to have no church affiliation; 13 percent of the residents who had been in the community for some time were affiliated with churches (*14*). The need for having their location known to our mobile population—perhaps by locating along a modern highway—is further suggested by the fact that 50 percent of all Protestant church members have joined their congregations during the last 10 years (*19*).

Rural Effects

Improved transportation through highways and motor vehicles has generally been regarded as one of the more important forces underlying the American agricultural revolution (*20*). Both passenger automobiles and trucks are particularly well suited to the needs of farmers and farm operations. Nearly one-fourth of all motortrucks are in farm use, although the farm population constitutes only a small portion of the total population—slightly over one-tenth. And since 1940, the number of farm trucks has been tripled although the farm population has declined. As can be seen from figure 8, both the number of farm operators working off the farm and the number of hired farm workers have been increasing significantly during the same period that the total number of farm operators has been declining. These changes obviously have resulted from the increasing mobility of the farm population; highways are generally the sole means of transportation in rural areas. Farm labor—both migratory and local day workers—arrives practically 100 percent by highway. The importance that highway networks have on the availability of an adequate supply of farm labor is suggested by the fact that certain areas in New Mexico and Nevada, located some distance from major highways, have a chronic shortage of farm labor.

Off-farm employment

The tendency for more and more farm people to work in off-farm employment appears to have been the result of several influences. As a result of the current technological revolution in agriculture, of which highway transportation improvements are an important part, farm people now have more time available for nonfarm employment. Also, the increasing dispersal of industry into rural areas has made more employment opportunities available. From a recent study of rural industry in North Carolina, it was found that one-third of the population in rural areas consists of nonfarmers and that a primary contributor to this has been the automobile. The association of modern highways with increased off-farm employment has been noted in a number of other locations; for example, in Iowa the improved access provided by an Interstate route was credited in part for a higher-than-average rate of off-farm employment (*21*).

Living conditions

Highways are having a profound influence on living conditions in rural areas. Changes in rural life patterns, attributable in part to improved highway transportation, include wider opportunities for nonwork activities, increased opportunities for off-farm employment, and a general improvement in or upgrading of rural areas as places in which to live. That opportunities for such nonwork associations as shopping, recreation, church, lodge, and farm meetings are increased with improved transportation is suggested by the increasing participation in these activities by farm people. In 1920, for example, 12 million attendances at farm meetings were recorded; in 1957, 77 million attendances were recorded even though the total number of farmers has been declining (*22*). The influence of improved highways in facilitating attendance at farm meetings has been noted especially in Missouri, where highways have been credited with speeding the work of county agents and facilitating attendance at social gatherings and church (*23*).

In providing alternative opportunities for the close family relationships that have been traditional in rural areas, improved highway transportation may tend to weaken such relationships. While the many changes that have altered farm life at such a rapid pace have created problems in family relationships and social orientation, these changes have, nevertheless, opened up new horizons and new opportunities for self improvement and enjoyment of life in rural areas.

That the attractiveness of a rural area as a place to live should be enhanced as a result of improved highway service seems only natural, and this development has been noted in several instances. In Montana, for example, a road improvement was rated by 78 percent of the farm people queried as making the farm home a more pleasant place to live. Among the specific advantages referred to by the Montana farmers contacted were: (1) ease in visiting other farms, (2) elimination of dust, (3) easier marketing and buying, (4) improvement in schoolbus roads, (5) easier commuting to college, and (6) faster service in emergencies, such as medical visits. In Texas, several improvements have been observed in the rural community served by the Camp Creek Road. Following the upgrading of this Road, the number of dwellings along the highway increased and, apparently, reversed the tendency for this farm neighborhood to disintegrate as a result of farmers or retired farmers moving to town. Several of the new house owners said that they would not have built along this highway had it not been improved.

Farms partially taken for highway right-of-way ordinarily experience a sharp impact. As suggested earlier, there are some indications that partial takings have the effect of hastening changes that would occur later in the absence of the highway. Changes, which have been tentatively associated with partially taken farms, include increased employment off the farm, increased farm consolidations, dispersed farm operating units, fewer buildings per farm, and higher farm mortality. It is interesting to note that, with the regrouping following highway acquisition, the farm units losing land for highway right-of-way have, in several instances, ended up with more land.

Highway Effects on Recreation

The different ways in which highways have affected recreation have been commented on recently by Wilfred Owen, who deplores the taking of park and recreation land for highway right-of-way; but he also points out that highway transportation often makes possible the fullest enjoyment of park areas. The acquisition of highway right-of-way has in some cases necessitated the taking of portions of recreational areas; this effect of a highway should obviously be avoided if possible. Criticism has also been leveled at modern highways for the alleged lack of provision of "intellectual stimulation" and "emotional content" (*24*); but highways have often been given credit, along with increased leisure and income, for the tremendous increase in recreational facilities and activities. At a 1958 New York-New Jersey Regional Recreational Conference, for example, the tremendous expansion of the arterial network crisscrossing the metropolitan region was referred to as making possible the phenomenal growth of the park system. In the New York-New Jersey region, the arterial system not only provides easy access to the State park systems but has, in addition, provided the neighborhoods in the city through which it passes with hundreds of acres of urgently needed neighborhood recreation space.

There is, of course, a strong association between highway travel and recreation. In California, the total passenger-miles traveled for recreation has been reported to be as great as for all other purposes, and the strong reliance of many recreational areas on good highway transportation has been well documented. In Yellowstone National Park the number of annual visitors increased from 52,000 before 1917, when no cars were permitted inside the park, to 250,000 annually in the 1917–27 period and to 1.4 million in 1959 (*25*).

Drive-ins and Services for Mobile Public

The various drive-ins and services available for the mobile public are among the most obvious of the ways in which highway transportation is influencing the American way of living. The variety of commercial enterprises or services that have been established as drive-ins or as facilities for motorists is quite remarkable, regardless of whether these highway-oriented establishments are considered desirable. In fact, someone has suggested that a motorist can drive in for almost any service except parking.

Drive-in facilities have been used for such endeavors as banks, churches, laundries, telephones, insurance claim windows, drug prescription windows, tax offices, car washes, mail and library deposit boxes, and motor-vehicle registration windows; and the number has grown phenomenally. The original drive-ins—filling stations—have increased in number to more than 182,000. Other types of drive-in facilities that have become fairly numerous include motels, 58,000; bank windows, 6,000; and drive-in restaurants, 30,000. Drive-in restaurants are among the fastest growing types of drive-in establishments. Three out of each five new restaurants being established are drive-ins, and about one-third of all the money spent at restaurants is spent at drive-ins. There may be some cause for concern about the rapid growth of these eating establishments since objectionable noise and litter problems sometimes are associated with such businesses. An analysis of the relative desirability of retail trade locations shows

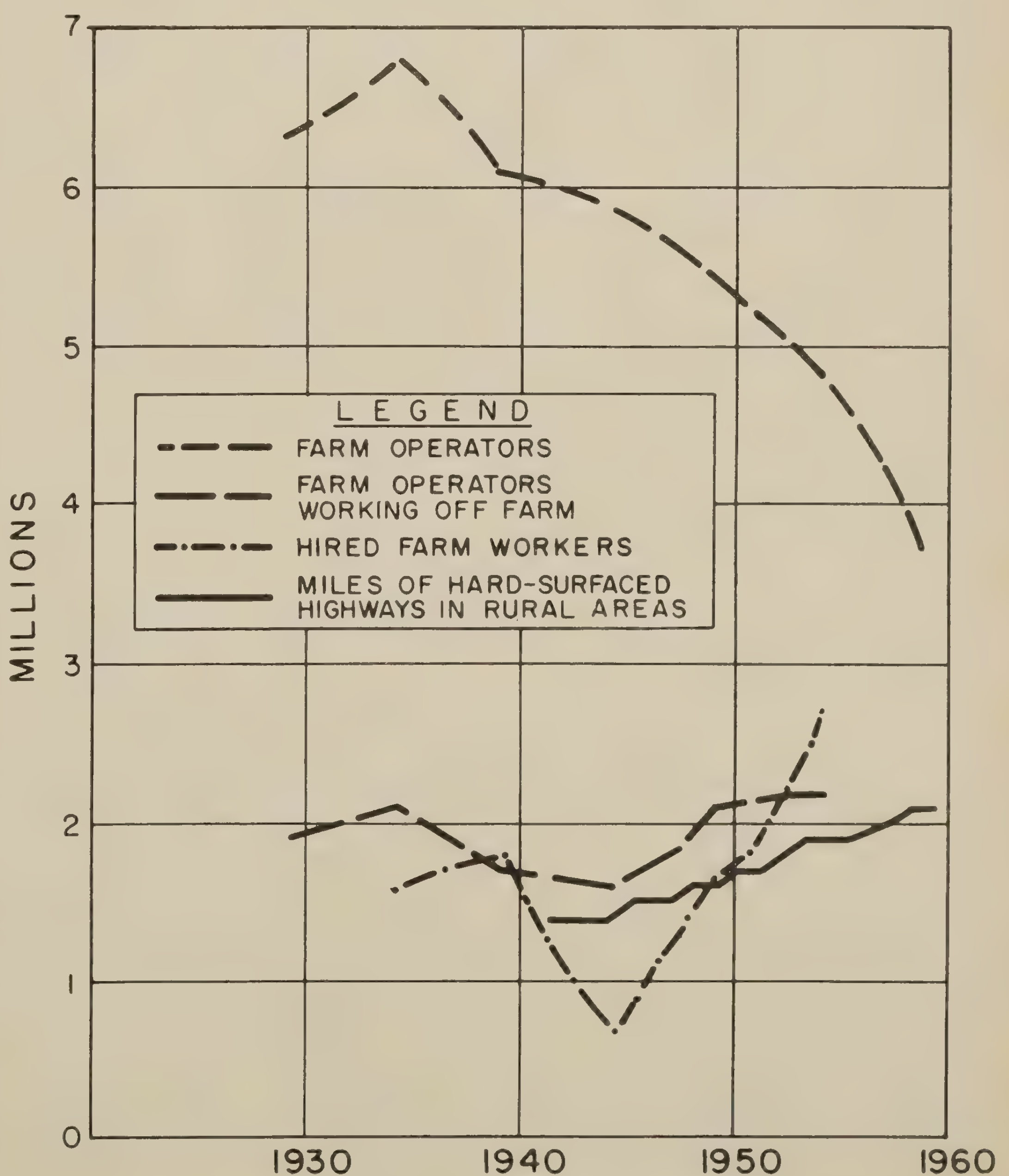

Figure 8.—Effect of highways on farm labor.

