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# Traffic Assignment



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# HIGHWAY RESEARCH BOARD
## Bulletin 61

# *Traffic Assignment*

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# FOREWORD

THE ESTIMATED allocation of traffic to a proposed highway facility is commonly termed "traffic assignment." The estimated allocation may indicate annual average daily traffic volumes, periodic directional movements, and composition by types. Traffic assignment is fundamental to the justification of a proposed highway facility and to its structural and geometrical design, to spotting points for access, and for advance planning of traffic regulation and control measures. As yet, traffic assignment is considered to be more of an art than a science and the researches reported in this bulletin represent some initial efforts to place traffic assignment on a scientific foundation.

The assignment of traffic to a proposed highway facility involves an estimation of volumes of the following components of the traffic stream expected to use the facility: (1) traffic diverted from alternate routes; (2) traffic created by the new facility (traffic previously suppressed by reason of congestion of the alternate routes); (3) traffic resulting from intensified land use provided by a new and convenient avenue of land access; and (4) traffic increase due to growth in vehicle registration and increased use of vehicles.

Traffic assignment usually is expressed in terms of the anticipated usage of the facility upon its completion and in terms of a forecast of its usage at some future date. The immediate usage of the facility involves the estimation of volumes of the first two items, and the forecast for the future will involve the additional estimation of Items 3 and 4.

The papers represent the findings of several researches into the comparative traffic usage of highway facilities of different degrees of attractiveness. No discrimination is made between diverted traffic and generated traffic in these studies, but it is assumed that the relative proportions will remain reasonably constant, and that the ratios of usage as found will be applicable for use in estimating diversion from existing facilities to proposed facilities under similar circumstances.

The researches reported attempt to determine the choices made between alternate routes serving traffic transfers between areas so situated with respect to the routes that the routes compete with each other for usage; choice of route depends upon the driver's personal response to the relative attractiveness of the competing routes. Research has been pointed toward a determination of the limiting time and distance ratios for zero diversion and 100-percent diversion as well as the proportion of usage for ratios between the limiting values.

The traffic created by a new facility, sometimes called "traffic of primary generation," or "induced traffic," is still estimated largely on the basis of the traffic analysts' experience and judgment. Generated traffic results from the provision of greater freedom of movement and may come about from more trips made in the area by the same vehicles or from trips made by vehicles previously inhibited from traveling in the area. Whether the travel was reduced, or completely suppressed, the cause is assumed to be due to a lack of freedom of traffic movement. "Tolerable congestion" is relative, and depends upon the nature and urgency of the trip and upon subjective responses to intensity and duration of congestion and traffic controls.

Traffic resulting from intensified land use provided by a new and convenient avenue of land access is sometimes called "traffic of secondary generation." Estimates of secondary generation are likewise based on the analysts' judgment derived from experience and best information available relating to shifts and growths in traffic generators.

As pointed out in the concluding paper of the series, refinement of method of analysis is definitely needed. Much research is still needed to determine the laws of diversion; studies of traffic generation, both of primary and secondary order, are vitally needed to complement the studies in diversion. It appears that research to establish indices of congestion and their relation to diversion and generation may be especially valuable.

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# Traffic Assignment

## COMPARATIVE TRAFFIC USAGE OF KANAWHA BOULEVARD AND ALTERNATE CITY ARTERIALS AT CHARLESTON, WEST VIRGINIA

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DURING the operation of an origin-and-destination survey of Charleston, West Virginia, in the fall of 1950, it was decided to extend the field work to provide material for analysis to determine the driver preference between competing routes of travel. Two separate supplemental surveys were made, providing data for two individual analyses.

The main part of Charleston lies along a relatively narrow, flat section of land between the Kanawha River on the south and hills on the north. This is responsible for a street layout of which the principal arterial routes are parallel and run east and west, connected by cross streets at varying intervals. One of these arterials is Kanawha Boulevard extending along the north bank of the river, a multilane, divided highway of superior travel characteristics. There is no restriction of access to the boulevard but access from abutting property is infrequent and only from the north side. There is no access either from side streets or from abutting property from the south side along the bank of the river, except for two individual driveways to parking lots located adjacent to the business section of the city.

The speed limit on the boulevard is 40 mph. Traffic is restricted to passenger cars only. There are 5 traffic control signals in a length of 4.8 mi. On the other arterials paralleling the boulevard the speed limit is 25 mph. Parts of several of the streets are limited to one-way traffic, signalized at approximately 25 mph., and there are frequent signals. There is no limitation of access.

The first supplemental survey to gather data for research was made by house-to-house interviews at a selected number of addresses in a selected area containing several zones of the original survey and comprising a belt extending across that section of the city between the river and the hills. Interviewers obtained data on origins and destinations and routes of travel for three types of trips: (1) trips from home to work, occurring during the morning peak of travel between the hours of 7 a.m. and 9 a.m.; (2) trips from work to home, occurring during the afternoon peak of travel between the hours of 4 p.m. and 6 p.m.; and (3) trips for any purpose occurring between the hours of 7 p.m. and 9 p.m.

Travel-time studies were made by the floating-car method during each of these three periods to establish the average time of travel between check points located at each intersection on the boulevard, on all the parallel arterials, and on each of the cross streets.

Measurements of distance between intersections were also obtained for each route and cross street.

The second supplemental survey to obtain data for investigation consisted of the operation of a station located on the boulevard, on the screen line for the comprehensive traffic survey, to obtain origins and destinations of all trips using that facility to compare with the total transfer across the screen line as determined by the larger survey. Thus, by a process of elimination, an indication of the relative choices of routes by the trips of the different zone to zone transfers could be obtained. Extra time-delay studies were also necessary to this analysis. This study is not completed at this time and no results are available.

The relationships, presented in this study, were determined by comparisons of time and distance components between the points of choice of the trips for which information was obtained. Point of choice is the point where the driver must decide which route he will use in making his trip. For example, A and E are the points of choice for the trips shown in Figure 1. Trip components from origin (O) to point of choice (A) and from point of choice (E) to destination (D) were not used in determining any of the relationships. Since these components were the same for both the trip via the boulevard and the trip via a city arterial, it was reasoned that they would have little or no influence on the choice of route.

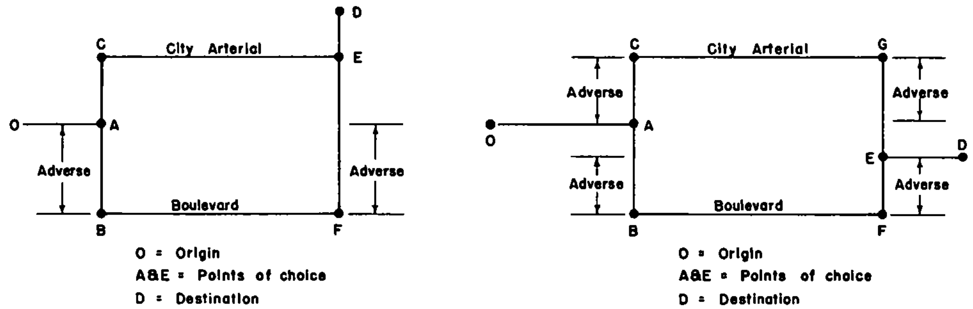


Figure 1. Sketches showing points of choice and adverse travel.

Figure 2 shows the percentage of trips using the boulevard for various ratios of time via the boulevard to time via city arterials. This figure clearly shows that as the ratio of travel time increases the percent of trips via the boulevard decreased. The relationship between the variables is not linear but curvilinear.