630431—62——2

that drive-in restaurants are incompatible with nearly all other types of businesses (*26*).

The growth and variety of other services for the mobile public has paralleled that of the drive-ins. A phenomenal growth has occurred in the number of mobile homes; retail sales of mobile homes have increased from about $13 million in 1930, to $39 million in 1954, to $600 million in 1957. About 3½ million people are now housed in mobile units, the majority in some 13,000 mobile-home parks. The popularity and community acceptance of mobile-home living varies considerably from region to region. As might be expected, it appears to depend in an important way on climate; mobile homes generally have been more popular in southern and western regions of the country. There appears to be a growing awareness of the need for planning sites for these abodes to fit in with residential areas of the conventional type and with other land uses.

Other, but less common, activities associated with mobility on the highways include swimming pools and, curiously, bee hives. A few resourceful beekeepers have been able to stretch out the honey-making season by mounting bee hives on trucks and transporting them between Minnesota and Texas, between southern California and Idaho, and between New York and Florida (*27*).

REFERENCES

(*1*) *Implications of Sociological Research for Urban Passenger Policy*, by Margy E. Myerson, Highway Research Board Proceedings, 34th annual meeting, 1955, vol. 34, pp. 1–7.

(*2*) *Highways as an Instrument of Economic and Social Change*, by R. G. Hennes, in *Economic Analysis in Highway Programming, Location and Design*, Highway Research Board Special Report 56, 1960, pp. 131–135.

(*3*) *The Economic and Social Impact of the Connecticut Turnpike*, by W. C. McKain, Jr., in *Land Acquisition and Economic Impact Studies*, Highway Research Board Bulletin 189, 1958, pp. 90–95.

(*4*) *Recent Population Trends and Their Highway Implications*, by E. L. Kanwit and T. R. Todd, Highway Research Board Proceedings, 40th annual meeting, 1961, vol. 40, pp. 1–34.

(*5*) *The Economic and Social Impact of Highways, Blairsville: A Bypass Study*, by Pennsylvania State University, University Park, Pa., 1961 (unpublished).

(*6*) *The Friendly Interchange*, by Blair Associates, Providence, R.I., Oct. 19, 1960. (A planning study of Interstate 95 and the Huntington Avenue Expressway as they affect a community in Cranston, R.I.) A report prepared for the City Plan Commission of Cranston, R.I. (unpublished).

(*7*) *Inner Belt and Expressway System, Boston Metropolitan Area Interim Report*, vol. III, of *Socio-Economic Studies*, Boston, Feb. 1960, p. 3-48. A report prepared for the Massachusetts Department of Public Works, by Hayden, Harding & Buchanon, Inc., and Charles A. Maguire & Associates, Consulting engineers (unpublished).

(*8*) *Cities in the Motor Age*, by Wilfred Owen, 1959, pp. 49–51.

(*9*) *Fitting the Highway into the Urban Plan*, by E. L. Armstrong, Public Works, vol. 92, No. 1, Jan. 1961, pp. 98–102.

(*10*) *Motor-Vehicle-Use Studies in Six States*, by T. A. Bostick, R. T. Messer, and C. A. Steele, PUBLIC ROADS, vol. 28, No. 5, Dec. 1954, pp. 99–126.

(*11*) *Highway Transportation*, by the Bureau of Public Roads, Publication 841–S of the National Academy of Sciences–National Research Council, 1960.

(*12*) *The Impact of Highways on Selected Public Service*, by Wilbur Smith & Associates, New Haven, Conn., 1960, pp. 19–23.

(*13*) *Human Ecology*, by A. H. Hawley, 1950.

(*14*) *Studies of Surburbanization in Connecticut*, by N. L. Whetten and E. C. Devereux, Jr., Storrs Agricultural Experiment Station Bulletin 212, Oct. 1936, Connecticut State College.

(*15*) *Some Protestant Churches in Urban America*, by H. P. Douglass, in *The Sociology of Urban Life*, edited by T. L. Smith and C. A. McMahan, New York, 1951, p. 517.

(*16*) *The Church and the Suburbs*, A. M. Greeley, 1959, p. 65.

(*17*) *Rural Churches Consider Facts and Figures*, in *National Council Outlook*, vol. VI, No. 9, Nov. 1956, pp. 11–12.

(*18*) *Yearbook of American Churches for 1961*, 29th annual issue, National Council of Churches of Christ in U.S.A., Oct. 1960, p. 280.

(*19*) *Urban Church Planning*, by Walter Kloetzli and Arthur Helman, 1958, p. 44.

(*20*) *America's Needs and Resources, A New Survey*, by Dewhurst & Associates, 1955, p. 808.

(*21*) *The Effects on Farm Operating Units of Partial Taking for Controlled-Access Highways.* A report to the Bureau of Public Roads by the Agricultural Research Service, U.S. Department of Agriculture, 1960, p. 60 (unpublished).

(*22*) *Vehicles, Roads, People: A Fact Book on Highway Transportation and Safety for County Extension Workers*, by Automotive Safety Foundation, Washington, D.C., 1960.

(*23*) *Highway Facts in Missouri*, by Automotive Safety Foundation, Jefferson City, Mo., 1960, p. 5.

(*24*) *Implications of Recreational Needs for Highway Improvements*, by Marion Clawson, presented at the 40th annual meeting of the Highway Research Board, Washington, D.C., Jan. 1961. To be published in HRB Bulletin No. 311.

(*25*) *Public Use, National Parks and Related Areas*, by National Park Service, U.S. Department of Interior, 1956 and 1959.

(*26*) *The Selection of Retail Locations*, by R. L. Nelson, 1958, pp. 70–77.

(*27*) *Bees on Trucks*, in the *Wall Street Journal*, Dec. 8, 1959.

New Publications

Highway Progress, 1961

Highway Progress, 1961, the annual report of the Bureau of Public Roads for the fiscal year 1961, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at 35 cents a copy.

In this report, the Bureau of Public Roads, U.S. Department of Commerce, presents a review of its accomplishments in connection with the Federal-aid highway program and many other activities. An illustrated publication of 108 pages, this report is a descriptive account of the tremendous progress made during fiscal year 1961 on construction of the National System of Interstate and Defense Highways and on improvement of primary highways, secondary roads, and urban arterials under the regular Federal-aid program. Also included is a description of the highway construction work undertaken directly by the Bureau of Public Roads in national forests and parks and on other Federal lands, and a description of the activities of Public Roads in providing technical assistance to foreign countries to further their programs of highway development.

A description of the significant new legislation contained in the Federal-Aid Highway Act of 1961 and of two important reports submitted to the Congress are included also: the reports are on the new estimate of the cost of completing the Interstate System, and the highway cost allocation study.

Other material in the annual report includes information on the activities and accomplishments of Public Roads in highway planning and design, and urban transportation planning, and on its extensive and varied research program. Included as an appendix in the report are 21 statistical tables covering the progress and activities of the Federal-aid program during the fiscal year 1961.

Highway Statistics, 1960

The Bureau of Public Roads has recently published *Highway Statistics, 1960*, the sixteenth in this annual series. The new bulletin presents the 1960 statistical and analytical tables of general interest on motor fuel, motor vehicles, highway-user taxation, State and local highway finance, highway mileage, and Federal-aid for highways. The 206-page bulletin may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D.C., at $1.25 per copy. Earlier annual issues of the series, and a summary of Highway Statistics to 1955, are available from the Superintendent of Documents as indicated on the inside back cover of PUBLIC ROADS.

Estimated Travel by Motor Vehicles in 1960

BY THE HIGHWAY PLANNING DIVISION
BUREAU OF PUBLIC ROADS

Reported by THEODORE S. DICKERSON,
Highway Research Engineer

MOTOR-VEHICLE travel in the United States in 1960 totaled 718.8 billion vehicle-miles, an increase of 3 percent over the travel in 1959.[1] The travel data were compiled from information supplied by the State highway departments and toll authorities. Total travel for 1961 is estimated at 733 billion vehicle-miles, a 2-percent increase over 1960, based on information for the first 10 months of the year.

The proportions of travel by road system and by vehicle type changed little from 1959 to 1960. Of the 1960 travel, 40 percent was on main rural roads, which comprise 14 percent of the Nation's total of 3.5 million miles of roads and streets. Another 46 percent of the travel was on urban streets, which comprise only 11 percent of the total mileage. Local rural roads, which make up 75 percent of the total mileage, carried only 14 percent of the travel.

Passenger cars represented 84 percent of the vehicles and accounted for 82 percent of the travel in 1960; trucks and truck combinations represented 16 percent of the vehicles and accounted for 17 percent of the travel; buses accounted for less than 1 percent of both the vehicles and the travel.

Average vehicle performance in 1960 differed very little from that reported in 1959. The average motor vehicle traveled 9,652 miles in 1960, almost half of it in cities, and consumed 777 gallons of fuel at a rate of 12.42 miles per gallon. The average passenger car traveled 9,446 miles and consumed 661 gallons of fuel, at a rate of 14.28 miles per gallon. A slight decrease from 1959 appeared in average annual mileage traveled and fuel consumed by commercial buses, while trucks showed a modest increase in both average annual miles traveled and fuel consumed.