When the travel time via the boulevard was one-half the travel time via city arterials, over 90 percent of the trips were made via the boulevard. Conversely, when travel time via the boulevard was one and one half times the travel time on city arterials, the use of the boulevard dropped

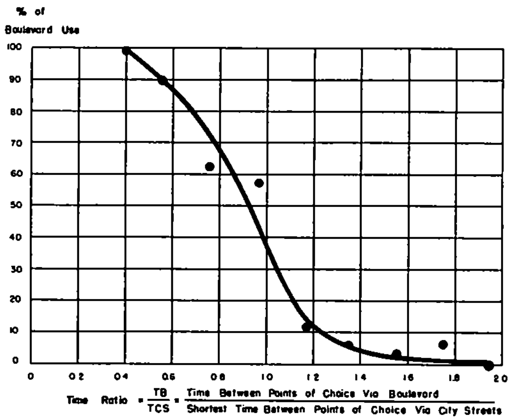


Figure 2. Percent of Kanawha Boulevard use based on time ratio.

to less than 5 percent. Between 35 and 40 percent of the trips were made on the boulevard when travel times were equal. The average over-all speeds on the boulevard were 1.8 times as fast as speeds on the other arterials; therefore, when travel times were equal the trip by the boulevard was greater in distance. Thus 35 to 40 percent of the drivers chose the boulevard when they did not save time and definitely traveled further. This indicates an attractiveness of a superior facility beyond a saving of time and distance. More than 10 percent of the drivers used the boulevard even though the travel time was 0.2 longer and the distance one and one half times or more than the distance via an alternate city arterial. These drivers actually lost time and distance perhaps in an effort to gain freedom of movement, to relieve tension or for other intangible reasons. On the other hand more than 20 percent of the drivers chose a city arterial when it was possible to save 0.3 of the travel time by way of the boulevard. However, in most of these cases the distances traveled were very nearly equal for each route and the potential time saving was only a minute or two. Thus some drivers chose the boulevard although they lost time and distance and some chose other city arterials with a consequent loss of time. It would seem that some drivers place no precise value on time or distance savings, particularly if the potential savings are small.

Figure 3 shows the percent of trips via Kanawha Boulevard for various times savings in minutes. This curve indicates that as the amount of time saved by the boulevard increased the use of the boulevard increased. When there was a negative saving, i.e., a loss of a minute or more, less than 5 percent of the trips were made on the boulevard. This may be accounted for by the fact that a loss in distance accompanies a loss in time for a trip via the boulevard. When the time saved was 0 min., 30 percent of the trips were made by the boulevard. These trips, too, have a loss of distance. When the saving is 3 min. or more the use of the boulevard jumps to more than 90 percent. For most of these trips the distance is equal or less than via the boulevard.

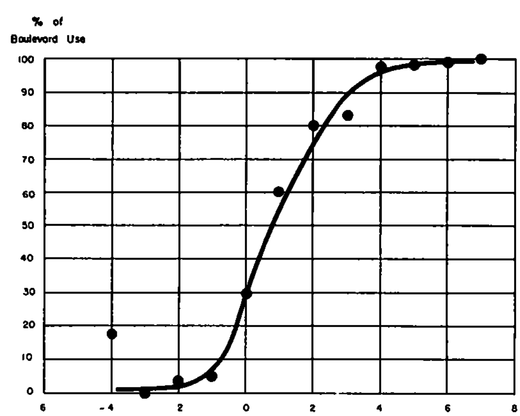


Figure 3. Percent of boulevard use based on time savings in minutes.

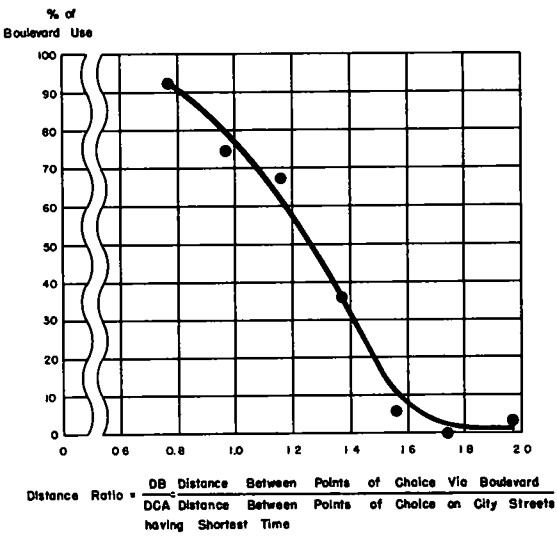


Figure 4. Percent of boulevard use based on distance ratio.

Figure 4 shows the percent of Kanawha Boulevard use based on distance ratios. The curve indicates that the percent of drivers using the boulevard decreased as the ratio of distance via the boulevard to distance via city arterials increased. Little more than 10 percent of the drivers chose Kanawha Boulevard when distances were 1.5 times that of an alternate city street. However, most of these trips had a loss in time, thus making the boulevard less attractive. When distance was the same by either route more than 75 percent of the trips were via the boulevard.

Figure 5 shows the effect of peak and off peak periods on the percent of drivers using the boulevard. This figure is based on time ratios. The curves indicate a greater use of the boulevard during the afternoon peak hours, 4 to 6 p.m., than during the other two periods. The least use occurred in the evening between 7 and 9 p.m. Evidently drivers sought the quickest route home during the 4 to 6 p.m., rush hours. Several factors might influence these curves. There is more congestion between 4 and 6 p.m. than between the hours of 7 and 9 a.m. This is probably due to working hours. People have different hours to report for work, however the majority quit at 5:00 p.m. Also, the one-way-street pattern presents fewer alternate city streets for the westbound traffic, which was the 4 to 6 p.m. traffic in this study. This should cause a greater use of the boulevard during the hours 4 to 6 p.m.

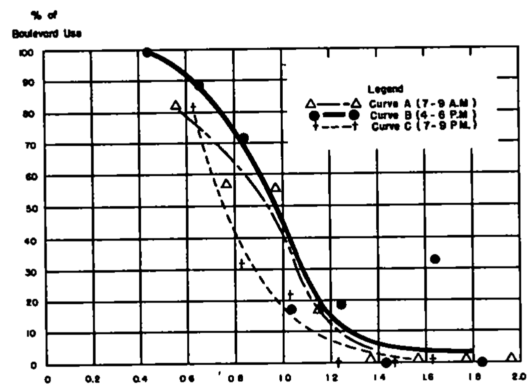


Figure 5. Effect of peak and off-peak periods on boulevard use based on time ratio.

Curves A and C are best for comparison, since they represent trips in the same direction (one during peak hours the other in an off-peak period). These curves indicate that a greater percent of drivers used the boulevard in an effort to gain time, or avoid congestion, or for some other reason during the peak hours than during the off-peak hours. This seems logical, since most people are seeking recreation or pleasure in the evening while they must report to work at a certain time in the morning.

Figure 6 shows the effect of peak and off-peak hours on the use of the boulevard based on distance ratios. These curves also indicate the greatest

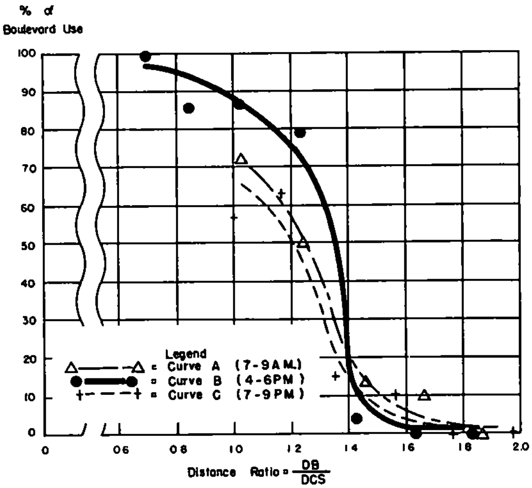


Figure 6. Effect of peak and off-peak periods on boulevard use based on distance ratio.

percent of use in the afternoon (4 to 6 p.m.) and the least use in the evening (7 to 9 p.m.). Here again, comparing peak and off-peak trips in the same direction, a distance saving appeared more valuable during the morning peak (7 to 9 a.m.) than during the evening off-peak hours (7 to 9 p.m.).