The travel and related information for 1960 is shown in table 1 by road system and vehicle type.

[1] *Estimated Travel by Motor Vehicles in 1959*, by Alexander French, PUBLIC ROADS, vol. 31, No. 7, Apr. 1961, p. 158.

Table 1.—Estimated motor-vehicle travel in the United States and related data for calendar year 1960 [1]

Vehicle type	Motor-vehicle travel					Number of vehicles registered	Average travel per vehicle	Motor-fuel consumption		Average travel per gallon of fuel consumed
	Main rural road travel	Local rural road travel	Total rural travel	Urban travel	Total travel			Total	Average per vehicle	
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles/gal.*
Passenger cars [2]	225, 755	77, 528	303, 283	284, 800	588, 083	62, 258	9, 446	41, 169	661	14. 28
Buses:										
Commercial	869	154	1, 023	1, 849	2, 872	76	37, 789	618	8, 132	4. 65
School and nonrevenue	597	635	1, 232	249	1, 481	196	7, 556	209	1, 066	7. 09
All buses	1, 466	789	2, 255	2, 098	4, 353	272	16, 004	827	3, 040	5. 26
All passenger vehicles	227, 221	78, 317	305, 538	286, 898	592, 436	62, 530	9, 474	41, 996	672	14. 11
Trucks and combinations	61, 262	20, 460	81, 722	44, 687	126, 409	11, 945	10, 583	15, 882	1, 330	7. 96
All motor vehicles	288, 483	98, 777	387, 260	331, 585	718, 845	74, 475	9, 652	57, 878	777	12. 42

[1] For the 50 States and District of Columbia.
[2] Includes taxis; also motorcycles (575,497 registered).

A Preliminary Evaluation of Color Aerial Photography for Use in Materials Surveys

(continued from p. 20)

the spring or summer because of the lower sun angle. These shadows are particularly apparent in photographs taken in high latitudes. The intensity and wavelengths of sunlight also vary with the time of day as well as with the latitude. To obtain proper color balance and minimize shadows, aerial photographs should be taken as close as possible to the peak of the solar altitude.

BIBLIOGRAPHY

(*1*) *Manual of Photographic Interpretation* American Society of Photogrammetry, Washington, D.C., 1960.

(*2*) *Forestry Applications of Aerial Color Photography*, by R. W. Becking, Photogrammetric Engineering, vol. 25, No. 4, 1959.

(*3*) *Physical Aspects of Air Photography*, by C. C. Brock: Longman, Green & Co., Ltd., London, 1952.

(*4*) *Some Uses and Limitations of Aerial Color Photography in Agriculture*, by R. N. Colwell, Photogrammetric Engineering, vol. 26, No. 2, 1960.

(*5*) *Kodak Data for Aerial Photography*, Eastman Kodak Publication No. M–125, 1961.

(*6*) *Color Aerial Photography in Photogeologic Interpretation*, by W. A. Fischer, Photogrammetric Engineering, vol. 24, No. 4, 1958.

(*7*) *Experiments in the Use of Color Aerial Photographs for Geologic Study*, by B. H. Kent, Photogrammetric Engineering, vol. 23, No. 5, 1957.

(*8*) *A Performance Estimate Comparing Conventional Geologic Mapping with that Accomplished with the Aid of Color Photographs*, by P. A. Laylander, Photogrammetric Engineering, vol. 22, No. 5, 1956.

(*9*) *Color Aerial Photography Facilitates Geologic Mapping on the Atlantic Coastal Plain of New Jersey*, by J. P. Minard, Photogrammetric Engineering, vol. 26, No. 1, 1960.

(*10*) *Reference Guide Outline: Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958*, U.S. Department of Commerce, Bureau of Public Roads.

(*11*) *The Use of Panchromatic, Infrared and Color Aerial Photography in the Study of Plant Distribution*, by O. W. Schulte, Photogrammetric Engineering, vol. 17, No. 5, 1951.

(*12*) *An Aspect of Color Photography and Interpretation*, by R. G. Tarkington, Photogrammetric Engineering, vol. 19, No. 3, 1953.

(*13*) *Color and Infrared Experimental Photography for Coastal Mapping*, by C. Theurer, Photogrammetric Engineering, vol. 25, No. 4, 1959.

(*14*) *Interpretation Methods and Field Use of Aerial Color Photographs*, by J. F. Wear, Photogrammetric Engineering, vol. 26, No. 4, 1960.

(*15*) *Atmospheric Haze in Aerial Photography*, by P. Bullock, Photogrammetric Engineering, vol. 22, No. 5, 1956.

ACKNOWLEDGMENTS

Appreciation is expressed to the National Park Service for making this project possible; to D. E. Winsor, Federal Highway Projects Division, Bureau of Public Roads, Washington, D.C., for initiating this investigation; to D. C. Harrington, R. A. Bohman, W. Fitzer, and other personnel of the Materials Laboratory of the Federal Highway Projects Office, Region 9, for help and guidance in conducting this project. The interest and cooperation of the Continental Engineering Co., Denver, Colo., which was essential to the success of this project, is also appreciated.

Advance Route-Turn Markers on City Streets

BY THE TRAFFIC OPERATIONS RESEARCH DIVISION
BUREAU OF PUBLIC ROADS

Reported [1] by LAWRENCE D. POWERS
Highway Research Engineer

The study reported in this article was undertaken to focus attention on the possible need for more adequate signing on highway through routes located in urban areas. While major through highways are often expressways or bypasses near large cities, secondary marked routes are expected to be continued through smaller towns and suburban communities. Although emphasis has been concentrated recently on directional signing and marking of routes on high-speed facilities, it was believed that more adequate traffic guidance should be provided on marked routes over urban streets.

In urban areas numerous intersections, complex traffic patterns, competing signs, and varied backgrounds were thought to be confusing to drivers on a through route, particularly to those unfamiliar with the route and, perhaps, traveling over it for the first time. This study showed that a definite benefit was obtained from the presence of one advance route-turn marker but that a second advance-turn marker seemed to be of little added value.

Additional observations were made by a group of junior engineers concerning the study, its results, and other factors related to the effectiveness of the use of advance-turn markers.

Introduction

MANY CITIES without facilities for bypassing through traffic or carrying it on freeway-type facilities must rely on the urban street system to carry marked routes. Even where major through routes in cities are carried on expressways or bypasses, secondary marked routes probably will continue to be carried through smaller towns and suburban communities. It has come to be recognized that more and more attention needs to be given to the advance warning of changes in the direction of a route and the guidance of traffic; most of the emphasis heretofore has been on traffic guidance for high-speed facilities. The need for adequate advance signing is gaining in recognition as being of equal importance in urbanized areas, where drivers are faced with conditions of numerous intersections, marginal conflicts, complex traffic patterns, and many competing signs and confusing backgrounds.

Consider the following situations: An imaginary turn on a fictitious route, in an imaginary city, is marked by a single directional marker at the intersection.

A driver aware of the impending turn in the route, perhaps because he has driven over it and has become familiar with it, may drive along in confidence, get into the proper lane in advance of the turn, signal for his turn, and generally proceed along the route as though it were not marked at all.

Another driver, who may have driven over the route previously but is not familiar with it, perhaps, may remember that he is in the vicinity of a turn but may not be sure of its exact location. Consequently, he may tend to drive more slowly to avoid overshooting the turn, and he may pay less attention to traffic conditions because he is searching for the turn marker.

Yet another driver, traveling over the route for the first time, must rely on route markers and therefore divide his attention between driving and searching for such markers. When he arrives at the turn and sees the directional marker, he may not have enough time or maneuvering distance to make the turn safely.

Suppose that to assist the driver unfamiliar with a route, a marker is placed in advance of the intersection to warn him that the route is going to turn. He will be informed of the impending turn and have time to decelerate safely and to prepare for the maneuver. However, many distracting backgrounds and competing signs in urban areas may pose a problem. Suppose that the driver misses seeing the advance marker because his attention is diverted by traffic or because the marker is obscured by large vehicles. Perhaps, as insurance, another advance-turn marker should be placed in advance of the first one. In an attempt to determine what justification might be found for a second advance-turn marker, or even for one, a controlled study was made of the effect of the presence and number of advance-turn markers on the ability of drivers to negotiate a route in an urban area.

Conclusions

As a result of this study, it has been concluded that a need exists for at least one advance-turn marker placed ahead of the intersections in urban areas where a route turns. The use of a single directional marker at the intersection does not permit enough time for the drivers' responses, and thereby may create confusion, congestion, and possible traffic hazards.

Little evidence was obtained from this study to establish the general value of a second advance-turn marker. However, the second marker may have some value where alinement of route or large vehicles may obstruct a driver's view, and/or where heavy traffic or other distractions may prevent a driver from seeing only one advance marker. Some slight evidence was obtained from the analysis of the turn signal data to indicate that the use of two advance-turn markers also may be advantageous in areas where a long distance exists between successive turns.

Study Site

The route used for this study of the effectiveness of advance-turn markers was a fictitious route, with many turns, through the downtown area of Washington, D.C. The number of advance-turn markers was varied for each intersection on the test route, which was approximately 4 miles in length and had 12 turns. Intersections for turns were selected according to the following listed criteria: (1) a minimum block length of 400 feet in advance of an intersection; (2) signal control;[2] (3) absence of islands or channelized movements; (4) four legs at right angles; and (5) at least two moving lanes on the intersection approach. Of the 12 turns used in the study, 6 were to the right and 6 were to the left. For each direction of turn, three intersections were a short distance from the preceding turn, one to three blocks, and the other three were a longer distance away, more than three blocks. See figure 1.

[1] Presented at the 41st annual meeting of the Highway Research Board, Washington, D.C., January 1962.

[2] It would have been more desirable to have had all the intersections without signals; however, this was impossible in the downtown area. Therefore, to have all intersections as much alike as possible for this study, all those used had signal controls.

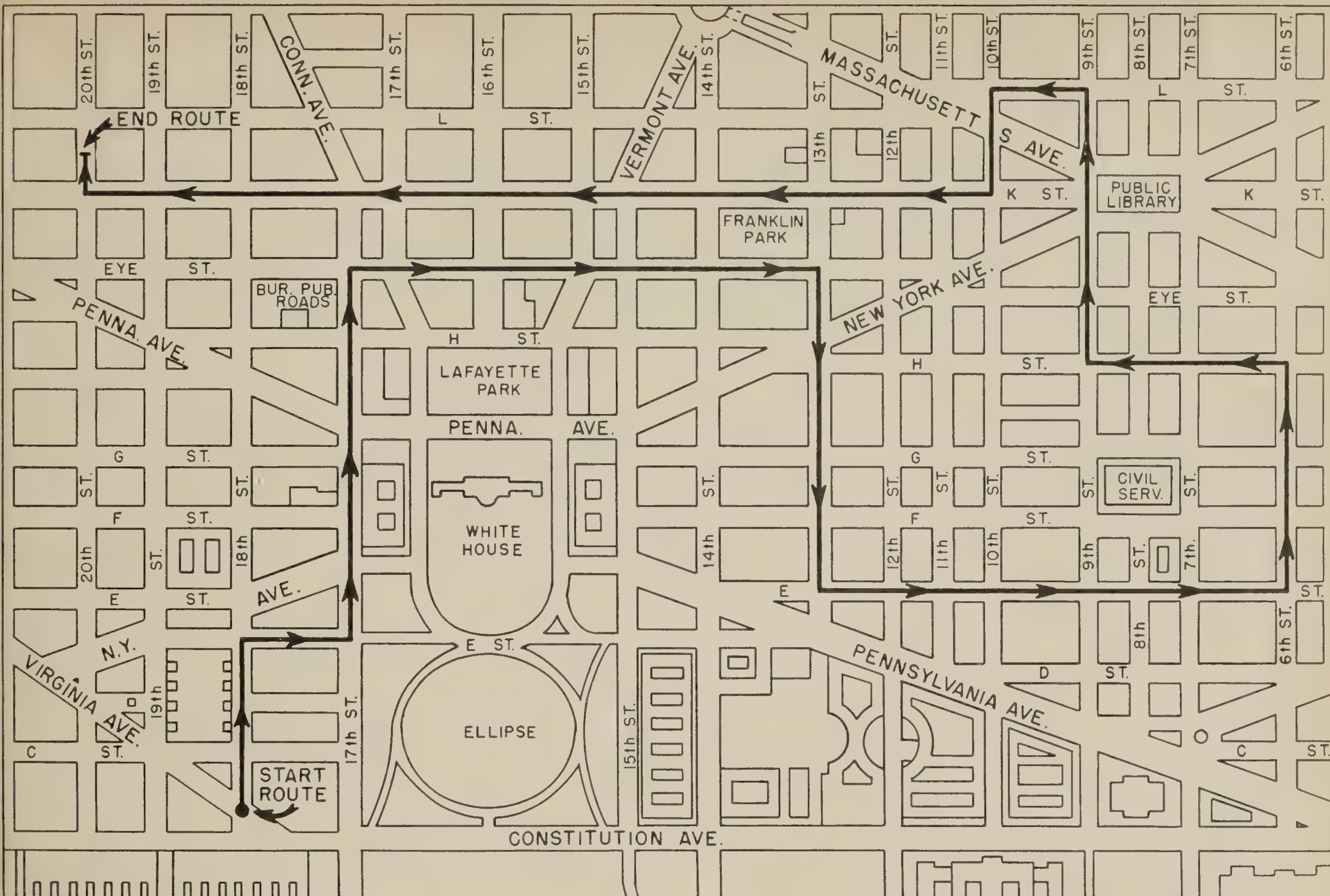

Figure 1.—Map of area in Washington, D.C., showing route for test with advance-turn markers.

A directional assembly with a horizontal arrow was mounted on the far right corner of each intersection where the route turned. The design of the route marker was chosen to conform to the standards in the *Manual on Uniform Traffic Control Devices for Streets and Highways, 1961.* The route marker consisted of a 16-inch white circle on an 18-inch black square (fig. 2), with the designation 00 in 9-inch Series C numerals centered in the circle.[3] Appropriate marker assemblies were made up of this route marker and an appropriate arrow. The arrow plates were 13 inches by 10 inches, the standard size included in the previous issue of the *Manual.* White, nonreflectorized cardboard was used for these markers.

The number of advance-turn markers—none, one, or two—was varied at each intersection on each of the three test days. A balanced design was selected so that each test driver saw each marker combination twice for each direction of turn. The number of long and short turns unfortunately was not balanced with the marker combinations seen by each driver.

[3] The markers were prepared by the District of Columbia Department of Highways and Traffic.

All markers were placed on the right-hand side of the street with a distance of approximately 150 feet between all markers for any one intersection. For ease of mounting, the markers were placed on light poles, signal poles, existing signposts, trees, or portable stanchions. The height of the signs varied from 7 to 11 feet from the sidewalk. The higher limit was sometimes used to avoid other signs, signals, parked and moving vehicles, and other obstructions.

Figure 2.—Advance-turn marker assembly used for the study.

Procedure

The 53 test drivers used in this study were all graduate engineers who had been working for the Bureau of Public Roads for from 6 months to 3 years. The drivers were divided into three groups—two with 18, and one with 17—and each group was used for one day. To avoid any emphasis on the route or the markers, the test drivers were told that the aim of the study was to observe driver characteristics in a downtown environment, and that all 53 of them would drive the same course so that a consistent basis for comparison would be provided.

The drivers were told that the observer in the car would not give directions and that they were to follow the marked-out course. They were also instructed to drive in a normal manner and to obey all traffic laws, such as signaling for turns, turning from the proper lane, and obeying speed limits.

Test runs were made between the hours of noon and 3 p.m., and each subject drove the course once. To prevent the test drivers from overtaking each other, they were started at 5-minute intervals. An observer in each car recorded information as follows: Estimates in car-lengths of the distance from each turn at which the driver entered the proper turning lane and at which the proper turn signal was given, any errors made, and any additional information deemed necessary by the observer. For the purpose of this study, missed turns and correct turns that created hazardous conditions were considered to be errors. Any distances estimated as being longer than 15 car-lengths, approximately 300 feet, were recorded as 15 car-lengths. When a driver missed a turn, he was directed to the point on the route at which he would have been had he made the proper turn, from which point he continued on the test route.

Effectiveness of Advance-Turn Markers

Errors

The desired situation is one in which the driver makes the correct turn without creating a hazard. Therefore, errors, consisting of missed turns or correct turns that created hazardous conditions during this test, were considered one measure of the effectiveness of the advance-turn markers. Without advance-turn markers and with only a directional marker at the intersection, the test drivers made 19 errors, 9 percent of the possible 212 turns for this condition, as shown in table 1. For all practical purposes, the drivers made no errors when advance-turn markers were used. One error was made when two advance-turn markers were in place; however, this error was attributed to extraneous factors.