Figure 7 shows the effect of trip length on the use of the boulevard, based on time ratios. "Trip length" refers to distance parallel to the boulevard and arterials and does not include any cross-street distances.

From the figure it is evident that more people use the boulevard for trips longer than 2 mi. than for trips of 0.2 mi. Comparing the two curves, when the time ratio is 0.8, 45 percent of the trips with less than 2 mi. of boulevard travel used the boulevard, while approximately 85 percent of the trips over 2 mi. in length used the boulevard. The reason for this is obvious: The longer the trip the greater the time saving via the boulevard. Only one trip over 2 mi. long had a loss of time via the boulevard. Since this was the only trip with a time loss via the boulevard the lower portion of the curve was sketched in.

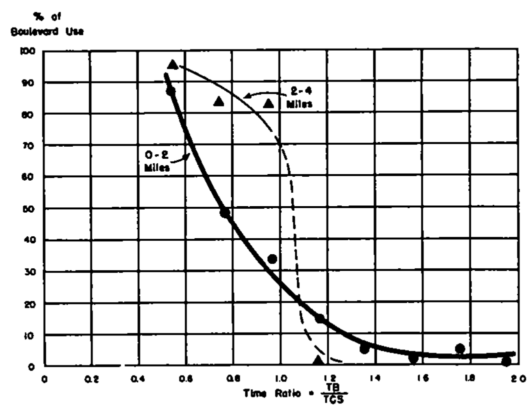


Figure 7. Effect of length of travel parallel to Kanawha Boulevard on boulevard use based on time ratio.

Figure 8 shows the effect of length of travel on the boulevard based on time saved in minutes. Here again the longer the trip the greater the percent of trips via the boulevard. More information is needed on the effect of length of travel on superior facility use, especially where the long trips have nearly the same time by either facility.

Figure 9 shows the effect of excess distance to the boulevard on the use of the boulevard. "Excess distance to the boulevard" is the distance from the points of choice to the boulevard in excess of the distance from the points of choice to an arterial.

This figure indicates that as the excess distance to the boulevard increased in relation to the distance traveled on the boulevard the percentage of use of the boulevard decreased. When there was no excess distance to

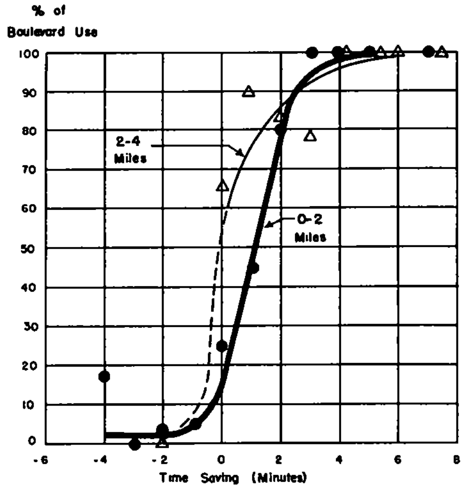


Figure 8. Effect of length of travel parallel to Kanawha Boulevard on boulevard use based on time saving.

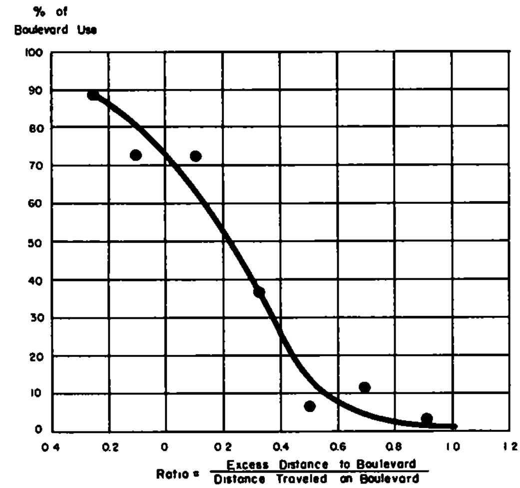


Figure 9. Percent of boulevard use for ratios of excess distance to the boulevard to distance traveled on the boulevard,

the boulevard, about 72 percent used the boulevard. However, when the excess distance to the boulevard was 0.9 of the distance traveled on the boulevard, not one trip was made via the boulevard. Thus, few people, if any, will travel an excess distance equal to the distance traveled on a superior facility in order to use it.

## Conclusions

As a result of the foregoing study the following conclusions have been made:

1. As travel time via a superior facility increased in relation to travel time via other city arterials the use of the superior facility decreased.

2. Not everybody will use a superior facility in order to save a minute or two.

3. As the ratio of distance traveled via a superior facility to distance via city streets increases, the percentage use of the superior facility decreases.

4. The use of a superior facility differs during peak and off-peak hours. The greatest use occurs during peak hours.

5. There is a significant difference in the percent of use of a superior facility for trips of different lengths. The longer the trip parallel to or on a superior facility the greater the use of the superior facility.

6. When the distances from the point of choice to the superior facility or to a city arterial are equal, about 72 percent of the trips are via the superior facility. However, when the distance from the points of choice to the superior facility minus the distance from the points of choice to the city arterial is equal to the distance traveled on the superior facility few people will use the superior route.

It is evident that more studies of driver preference are needed in order to give engineers a clearer picture of traffic diversion as it actually exists. These studies can then be used as a basis for estimating traffic diversion to new or improved routes.

# COMPARATIVE TRAFFIC USAGE OF OLENTANGY RIVER ROAD AND ALTERNATE CITY ARTERIALS IN COLUMBUS, OHIO

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THE SUBJECT study and several similar studies being conducted in various parts of the country are the result of some very notable pioneer work done by M. Earl Campbell, engineer of traffic and operations of the Highway Research Board.

In 1949, Campbell canvassed state highway departments by questionnaire to gather data on methods of making traffic-usage predictions for proposed expressway installations. His work resulted in publication of a Compendium of Correspondence in 1950.

This publication showed conclusively that a wide variety of methods and thinking were being employed throughout the country in making such traffic assignments and that most of these methods were based upon personal judgment and opinion only.

Campbell had previously developed theoretical curves depicting the probable attraction values of the two principal factors, namely, time saving, and distance saving, and the compendium clearly indicated the need for technical research in this field.

Following the lead thus established, the Bureau of Public Roads encouraged the states, through their Planning Survey organizations, to organize projects to test Campbell's conclusions. The tentative procedure as proposed by the bureau was to determine traffic usage on existing high-type facilities and their competitive routes and to develop traffic usage curves in relation to time and distance factors.

In Ohio the Olentangy River Road in the urban area of Columbus was selected as the best of several subjects available for study. Accordingly, agreement was entered into with the Bureau of Public Roads in the spring of 1950 to conduct an analysis of comparative traffic usage of the Olentangy River Road and alternate city arterials.

## DESCRIPTION OF FACILITY

The Olentangy River Road is a north-south artery feeding into the Columbus downtown area from the urban area north and northwest of the city.

Its geometric design varies from a six-lane, undivided highway at its southern end to a two-lane, rural road at its northern terminus, where it junctions with US 23 some 20 mi. north of the Columbus downtown area. The portion selected for study consisted of the southerly 9 mi., stretching from downtown Columbus to SR 161, west of the village of Worthington, and contained 0.27 mi. of six-lane, undivided highway, 0.38 mi. of six-lane,

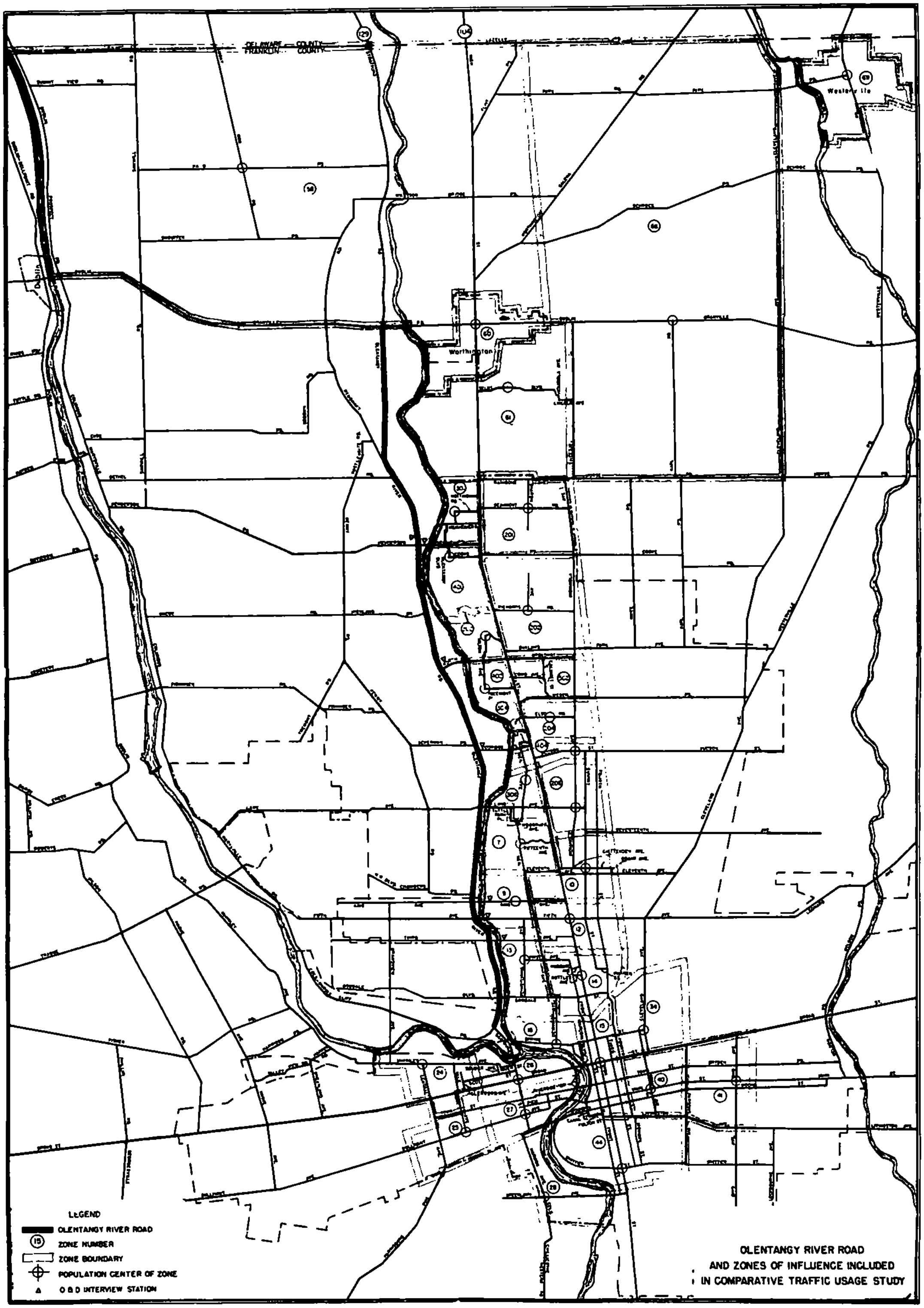


Figure 1. Map of Olentangy River Road and zones of influence included in this study.

divided highway, 4.14 mi. of four-lane, divided highway and 4.27 mi. of rural, two-lane road at the time the study was made.

Built and improved to its present geometric standards by the City of Columbus and Franklin County between 1936 and 1940, the highway is not an expressway, or limited-access facility, in the strictest sense. As originally built and designed, the section under study contained 14 intersections, all at grade. Eight of these intersections are controlled by traffic signals and the remainder by "Stop" signs and channelization which give the right-of-way to the River Road traffic. A minor amount of private access existed at the time of construction, and this was allowed to remain as a not-too-serious threat to the efficiency of the highway. However, in recent years, due to the pressure of big business and influential citizens, the political subdivisions in control have not been able to hold the line against encroachments in the form of private access. However, the Olentangy River, which lies to the east of this road and roughly parallels it for a considerable portion of its course, has been such an effective natural barrier against establishment of access that the highway is and will continue to be superior to its competing routes.

## THE PROJECT

We were fortunate in having a complete and recent origin-and-destination study of the entire area of Franklin County. This study had been made in May of 1949. By making relatively minor subdivisions of several zones in the northern part of the City of Columbus and taking a few manual traffic counts, we were able to reconstruct a very reliable picture of zone-to-zone traffic movements in the study area as of June 1950. The only additional traffic information necessary to the Olentangy River Road Study consisted of establishing and operating origin-and-destination stations to trap all traffic as it left the river road bound to the north and east. All of the competing alternate facilities under study were east of the river road.

The remainder of the field work consisted of a zone-to-zone time-delay study during the peak and off-peak hours by way of the Olentangy Road and by way of the competing facilities. Time and distance were measured from centers of population of the zones.

Using the above data, we were able to compute the percentages of traffic making zone-to-zone movements via the river road, the relative time consumed in making the trips via the river road versus the best competing facility and the relative distances.

By expressing the percentage of use of the Olentangy River Road in terms of time saved or time lost in comparison with the competing facility having the minimum time or distance and plotting these data on rectangular coordinates, the spot diagram (Fig. 2) resulted. By refining, weighting and combining these points, a curve very similar to Campbell's theoretical curve was obtained. However, the extreme ends were sketchy and indefinite. At this point, in making a review of our work to date, it became apparent that our originally selected area of influence was too small. Accordingly, we expanded that area by including additional outlying zones in our analysis.

This did not require any additional field work except obtaining time-distance data in those added zones. Traffic information was available from the original field work. This expansion provided 2,458 additional trips, making a total of 7,287 usable trip samples on the river road.