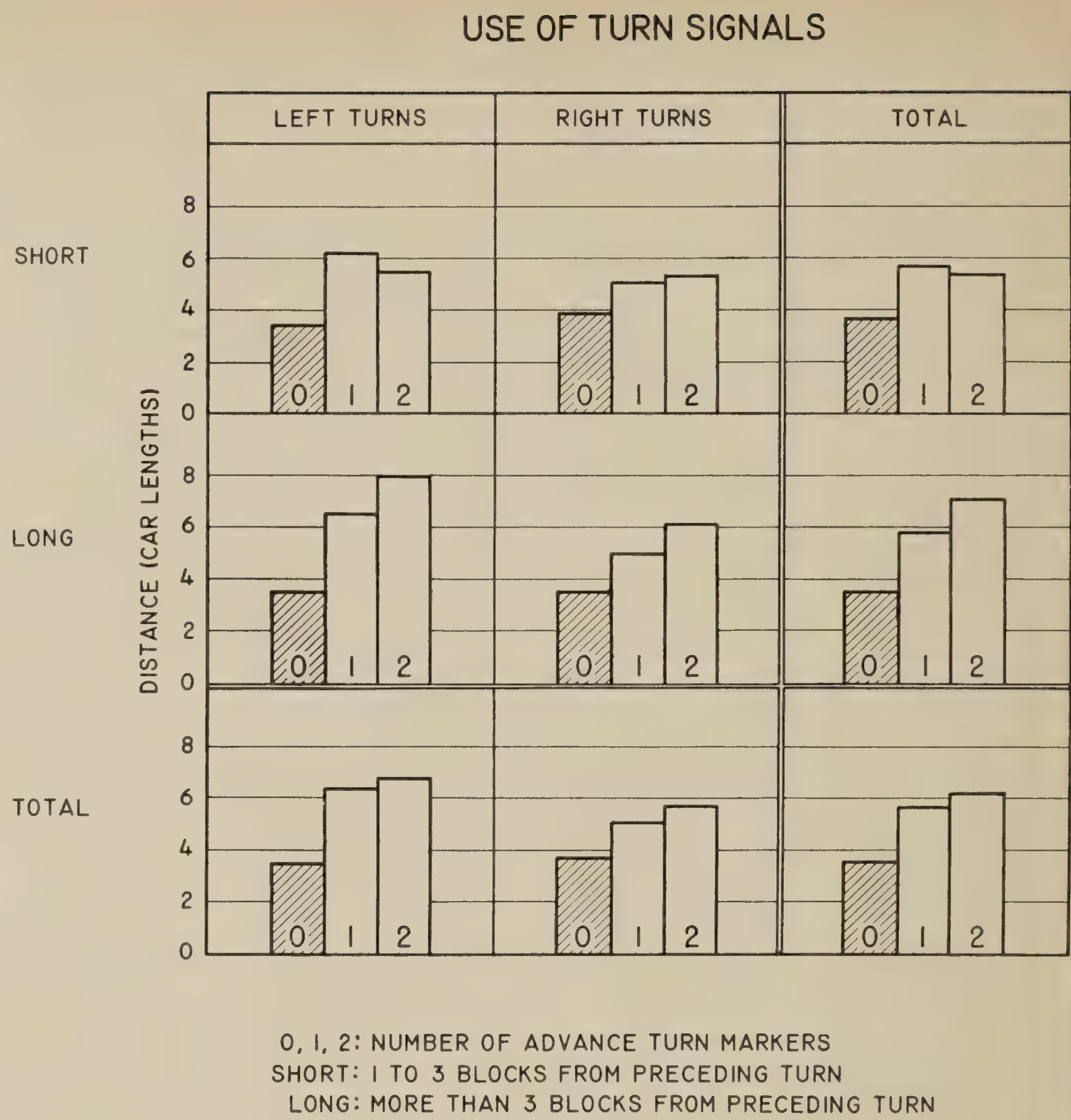

Figure 3.—Chart showing effects of advance route-turn markers on use of turn signals.

A chi-square test performed on the frequencies of errors for this study indicated that there was less than one chance in a thousand that such a disproportionate number of errors could have been made by chance.

Fourteen of the 19 errors were made at left turns; 9 of these 14 were made at the same intersection, where a combination of topography and traffic density were deemed responsible for the high number of errors. As a total of 18 drivers encountered this intersection when there were no advance-turn markers, these 9 errors represent a 50-percent error occurrence.

Table 1.—Errors in following route

Number of advance-turn markers	Possible number of turns	Errors	
		Number	*Percent*
0	212	19	9.0
1	212	0	0.0
2	212	1	0.4

Table 2.—Average distance from intersection at which subject was in proper lane for turn

	Average distance from intersection per number of advance-turn markers—		
	0	1	2
Type of turn:	*Car-lengths*	*Car-lengths*	*Car-lengths*
Short left	5.6	7.4	9.1
Short right	7.0	9.0	10.0
Long left	6.6	11.9	11.7
Long right	6.5	8.6	8.4
All left	6.1	9.6	10.4
All right	6.8	8.8	9.1
All short	6.3	8.2	9.5
All long	6.6	10.2	10.0
Average for all turns	6.4	9.1	9.7

Table 3.—Summary and analysis of variance for variables indicated

Source	Degrees of freedom	Distance in proper lane			Distance at which turn signal given		
		Sum of squares	Mean square	F[1]	Sum of squares	Mean square	F[1]
Number of advance-turn markers	2	1,302	651	[2] 32.6	833	417	[2] 37.9
Direction of turn	1	32	32	1.6	78	78	[2] 7.1
Subjects	52	2,449	47	[2] 2.4	3,963	76	[2] 6.9
Number of advance-turn markers by direction of turn	2	106	53	2.7	75	38	[3] 3.5
Number of advance-turn markers by subjects	104	1,666	16	0.8	1,073	10	0.9
Direction of turn by subjects	52	925	18	0.9	406	8	0.7
Number of advance-turn markers by direction of turn by subjects	104	1,742	17	0.9	790	8	0.7
Error variance	318	6,331	20	------	3,466	11	------
Total variance	635	14,553	------	------	10,684	------	------

[1] F represents the ratio of the mean squares.
[2] Significant at 0.01 level.
[3] Significant at 0.05 level.

Proper lane and use of turn signals

The distance from the turn at which the driver entered the proper lane to make the turn was considered one measure of the effectiveness of the advance-turn markers. A third measure of effectiveness, and also of the driver's awareness of the presence and direction of the turn, was assumed to be the distance from the turn at which he displayed the proper turn signal. These distances were estimated by the observer to the nearest car-length. All subsequent data analysis was carried out in terms of car-lengths.

For convenience in the field, distances greater than 15 car-lengths were recorded as 15. For distances in the proper lane, values of 15 averaged 11 percent with no advance markers, 25 percent with one advance marker, and 33 percent with two advance markers. For turn signals, the respective figures were 1 percent, 8 percent, and 9 percent. Because many of the distances recorded as 15 may actually represent greater distances, and because they represent a substantial percentage of the field entries for the lane data, the average distances and the variability of the distribution of lane distances are probably higher than were computed. The data on lane distances related to the number of advance markers are shown in table 2. The data have been analyzed as to whether the turn was to the right or to the left and as to whether the distance from the preceding turn was long or short. The same type of analysis was made for the data on average distance from the intersection at which the proper turn signal was given; these data are shown in figure 3.

In almost every case there appears to have been some benefit from the use of an advance-turn marker. When distance in the proper lane is the criterion, for both right and left turns, some additional benefit may have been derived from two advance markers where the turn was a short distance from the preceding turn; one advance-turn marker seems to have been sufficient for long turns. When turn signal distances are analyzed, however, the situation was just the opposite. For both right and left turns, no additional benefit was seen for short turns whereas there appeared to have been some for long turns.

Analysis of Variance

In order to further isolate the factors influencing the effectiveness of the route marker installations, an analysis of variance was performed on each of the major dependent variables (table 3). For the variable, distance in proper lane, the number of advance-turn markers was a significant factor but the direction of the turn did not seem to have an appreciable effect. A high variability was noted in magnitude of response among subjects. However, all the interaction terms involving subjects were not statistically significant; therefore, it is concluded that the relative response between conditions with different numbers of advance markers was not significantly different from one subject to another. It is believed that the possible higher actual variability resulting from the 15-car-length cutoff would not have affected these results.

Figure 4.—Illustration of how trucks may prevent a driver from seeing an advance route-turn marker.

For the variable, proper turn signal, the number of advance-turn markers was also a significant factor in difference of response. In this case, however, the direction of turn does seem to have made a difference, possibly because drivers are more likely to signal for a left turn, which involves a greater probability of conflict, than for a right turn. This is reflected by the data in figure 3. In addition, since the interaction of the number of advance markers with the direction of the turn leads to statistical significance, it is concluded that certain combinations of the number of advance markers and the direction of the turn result in different effects. As in the case of the lane data, there was a high variability in the magnitude of response among subjects. Again, since all the interaction terms involving subjects were not statistically significant, it is concluded that the relative response to the different numbers of advance-turn markers was not significantly different from one subject to another. Combining the nonsignificant interaction terms with the error term and recomputing the ratios of the mean squares did not affect the results.

Discussion

It might be argued that the test subjects were not typical of the average driver. It is believed that their experience in the field of highway and traffic engineering would tend to result in somewhat higher performance in the study. However, this study was concerned with the relative effects of various numbers of advance-turn markers, and it is believed that such relative effects would be reflected in the performance of this group. Perhaps the observed effects would have been more pronounced with more typical subjects.

The number of errors that occurred was lower than had been expected. The reasons for this small number of errors are subject to conjecture but three factors are believed to have been responsible. One has already been mentioned: the subjects were all graduate engineers and, possibly, more alert and more aware than average drivers. Another factor was related to the target value of the sign; this will be discussed later. Finally, it should be noted that the directional markers at the intersections were always mounted on the far right corner, which is also a location for traffic signals in the District of Columbia. For convenience, these turn markers were often mounted on the signal poles, usually very close to the signal. It is presumed that most, if not all, drivers were looking for the signal and therefore had more of a chance to see the marker. Those stopped for the traffic signal also had much more time to see it. However, the chances for being stopped for a traffic signal were the same for all drivers, regardless of the number of advance markers. Therefore, the fact that almost all the errors were made when there were no advance-turn markers

Figure 5.—An intersection where the test route turned left is just beyond the stanchion in the center of the street. When no advance-turn markers were present, 50 percent of the test drivers missed this turn.

indicates that the presence of an advance-turn marker was beneficial in reducing errors.

As was noted previously, any distance of more than 15 car-lengths was reported as 15. Consequently, the average distances for the condition where one or two advance-turn markers were present were very likely higher than those calculated because many of them were recorded as 15 car-lengths. Other factors that might have affected the test results are: the subjects were not specifically told the purpose of the study, and they did not receive instructions to relate the proper lane and the use of the turn signal to their knowledge of the impending turn. They might have been in the proper lane by chance. Conversely, they might have activated their turn signals when close to the intersection even though the markers had been seen further back. However, it is believed that the net result of these factors tended to minimize the observed differences.

Figure 6.—Illustration of how well the white route marker on a black square shows up against both dark and light backgrounds.

FIELD CREW OBSERVATIONS

The field crew [4] made additional observations concerning the study and its results. At several intersections topography, alinement, or physical obstructions, such as transit buses or trucks, obscured to some extent the driver's view of the turn markers. Illustration of how parked trucks may prevent a driver's seeing one advance route-turn marker is shown in figure 4.

Errors

A large percentage of the missed turns came from one intersection in the heart of the downtown area, shown in figure 5. The block on the approach to the intersection was on a downgrade, whereas the intersection itself and the preceding one were level. Neither the intersection nor the directional marker could be seen until the driver had passed through the preceding intersection. While he was on the downgrade, the directional marker, mounted on the far side of the level intersection, was not in his direct line of sight. Because he was not aware of the impending left turn until he was close to the intersection, the heavy traffic often prevented the driver from getting into the proper turn lane.