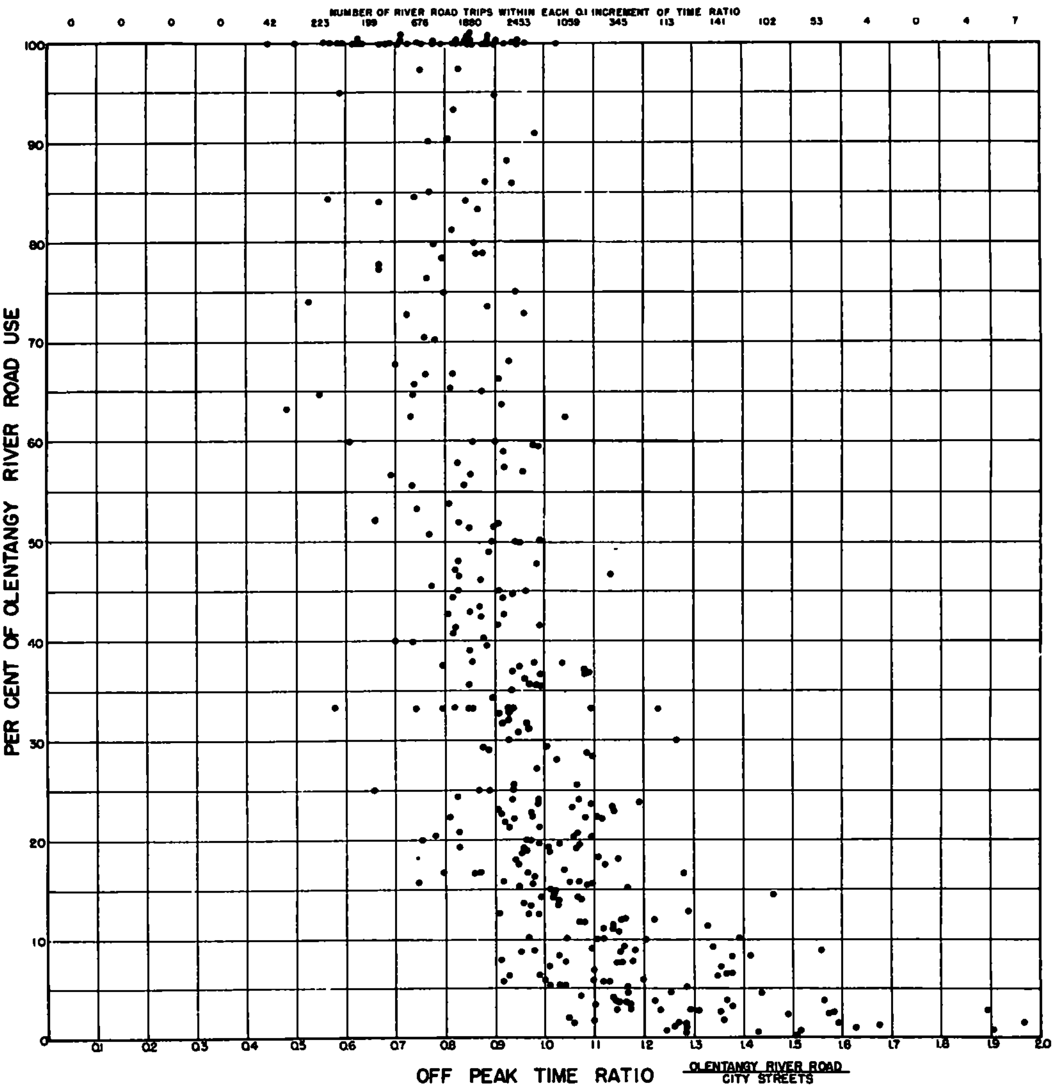


Figure 2. Scatter diagram of relation between percent of traffic usage and off-peak time ratio.

By expansion of the study at this point the time curve (Fig. 3) was developed.

A similar application of data in terms of distance saved or lost resulted in the spot diagram (Fig. 4) and distance curve (Fig. 5).

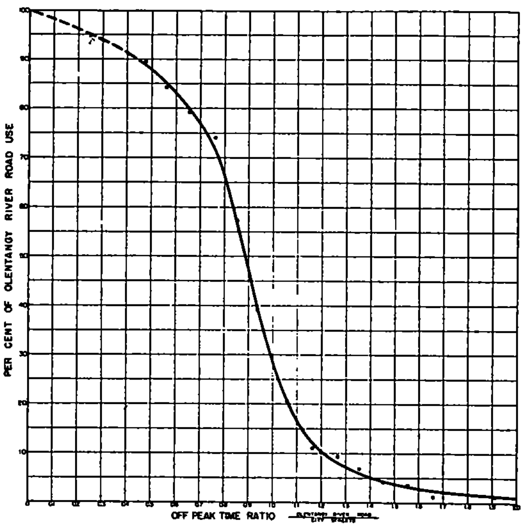


Figure 3. Percent of traffic usage in relation to the off-peak time ratio.

Time and distance curves platted on the same base (Fig. 6) show that 28.5 percent of the traffic will use the Olentangy River Road in spite of adverse time and distance ratios. Up to 71.5 percent will use that facility if time saving is favorable, even though the distance is greater.

This diagram also clearly shows that adverse time will discourage traffic more quickly than adverse distance.

## DERIVATION OF FORMULAS FOR PRACTICAL APPLICATION

On the basis of the data collected in this study, it is apparent that the curves depicting the percentage of use in relation to both the time ratio and the distance ratio are of the cumulative frequency or ogive type. Theoretically, these curves will intersect the Y axis at 100 percent of use when the time or distance ratio is 0, corresponding to a condition in which there is no alternate facility and all traffic is required to use the expressway. At the other extremes, the curves will approach but never intersect the X axis (or point of 0 percent of use of the expressway) as some few motorists will be attracted to an expressway regardless of time or distance factors. Between these limits of 100 percent and 0 percent, the intermediate percentages of use for the corresponding ratios of time and distance will vary with each type of facility and upon the many factors that involve traffic behavior.

In order that the data collected in studies of this type may become of practical value in assigning trips to a proposed facility, it would be convenient to devise formulas which will provide data closely conforming to the trend of the observed and analyzed data. The development of such mathematical expressions will, of course, provide only empirical approximations to the trend of the observed data. Some departure or deviation in these mathematical laws above or below the line of observed trend is to be expected. However, if such deviations are minor in character, usable traffic assignments can be made quickly by mechanical procedures.

Accordingly, an effort was made to derive a mathematical expression applicable to the trend of the curve depicting the percentage of use in relation to the time ratios in this study of the Olentangy River Road. The heavy, solid line denotes the curve obtained from the observed data, while the dashed line indicates the trend of a curve derived from the equation

$$P = \frac{100}{1 + (1.162\ T_R)^{5.85}}$$

in which P is percent of use and $T_R$ is the time ratio. This figure shows fairly close conformance between the two curves for time-ratio values greater than 0.7 and a gradual divergence below that point.

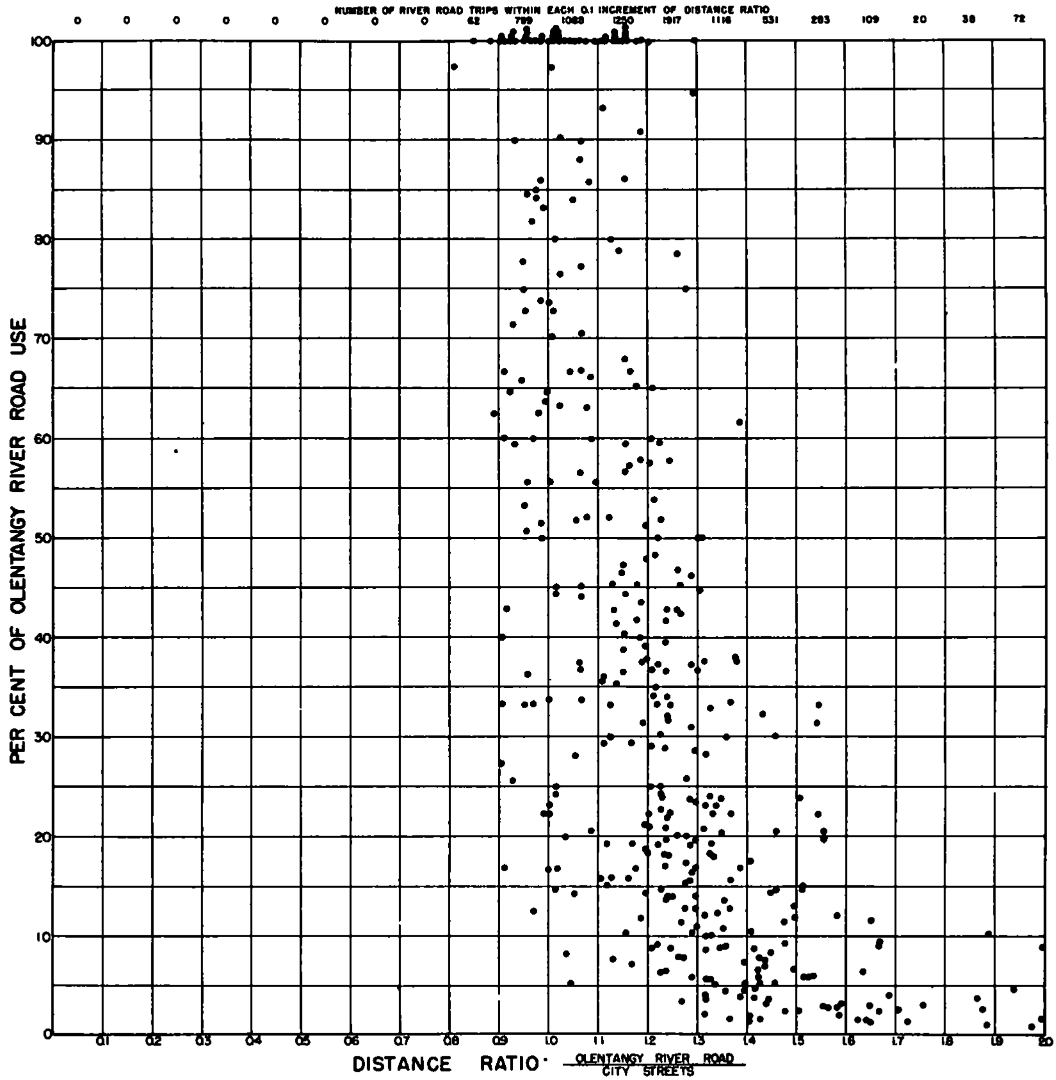


Figure 4. Percent of traffic usage and ratio of distance traveled.

Examination at this point showed a fairly accurate equation for values over 1.0 time ratio. Accordingly, attempts to apply one equation for the entire curve were abandoned, and our efforts were concentrated on developing an equation applicable only for values of 1.0 and over. This resulted in the equation

$$P = \frac{100}{1 + (1.16\ T_R)^{6.2}}$$

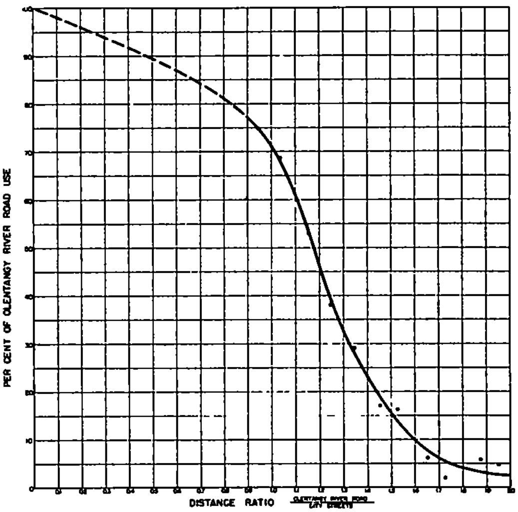


Figure 5. Percent of traffic usage in relation to the distance ratio.

From that point on it was a relatively simple procedure to develop an equation to closely fit the curve for values less than 1.0 time ratio.

This equation is

$$P = 100 - (4\ T_R)^{3.08}$$

At this point it might be well to point out that in spite of our expansion of the study to include the outer zones, relatively few trips were available in establishing the extreme limits of the curves.

It is readily admitted that the upper end of the observed-data curve (from 0 to 0.5 time ratio) is sketchy. Fortunately this part of the curve represents a negligible portion of all traffic.

Incidentally, a correction factor which lengthens the equation can easily be applied to make the equation conform to the curve in this area, but it is considered to be impractical.

This correction factor is $\sqrt[1.2]{6.1 - (8\ T_R - 2.72)^{1.81}}$

Similarly, an equation ($P = \dfrac{100}{1 + (0.86\ D_R)^{6.7}}$) was developed to fit the distance-ratio curve. It will be seen that this equation fits the observed-data curve between the distance-ratio values of 1.0 and 2.0. As the distance-ratio curve below 0.95 is extended beyond established values and represents a negligible volume of traffic, it is considered to be impractical to develop an equation to fit this portion of the curve.

Figure 10 shows the use curves as developed from the mathematical equations.

## CONCLUSIONS

It is conceivable that if a sufficient number and variety of existing facilities were thus studied, mathematical equations could be developed to aid in predicting traffic usage on any planned facility by careful selection and adjustment of these known equations much in the same fashion as now employed in selection of a Weir formula or earth-compaction curve.

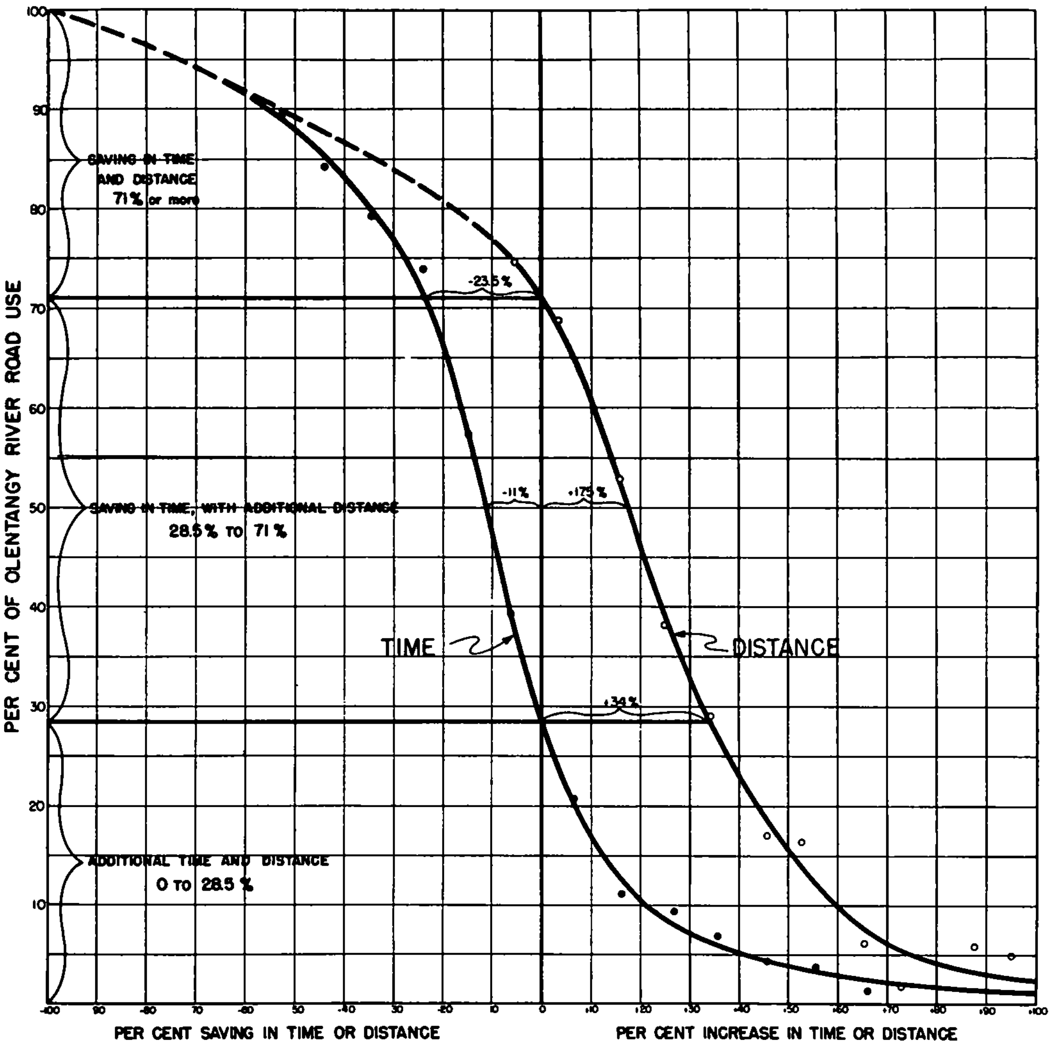


Figure 6. Percent of traffic usage in relation to the percent difference in time or distance.