Where no advance-turn markers were posted, drivers repeatedly had near-misses because they were positioned in the wrong lane. The driver often held up traffic near or at the intersection in an attempt to position himself in the correct turning lane. This situation was considered by the observer to be an error if the turn created a hazardous condition.

When the density of traffic was low on one-way streets, the driver frequently had no realization that the street was one-way. Consequently, on left turns the driver would often signal and turn from the wrong lane. For purposes of analysis, this was not treated as an error because no actual hazard was created; however, these subjects were not credited with being in the proper lane.

Design of Marker and Arrows

One possible reason for the low number of errors was the high target value of the design used for the route markers. Observation in the field showed that the white circle on black square design, based on the new standards in the *Manual on Uniform Traffic Control Devices for Streets and Highways, 1961,* was visible at a much greater distance than had been expected, and long before the numerals were legible. It easily could be picked out from the array of other signs visible along a street (fig. 6).

For the directional markers at the intersection, it was difficult to determine in which direction the horizontal arrow was pointing, except at relatively short distances away from it (fig. 7). The direction in which the advance-turn arrow was pointing could be determined at a somewhat greater distance because the position of the vertical part of the shaft gave a clue to its orientation. It would seem, therefore, that the old 13-inch by 10-inch arrows are inadequate, even for low-speed urban usage.

It was observed that some of the test drivers were not aware of any difference in meaning between the bent advance-turn arrow and the horizontal directional arrow. This was particularly evident in situations where two advance-turn markers were used and, because of a short block, the first marker had necessarily been placed close to the preceding intersection. Some drivers, unaware of the difference in the arrows, became confused and almost turned a block too soon.

Figure 7.—Note the differences in legibility of the route marker, numerals, and arrow when this photograph is viewed close up or at arm's length.

[4] The field crew included a group of men who, during their period of training as Junior Engineers in the Washington office of the Bureau of Public Roads, conducted the fieldwork, performed the preliminary data analysis, and submitted a preliminary report: David M. Ham, Thomas E. Knisely, Gardner M. Rice, George A. Rodes, Albert E. Stone, and John R. Webster.

A Preliminary Evaluation of Color Aerial Photography for Use in Materials Surveys

BY THE DIVISION OF PHYSICAL RESEARCH
BUREAU OF PUBLIC ROADS

Reported [1] by JESSE R. CHAVES,[2]
Highway Research Engineer

Findings from an experimental study on the use of color aerial photography for locating and determining the types of materials available for highway construction are included in this article. As a result of the impetus of an expanded highway construction program, significant problems confront location, design, and materials engineers. The introduction of new techniques and modern methods in highway location and design have made many conventional methods of materials investigation obsolete. Photogrammetry and related procedures have brought a new concept to highway location and design by transferring much of the job of highway location from the field to the engineering office. The opportunity to thoroughly review and generally classify the materials along the staked centerline of the highway, as a field operation, has been curtailed. The lead time for the materials engineer to obtain and test samples has been reduced to a point where the required reports and pertinent laboratory test data sometimes may not reach the design engineer in time for his full use. To relieve this situation, new methods are being sought for preliminary materials investigation.

One answer to the problem appears to be color aerial photography. Through this medium, the materials engineer, like the location and design engineer, has been able to bring the investigation primarily to the engineering office. Considerable progress has been made by the use of conventional black-and-white photographic interpretation. However, the relatively few tonal shades of white to black sometimes are somewhat of a handicap: Photographic interpretation used to locate materials sources, to map geologic materials, or to determine soil and ground conditions is dependent to a large degree on color variations. Thus, use of color aerial photographs will enable the materials engineer to obtain more information and permit him to do his work more efficiently and reliably.

Introduction

ALTHOUGH black-and-white aerial photography has been used in mapping for a number of years by Federal and State government organizations and by private groups, the general use of color aerial photography has been somewhat delayed. This article reports on an evaluation made in an attempt to determine the practicality of the use of color aerial photography for materials surveys, particularly by the Bureau of Public Roads and State highway departments.

Black-and-white aerial photography has been used for a number of years by some State highway departments for materials surveys and inventories, by private organizations and individual consultants for mapping studies and explorations for construction materials, and by the Bureau of Public Roads for materials searches in Alaska and several national forests and parks. In addition, the Bureau has sponsored projects in some States for materials surveys and exploration by aerial photography. Black-and-white aerial photographs for many of these studies may be obtained from the Federal Government; they are generally at a scale of 1:20,000.

The delay in use of color aerial photography for materials surveys has resulted primarily from its high cost, slow film speeds, and the poor quality of color reproduction. However, some U.S. Government agencies have been using color aerial photography: The Geological Survey of the Department of the Interior has used colored aerial transparencies for some geological mapping and mineral exploration studies; the Coast and Geodetic Survey of the Department of Commerce has used them for coastal mapping; the Corps of Engineers, Department of the Army, and other military organizations have used them for military intelligence studies, camouflage detection, and special terrain studies; and the Department of Agriculture has used them for detection of diseased crops and trees. Private commercial organizations and universities have experimented with color aerial photography for specialized uses.

In 1958, the Federal Highway Projects Office of Region 9, the Bureau of Public Roads, contracted to have some experimental color aerial photographs taken in Dinosaur National Park in Colorado and Utah. The results of this experiment were so promising that the possible advantages to be gained from using color aerial photography for soil and materials surveys were considered. Consequently, various other projects for aerial color photography were carried out in Colorado, New Mexico, Utah, and Wyoming.

Continuing the use of color aerial photography, the Bureau of Public Roads in 1961 entered into an agreement with the National Park Service for the Federal Highway Projects Office of Region 9 to conduct a comprehensive inventory of construction materials along the major highway system in Yellowstone National Park. The Park Service provided the funds for this work. In addition to carrying out the inventory, the Bureau of Public Roads made a preliminary evaluation of color photography for use in materials surveys. Reconnaissance mapping of significant geologic units, normally of concern in preliminary highway location and design, and aerial photographic interpretation of special ground conditions were carried out in conjunction with this materials search. In the evaluation, the color aerial photographs previously obtained by Region 9 in Wyoming, Colorado, Utah, and New Mexico were considered.

Conclusions

From the evaluation made in this study, it is concluded that good quality color aerial photography can be obtained and that it is of value in searches for highway construction materials. Although black-and-white aerial photography undoubtedly will continue to be used, it is believed that materials surveys can be completed more efficiently and reliably with color photography. The color transparencies have been found particularly useful for materials surveys as they generally provide information that cannot be seen on black-and-white photographs. The success of this proj-

---

[1] Presented at the 41st annual meeting of the Highway Research Board, Washington, D.C., January 1962.

[2] Much of the information for this article was provided by Robert L. Schuster, Associate Professor of Civil Engineering, University of Colorado, and Robert J. Warren, Highway Engineer, Federal Highway Projects Office, Region 9, Denver, Colo., U.S. Bureau of Public Roads.

ect and the experience with the other color photography flights in Region 9, for which 700 linear miles have been photographed in color since 1958, have prompted plans for 250 linear miles of color aerial photography during 1962.

As improvements are made in color film, such as the development of faster emulsions with greater exposure latitude that provide greater contrast, color aerial photography is expected to become more useful to highway engineers for a number of purposes. Although this investigation did not encompass the use of color for engineering soils surveys, the casual observations made concerning the identification of soil differences by photographic interpretation appears to be encouraging. An evaluation of color photography for a broad range of geologic materials and variety of soil forming conditions is needed before color photography is adopted for engineering surveys.

It also is believed that color aerial photography will be considered for use in photogrammetric mapping when the technical difficulties have been overcome in the development of a stable film base to which color emulsions will adhere.

Procurement of Aerial Photographs

Although the Bureau of Public Roads had contracted to have 428 linear miles of color photography taken in Yellowstone National Park in 1961, inclement weather and difficulty encountered in obtaining the required color film prevented completion of the contract; only 300 miles were photographed. It is planned to photograph the remaining mileage during the summer of 1962. The color aerial photographs were taken, at a scale of 1:6,000 (1 inch to 500 feet), in single flight strips along the major road system in the park. In addition, several segments were covered by two or more adjacent flight strips with standard sidelap, to furnish adequate coverage of the area. A number of side flights, mainly along minor rivers, were made where potential sources of materials were suspected. Some oblique photographs were taken to supplement the vertical photographs. A small segment of the photography flown at 1:6,000 was flown also at 1:4,800 (1 inch to 400 feet) to permit a comparison of the photographic detail. Black-and-white photographs (panchromatic) at a scale of 1:6,000 also were taken for segments totaling 100 miles. This permitted a comparison of the two types of photography.

Use of Color Transparencies

The use of color aerial photographs for materials surveys may take considerable time and effort in the office and the field. The time and effort required is related to the training of the personnel interpreting the photographs. The education, training, and experience of the color aerial photographic interpreter is significant. A background in the earth sciences, training and experience in aerial photographic interpretation, and a knowledge of highway construction materials, photogrammetry, and highway engineering are highly desirable requisites for aerial photographic interpreters.

Background orientation

The procedure of using color aerial photographs for a materials survey is similar to that used with black-and-white photographs. For this project, a search and review was made of published geological literature pertinent to the areas to be studied: literature such as geologic maps, bulletins, folios, and reports. Information on known sources of construction materials was obtained from Bureau of Public Roads and Park Service engineers, who were familiar with these areas. Thus, as much background information as possible was obtained before the initial study of the aerial photographs was undertaken. The amount of information available and its value varied for different areas. Rather detailed, recently published geologic maps and reports were available for some areas and only old generalized reconnaissance-type geologic maps were available for others. Background orientation of this nature is considered an essential part of a materials investigation.

Upon completion of the literature review, a rather rapid preliminary examination with a mirror stereoscope was made of the transparencies for the flight strips 4,500 feet wide. From this initial examination, the information obtained from the literature survey was correlated with the aerial photographic patterns. Specific geologic features and landforms were marked on the appropriate plastic envelopes in which the color transparencies had been placed. These features were later investigated in the field. This procedure made it possible to plan and more efficiently perform the field work.