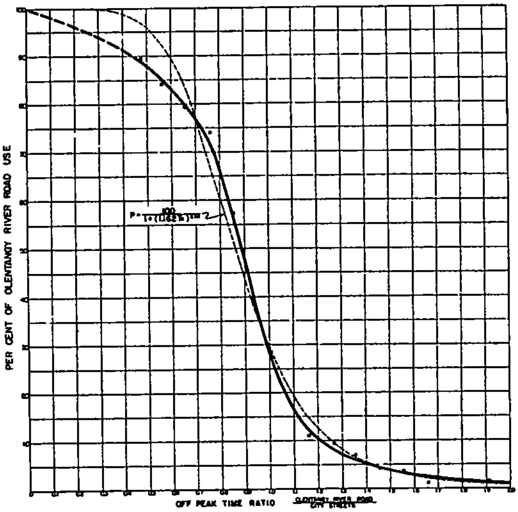


Figure 7. Percent of traffic usage in relation to off-peak time ratio and showing curve of trend based upon equation.

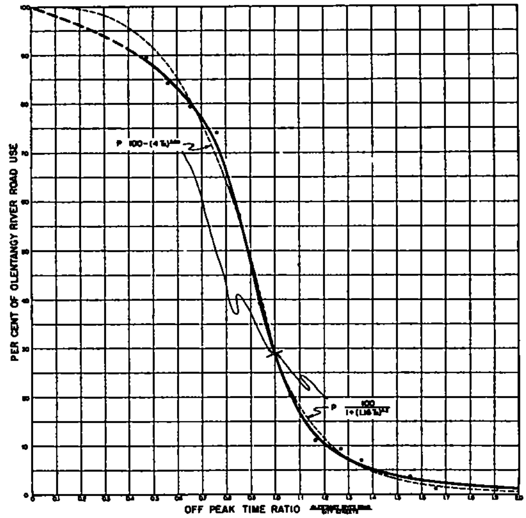


Figure 8. Percent of traffic usage in relation to off-peak time ratio and showing equations for curves of trend for ratios less than 1.0 and more than 1.0.

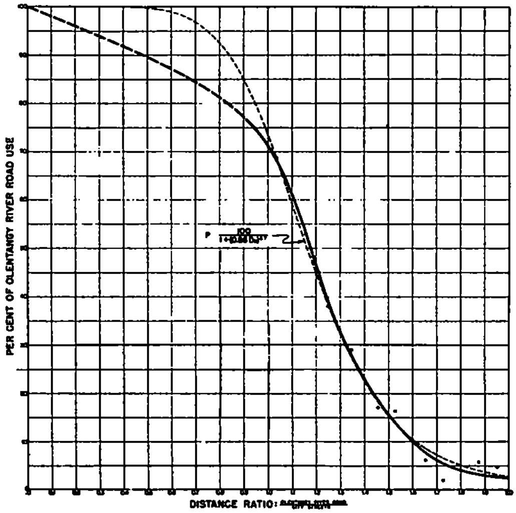


Figure 9. Percent of traffic usage in relation to ratio of distance traveled and showing curve of trend based upon equation.

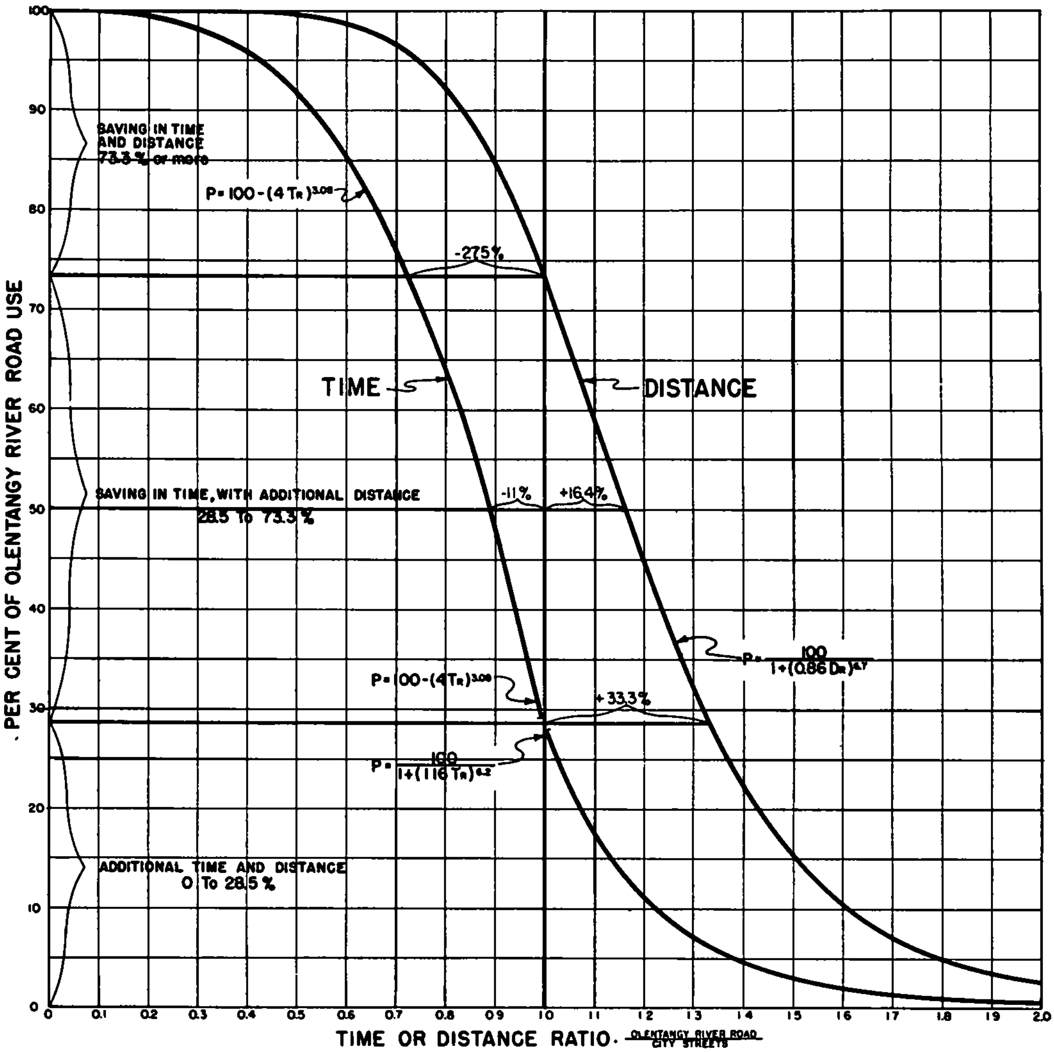


Figure 10. Percent of traffic usage derived from empirical formulas based on time and distance ratios.

# EFFECT OF TRAVEL TIME AND DISTANCE ON FREEWAY USAGE

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SYNOPSIS

Until recently, little information has been available concerning the factors that influence motorists in choosing routes of travel in urban areas. Although a number of different factors may be involved, the effect of travel time and travel distance seem especially desirable for initial study, because they are items that can be measured with reasonable accuracy on any route and their effect on the action of traffic related to the usage of that route. The relation of these two factors to the usage of the Shirley Highway, a freeway in Arlington and Fairfax Counties, Virginia, is reported in this paper.

The results from this study must be integrated with those from similar studies now underway in other urban areas before definite conclusions can be reached. In general, though, it appears that motorists regard travel time as more important than distance in choosing a route of travel. Of all the trips on the Shirley Highway examined, only 38 percent saved distance while 81 percent saved time.

That motorists are also influenced to some extent by factors other than travel time and distance is evidenced by the fact that 19 percent lost both time and distance. Furthermore, of all the trips studied that could have saved both time and distance on the Shirley Highway, 10 percent used an alternate route instead.

THE NEED for increased capacity of our urban highway systens is recognized equally by the average citizen and the highway engineer, since both are familiar with the continued increases in vehicles and travel, the growing number of accidents, and the economic loss due to traffic congestion. To be really effective, modernization must be on a scale sufficiently generous to permit the safe, rapid flow of the large volumes of traffic that stream daily into and out of our metropolitan areas and move from point to point within these areas. This requires more than minor improvement of existing inadequate streets. In many instances, new controlled-access expressways to provide increased capacity will be needed.