Ground examination

The ground examination consisted of examining rock outcrops, geologic materials in highway cuts, and river-cut banks that had been noted from the aerial photographs. Shallow holes were dug with shovel and mattock; and borings were made with a hand auger to expose materials below the ground surface. Materials brought to the surface as a result of animal digging also were examined. Whenever possible, the field notes were made to include descriptions of soils and rocks, and the approximate depths at which the various types of materials were located. Such ground examination is an essential part of the survey and its importance cannot be overemphasized. Reference numbers for field observations were placed on the envelopes of the appropriate aerial transparency. Wherever possible, a stereoscopic examination of the color transparencies was made in the field with a portable lightbox and pocket-lens stereoscope. Color and black-and-white photographs were also taken from the ground during the field investigation.

Examination of transparencies

After the preliminary phase, the color aerial photographs were examined in greater detail. Units such as granite, glacial till, alluvial fans, and landslides were mapped and their boundaries were outlined on the plastic envelopes of alternate photographs in each flight strip. Appropriate mapping symbols were developed for various types of rock, landforms, and ground conditions. Boundaries or areas that appeared doubtful from the transparency examinations were noted and later checked in the field. The descriptions written for the mapping units were included as a part of the preliminary report written for each segment studied during this project. Potential materials sources were noted and sites for future sampling were marked on the envelopes of the photographs.

To assure coordination of procedure with the policy and planning of the Park Service, the transparencies for each of the indicated sources were stereoscopically examined in the office by a Park Service official before any sampling or field investigation with mechanical excavation equipment was undertaken. All the approved potential sources of material were then explored with a truck- or crawler-mounted backhoe, capable of excavating to a depth of about 12 feet. Representative samples were taken for laboratory testing. A brief description of the materials taken from the test pits was written, and the approximate quantity in each potential source was determined by the field crew. (Although not used in this investigation, electrical resistivity equipment will be used in future explorations to help determine the depths and quantities of material in various deposits.) Final reports on the materials investigations, including the results of laboratory tests, were prepared for each individual highway segment in the park included in the project.

Viewing Equipment

A suitable lighting system is required for proper viewing of color aerial transparencies with a stereoscope. Almost any type of a lightbox can be used but a source of balanced light—one that provides a spectrum comparable to that of sunlight—is desirable. A combination of fluorescent and incandescent lamps of about equal wattage will provide a balanced source of light. Some means of varying the intensity of the light is also desirable because the number of color distinctions that the human eye can make varies with the intensity of light; more color distinctions can be made at relatively low levels of illumination. To prevent hot spots and provide an even distribution of light throughout the transparencies, a light diffuser is required. Because excessive heat causes color transparencies to curl and may permanently damage them, ventilation holes are required; and it is desirable to have a small air blower in the lightbox to dissipate the heat created by the lamps.

On this project, a small, portable homemade lightbox was used; it was equipped with fluorescent lights and could be operated on either 115 volts of alternating current or 12 volts of direct current. With this viewer, a lens stereoscope was used to examine transparencies in the field. A larger, less portable lightbox was used in the office for viewing with a mirror stereoscope.

Protection of transparencies

When not in use, the color transparencies were stored in transparent plastic envelopes; annotations were made on these envelopes with a grease pencil. The envelopes containing the transparencies were placed in three-ring notebooks, which provided convenient storage and made them readily available for use in the field.

Discussion

The findings of this study represent the result of only one summer's work in which color aerial photographs were used for locating material sources and for generalized mapping. As more use is made of color aerial photography, undoubtedly more information concerning utilization of such photographs will become available. Since the human eye is capable of distinguishing about 20,000 shades and hues of color, it is not too surprising to have found that color photographs have many advantages over black-and-white photographs for interpretation purposes. The use of black-and-white aerial photographs requires interpretation of specific ground conditions, soils or geologic materials, in terms of photographic tones. The number of tones or shades of gray that can be differentiated is extremely limited; many different types of soils or geologic materials of various colors may be reflected by about the same tonal expression. It should be remembered that neither photographic tones nor color alone are used in the identification of specific materials or in the determination of ground conditions. In some instances, the type of landform, gully, or drainage pattern may be the basis for recognition rather than the photographic tone or color.

Acceptable Color Photography

When color aerial photographs are used for materials surveys, relative rather than absolute colors are of primary importance. Thus, slightly off-color photographs are as usable as those showing exact or nearly exact ground colors. This statement should not be misinterpreted as an endorsement for marginal or poor quality work. Visually, it is only possible to tell whether the color registered on the photograph approximates that on the ground. The quality of the illumination of the transparency also affects the visible color, although the true colors may be registered on the film. If the illumination is deficient in a portion of the visible light spectrum, then the colors in that portion of the spectrum cannot be perceived.

Requirements as to endlap, sidelap, crab, and tilt are not as stringent for acceptable color photographs for materials surveys as those for mapping by photogrammetric methods. In general, acceptable color photography must have good definition of images and even light distribution, must be free of clouds, and must have the proper exposure and color balance. Color photography that has been considerably overexposed or underexposed, discolored in processing, or is off the designated flight lines should be rejected.

Overexposed color photographs have a washed-out appearance—many of the colors do not register on the film. Obtaining properly exposed photographs becomes a particularly serious problem in areas with little or no vegetative cover because of the excessive reflection of light and the fact that light meter readings are not always reliable in such circumstances. A greater percentage of the ground colors register on underexposed film than on overexposed; for this reason, slight underexposure is more desirable than overexposure. For the most part, the color photographs for this study were properly exposed, and the colors recorded on the film compared well with those observed on the ground.

Camera and films

The camera used for this project was equipped with a lens having a 6-inch focal length with a maximum aperture of f 5.6. The color transparencies from such a camera are 9 by 9 inches (23 by 23 centimeters). The average flight height above ground for 1:6,000 photography was 3,000 feet.

The color film used for this project had an exposure index of daylight-40. This is a reversal color film of the subtractive type that, when processed, gives a color positive transparency. Emulsion characteristics of this type of film usually vary somewhat from roll to roll; therefore, the exposure index as well as the color balance also varies. Because of this, it was necessary to make trial flights over the terrain for which photography was desired, to determine the proper combination of shutter speed and lens opening that would give optimum exposure and color reproduction for each roll of film. A corrective color-balancing filter had been provided with each roll of film because of these variations in film characteristics. Proper color balance must be obtained to assure relatively accurate color reproduction in the aerial transparency. To obtain this color balance and to minimize shadows, the aerial photographs on this project were taken as near peak solar altitude as possible.

Filters

Haze filters are sometimes used in taking color pictures to prevent the overall bluish hue that is caused by the dispersion of light by dust and water particles suspended in the atmosphere. Haze does not present a serious problem with low-altitude photography, but its effect becomes increasingly apparent as the height above ground of the aerial camera is increased. The magnitude of haze also varies with the time of day, season, and geographic location. Because of the use of haze filters, the need for color balance, and the slow speed of color film, aerial lenses for color photography must have larger apertures than those used for black-and-white photography. High quality lenses having good resolution, little color or spherical distortion, and relatively even light distribution are required for color aerial photography. With the development and use of faster color film, the requirements for lighting and size of lens opening are expected to be reduced.

Processing color film

Requirements for the developing and processing of color film are far more exacting than those for black-and-white film and must be met if acceptable color photographs are to be obtained. The composition of developing and fixing solutions and the developing time must be controlled carefully. The temperature of developing solutions, for example, must be maintained to within $\pm 1°$ F. Considerable care also must be exercised while drying or handling the film. Special, rather costly equipment is needed for adequate processing.

Color film should be developed within 24 hours after its exposure; when this is not possible, the exposed undeveloped film should be refrigerated. Because of the tendency for the dyes in unexposed color film to change with time, particularly in hot, humid climates, all unused color film should be stored at temperatures ranging from 45° to 65° F.

Advantages in Use of Color Photography

One obvious advantage in the use of color aerial photographs is that cultural features such as highways, trails, buildings, and aerial targets are more readily identifiable than on black-and-white photographs. Also, it is easier to orient oneself in the field by use of color aerial photographs because the terrain and culture appear to be more natural. Image definition is better on color aerial transparencies than on black-and-white prints because the use of prints results in some loss of detail.

Wet soils, organic soils, boggy ground, and seepage zones can be easily identified on color photographs because of the green grass and other vegetative growth in these wet areas. The brownish color of the organic soils is readily recognized. Minor drainageways, poorly drained depressions or swales, and seepage areas in landslides show quite clearly. On the black-and-white photographs, these areas have generally darker photographic tones, but identification or delineation is not as positive and, in some instances, the conditions are not apparent.

The identification and delineation of such rock types as granite, rhyolite, basalt, limestone, shale, and sandstone are greatly facilitated by color photography; large boulders in glacial till can be identified more readily. Color is particularly helpful in instances where the rock fracture pattern or other features are not distinctive and cannot be used for identification. In one instance, however, the fracture pattern for a granite was so distinctive that it appeared equally well on both the color and black-and-white photographs.

Various vegetative types can be identified more readily on color than on black-and-white photographs. It is not always possible to correlate a particular type of vegetation with a specific type of material or ground condition, but color photography will be useful wherever reliable correlations can be made. For example, aspen growing on alluvial fans in southern Colorado clearly outlined the extent of these deposits. Dense timber cover that completely obscures ground detail is a liability in aerial photographic interpretation with both black-and-white and color photographs. Thus, a dense cover of lodgepole pine in one area of Yellowstone National Park prevented the detection of local, thin deposits of glacial sand overlying volcanic flows.

In several cases the colors of certain features were not of the same density in adjacent pictures—vividly colored algae growing in hot springs appeared in almost true color on one photograph but were almost completely washed out in the next. This apparently was the result of the difference in the angle of reflected light from the ground for successive plane positions. Although this change in color density may be obvious when individual photographs are compared, it generally is not apparent when pairs of photographs are viewed stereoscopically. A similar difference in photographic tones also was noted on black-and-white photographs of sand and gravel river bars.

Photographic Scales

Color photographs were taken at several scales so that a comparison could be made as to their relative value for materials surveys. These scales and their respective flight strip widths were: 1:4,800 (1 inch to 400 feet), 3,600 feet; 1:6,000 (1 inch to 500 feet), 4,500 feet; and 1:12,000 (1 inch to 1,000 feet), 9,000 feet. All transparencies had an image area of 9 by 9 inches square. This study of photographs at different scales confirmed the experience in Region 9, which had indicated that a scale of about 1:6,000 would be the most desirable one for use in locating sources of materials.

Use of a scale at 1:4,800 permits more ground detail to be observed but the flight strip's width is one-fifth less than that for photographs made at the scale of 1:6,000. The advantage gained by having the extra 900 feet in the flight strip's width with the 1:6,000 scale more than offsets any slight advantage gained by use of the larger scale. The additional detail on the photographs taken at the 1:4,800 scale did not help appreciably in the detection of materials sources or in the determination of ground conditions. Photographs taken at a scale of 1:12,000 showed insufficient ground detail for optimum use; this smaller scale, however, did provide greater width of coverage and permitted a broader overall view. Examination of the photographs at this smaller scale required more time for study than those taken at a scale of 1:6,000 and many uncertainties remained regarding actual ground conditions. On the basis of the evaluation of these photographs, it is believed that use of scales ranging from 1:6,000 to 1:8,000 will provide sufficient ground detail and width of coverage for optimum use in materials surveys.

Cost of Color Photography

The cost of color photographs should be considered in relation to actual savings in time, money, and increased information made available through their use—not by the actual cost alone. The added advantages and savings gained through the use of color are not always measurable. The costs involved in procuring either black-and-white or color aerial photographs are small, if not insignificant, compared to the final cost of constructing a highway. If a single, good source of material is located for a project or if the haul distance to a suitable source can be shortened appreciably, the cost of photography and for the personnel involved may well be paid for many times. Similarly, the savings made by recognition and avoidance of unstable ground, hard bedrock, seepage areas, or other poor ground conditions in projecting a preliminary highway alinement are obvious.

The average price ranges per linear mile for 9- by 9-inch color aerial transparencies, shown in the following table, are for photography obtained by negotiated contract in Region 9; prices may not be the same elsewhere. The prices shown here included the cost of the plastic envelopes in which the transparencies were placed.

Scale	*Cost per mile*
1:4,800	$43.75–$60.75
1:6,000	38.25– 52.75
1:12,000	27.00– 33.50

The only available price for black-and-white photographs is for those at a scale of 1:6,000. The cost ranges between $20 and $27.50 per linear mile as compared to the range of from $38.25 to $52.75 for color transparencies at the same scale. The conventional photographs are printed on double-weight paper with a semi-matte finish. Two sets of black-and-white prints and an uncontrolled photographic index are included in this price.

It has been the experience of the Federal Highway Projects Office, Region 9, that color photography may be obtained at somewhat lower prices through competitive bids, but that the quality is often poor and not acceptable. Price quotations will also vary with the number of miles of photography required per job, and the distances involved in getting a plane to the area to be photographed. Color photography in Region 9 generally has been taken at the same time as the black-and-white photographs used for photogrammetric mapping.

Color aerial prints, rather than color aerial transparencies, are not acceptable for use in materials surveys because of their lack of good color reproduction as well as their excessive cost. Relatively large emulsion shrinkage of color prints causes them to curl with small changes in temperature and humidity. The high cost of color prints is a direct reflection of the skill and experience required and the difficulties that may be encountered in obtaining and producing color pictures of acceptable quality. Recently a price of $4 to $5 per print was quoted on color prints when the order was for 50 prints or more.

Care Required for Transparencies

Greater care is required in handling and working with color aerial transparencies than with black-and-white photographic prints. If a transparency is lost or damaged it cannot be replaced, as with prints. Furthermore, the reproduction of color transparencies is costly and the color reproduction from the originals cannot be relied upon. A disadvantage to the use of color transparencies is the need for suitable illumination to view them in an office and, if they are to be used in the field, a special portable lightbox adapted for battery operation is required. When they are used in the field under extremely hot and dry climatic conditions, the transparencies will curl; but, under similar conditions, black-and-white photographs printed on double weight paper also curl and become brittle.

Procurement of Quality Aerial Photography

Equipment used to process color film is rather expensive and some commercial organizations have neither the equipment nor the experience in taking or processing color photographs that are required to produce a good quality job. For this reason, color photography has been procured in Region 9 by negotiated contract, in order to obtain a high quality product at a reasonable price. Unless a State highway department has had previous experience with a commercial organization, it is recommended that, before a contract is entered into, the organization concerned be required to submit sample photographs taken of the area at the desired scale. Samples at other scales or at the required scale of other areas should not be accepted as evidence that the organization is capable of producing acceptable photographs for a particular area.

The type of camera and lens used for aerial color photography is highly important. There has been a tendency for commercial organizations to use lenses with focal lengths of more than 6 inches, such as 8¼ inches or 12 inches. Although the use of longer focal-length lenses produces better light distribution, which provides more uniform density in the picture, a higher flying height is required to obtain pictures at a given scale and this, in turn, increases the haze effect that causes the undesirable bluish hue in color transparencies. Quality lenses with shorter focal lengths do not produce noticeable vignetting, and the haze is less of a problem because of the lower flying heights required. Experience on this and other projects in Region 9 indicates that the quality of a camera for color aerial photography for materials surveys should be equal to or exceed that of a Zeiss RMK 15/23 equipped with a Pleogon lens. No attempt was made to evaluate various types of color aerial film in this study. The contractor used Kodak Ektachrome Aero Film; he had previously produced acceptable color aerial transparencies with this type of film.

The season and time of day are important factors that affect the quality of both color and black-and-white photographs. Preferably, color photographs should be taken during the interval between the complete disappearance of snow and the leafing of deciduous trees or between the time the trees are bare and the first snow. Photographs taken in the fall have longer shadows than those made in

(*continued on p. 11*)

U.S. GOVERNMENT PRINTING OFFICE: 1962

PUBLICATIONS
of the Bureau of Public Roads

A list of the more important articles in Public Roads *and title heets for volumes 24–31 are available upon request addressed to ureau of Public Roads, Washington 25, D.C.*

The following publications are sold by the Superintendent of ocuments, Government Printing Office, Washington 25, D.C. rders should be sent direct to the Superintendent of Documents. repayment is required.

NNUAL REPORTS

nnual Reports of the Bureau of Public Roads:
1951, 35 cents. 1955, 25 cents. 1958, 30 cents. 1959, 40 ents. 1960, 35 cents. 1961, 35 cents. (Other years are now out f print.)

REPORTS TO CONGRESS

Factual Discussion of Motortruck Operation, Regulation and Taxation (1951). 30 cents.

Federal Role in Highway Safety, House Document No. 93 (1959). 60 cents.

Highway Cost Allocation Study:
- First Progress Report, House Document No. 106 (1957). 35 cents.
- Final Report, Parts I–V, House Document No. 54 (1961). 70 cents.
- Final Report, Part VI: Economic and Social Effects of Highway Improvement, House Document No. 72 (1961). 25 cents.

The 1961 Interstate System Cost Estimate, House Document No. 49 (1961). 20 cents.

U.S. HIGHWAY MAP

Map of U.S. showing routes of National System of Interstate and Defense Highways, Federal-aid Primary Highway System, and U.S. Numbered Highway System. Scale 1 inch equals 80 miles. 25 cents.

PUBLICATIONS

Catalog of Highway Bridge Plans (1959). $1.00.

Classification of Motor Vehicles, 1956–57 (1960). 75 cents.

Design Charts for Open-Channel Flow (1961). 70 cents.

Federal Laws, Regulations, and Other Material Relating to Highways (1960). $1.00.

Financing of Highways by Counties and Local Rural Governments: 1942–51 (1955). 75 cents.

Highway Bond Calculations (1936). 10 cents.

Highway Capacity Manual (1950). $1.00.

Highway Statistics (published annually since 1945):
1955, $1.00. 1956, $1.00. 1957, $1.25. 1958, $1.00. 1959, $1.00. 1960, $1.25.

Highway Statistics, Summary to 1955. $1.00.

Highway Transportation Criteria in Zoning Law *and* Police Power and Planning Controls for Arterial Streets (1960). 35 cents.

Highways of History (1939). 25 cents.

Hydraulics of Bridge Waterways (1960). 40 cents.

Landslide Investigations (1961). 30 cents.

Manual on Uniform Traffic Control Devices for Streets and Highways (1961). $2.00.

Parking Guide for Cities (1956). 55 cents.

Peak Rates of Runoff From Small Watersheds (1961). 30 cents.

Road-User and Property Taxes on Selected Motor Vehicles, 1960. 30 cents.

Selected Bibliography on Highway Finance (1951). 60 cents.

Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958: a reference guide outline. 75 cents.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-61 (1961). $2.25.

Standard Plans for Highway Bridge Superstructures (1956). $1.75.

The Identification of Rock Types (revised edition, 1960). 20 cents.

The Role of Aerial Surveys in Highway Engineering (1960). 40 cents.

Transition Curves for Highways (1940). $1.75.

UNITED STATES
GOVERNMENT PRINTING OFFICE
DIVISION OF PUBLIC DOCUMENTS
WASHINGTON 25, D.C.

OFFICIAL BUSINESS