Accepting this as a premise, the highway engineer charged with the responsibility of planning these new systems is immediately confronted with three questions: (1) What is the capacity of the existing street system? (2) How much additional capacity is needed to serve adequately the present and future over-all traffic demand? (3) What new facilities will be required and what volume of traffic may be expected on them?

Data in the Highway Capacity Manual[1] are available for determining an answer to the first question. The second question can be answered through the use of the origin-and-destination study techniques developed during the past 5 or 6 years, when used in conjunction with estimates of future urban growth. The highway engineer is not so fortunate when it comes to answering the third question, however, for he has not been able to estimate with confidence the amount of traffic a new facility will attract from existing streets. Data upon which to base an answer to this question have been lacking. The delay in undertaking research on this subject may be attributed not to a failure to recognize the need of such information but, rather, to a lack of urban expressways upon which data of an empirical nature can be collected.

With attention focused more directly on the improvement and construction of highway transportation facilities in urban areas during the past few years, more projects suitable for this type of research have become available for study. Interest has recently been stimulated through the efforts of the Subcommittee on Factual Surveys of the American Association of State Highway Officials and studies have now been undertaken in several different cities. Such a study was conducted during the summer of 1950 on the urban portion of the Shirley Highway, a freeway in Arlington and Fairfax Counties, Virginia. The Traffic and Planning Section of the Virginia State Department of Highways assisted in this study by making the field interviews.

## CONCLUSIONS

Certain general conclusions are revealed from the data collected and analyzed in this study, but these findings must be integrated with those from similar studies now underway in other urban areas before definite conclusions acceptable for wide application can be reached. Considering all of the passenger car trips between the origins and destinations which might result in freeway usage:

1. A general relation is found between the proportion of trips via the freeway and travel distance ratios, but the variation in usage of the freeway is quite large when the distance by way of the freeway is approximately equal to or slightly greater than that by an alternate route.

2. Although there is some difference in the proportional use of the freeway for trips of different lengths, the difference does not appear to be greatly significant insofar as traffic assignment is concerned.

3. Good correlation is found between the proportion of trips via the freeway and the ratio of travel time via that route to the time via the most favorable alternate route.

4. A slightly better correlation than any other explored was found

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1/ - Highway Capacity Manual by the Committee on Highway Capacity, Department of Traffic and Operations, Highway Research Board. Published by the Bureau of Public Roads.

between the proportion of trips via the freeway and the actual time saved or lost in traveling by way of the freeway as compared with that by an alternate route.

5. Motorists, in traveling from one point to another in the study area, apparently regard travel time as more important than distance in selecting a route of travel. Of all the trips examined, only 38 percent saved distance by the freeway, while 81 percent saved time.

## THE PROBLEM

The complexity of travel in urban areas is known to all who study city traffic and city planning. Parallel streets offer many alternate routes of travel and motorists in their daily travel do not hesitate to change routes in order to avoid one which has become congested or otherwise unattractive to use. It is common knowledge that they will go considerable distances out of their way in order to reach attractive, free-flowing arterials of modern design.

Origin-and-destination traffic studies provide information concerning the total number of vehicles passing from one zone to another in urban areas but this knowledge, within itself, is not sufficient. It is essential, for purposes of design and for other reasons, to estimate the number that will be attracted to a new arterial route when it is constructed. The making of such traffic-volume estimates is commonly referred to as traffic assignment. Since the major proportion of the traffic that will use a new route will usually consist of vehicles diverted from the existing street system, the extent to which they can be diverted to the new route and the factors which influence that diversion are of vital importance to those who have the responsibility for planning adequate highway facilities.

In the absence of factual data there is, at present, some disagreement among highway engineers regarding the reasons a motorist chooses one route instead of another. Consequently, there is lack of agreement regarding the proper basis upon which to make traffic assignments. Travel time, travel distance, length of trip, ability to keep moving, safety, convenience, economy, habit, and other factors may enter into the choice. Very little is known, as yet, about the individual effect of any one of these factors. Some engineers consider travel time alone to be the most significant; others believe travel time and travel distance to be equally important; opinions concerning the significance of the other factors are usually indefinite and varied.

Although it is possible that a number of different factors may be involved, travel time and travel distance appear the most promising for initial study, because they are measurable items. Both travel time and distance can be determined with reasonable accuracy on any route, even one proposed for construction. Furthermore, if a definite relation exists between either one or a combination of these two factors and the choice of routes, that relation, when established, will provide a practicable basis upon which traffic assignments can be made with confidence. It was, therefore, the effect of these two factors on the usage of the Shirley Highway that was explored in this study. The findings reported here pertain strictly to diverted traffic and are limited to passenger-car travel.

SHIRLEY HIGHWAY SELECTED FOR STUDY

The Henry G. Shirley Memorial Highway extends southwesterly through Arlington and Fairfax Counties in Virginia from a point near the Pentagon. At the north end it connects with a network of expressways serving that building, and via this network, with three bridges crossing the Potomac River to Washington, D. C. Access to either the Shirley Highway or several alternate routes of travel from any one of the three bridges is readily available by way of this network.

The highway is a four-lane, divided freeway with full control of access throughout its entire length. Each lane is 12 ft. wide, and a 30-ft. grass median separates the opposing directions of travel. The posted speed limit for passenger cars in Arlington County is 50 mph. while in Fairfax County it is 55 mph. Through trucks were prohibited from using the route at the time of this study.

The length of the freeway is approximately 18 mi. from its beginning near the Pentagon to the point where it joins US 1, south of Alexandria. Slightly more than 5 mi. at the north end pass through a residential area suitable for a study of this type. Within the 5-mi. section are five traffic interchanges where vehicles may enter or leave the freeway. At the time of this study, the average weekday traffic volume near the middle of the study section was about 30,000 vehicles per day, including both directions of travel.

Figure 1 shows the Shirley Highway from a point just north of the Glebe Road interchange. This picture, taken in September 1950 at 5:30 p.m., shows the heavy outbound movement of traffic during the evening peak period of travel. Figure 2 is a view in the opposite direction, looking south from the Arlington Ridge Road interchange. This picture was taken in April 1950 about 9 a.m., just after the inbound morning peak had passed. Some of the populous residential area served by the freeway is shown in the background.

Figure 1. The Shirley Highway attracts large volumes of traffic. The outbound travel during the evening peak period is shown here.

Figure 2. Inbound travel on the Shirley Highway just after the morning peak has passed.

There are three principal alternate routes of travel, in addition to the Shirley Highway, which serve the area. These are the Mount Vernon Memorial Highway, Jefferson Davis Highway (US 1), and Columbia Pike. The latter two are typical city-street arterials with the usual signalized intersections, commercial development, and accompanying traffic congestion. The Mount Vernon Memorial Highway, being in the nature of a parkway, is more attractive to travel than the other two. There are, of course, many city streets of lesser importance than the three arterials named that also serve the area.

Figure 3 shows the general area of the study and the location of the Shirley Highway in relation to the alternate routes and the city streets serving the area.

## STUDY PROCEDURE

The procedure adopted utilizes origin-and-destination data collected in the Washington Metropolitan Area Transportation Survey, combined with those obtained from roadside interviews made at points of exit along the Shirley Highway. With these data at hand, supplemented with travel time and distance measurements, it was possible to relate the percentage of traffic using the freeway between certain origins and destinations with the ratio of travel time or distance by way of the freeway to that by an alternate route.

The Washington transportation survey provided information concerning the total number of passenger cars moving from one zone to another regardless of the route traveled. This survey was conducted during the summer and fall of 1948 by the home-interview method, a 5 percent sample of the dwelling units being interviewed.

In order to adjust for the larger volume of traffic in 1950, the

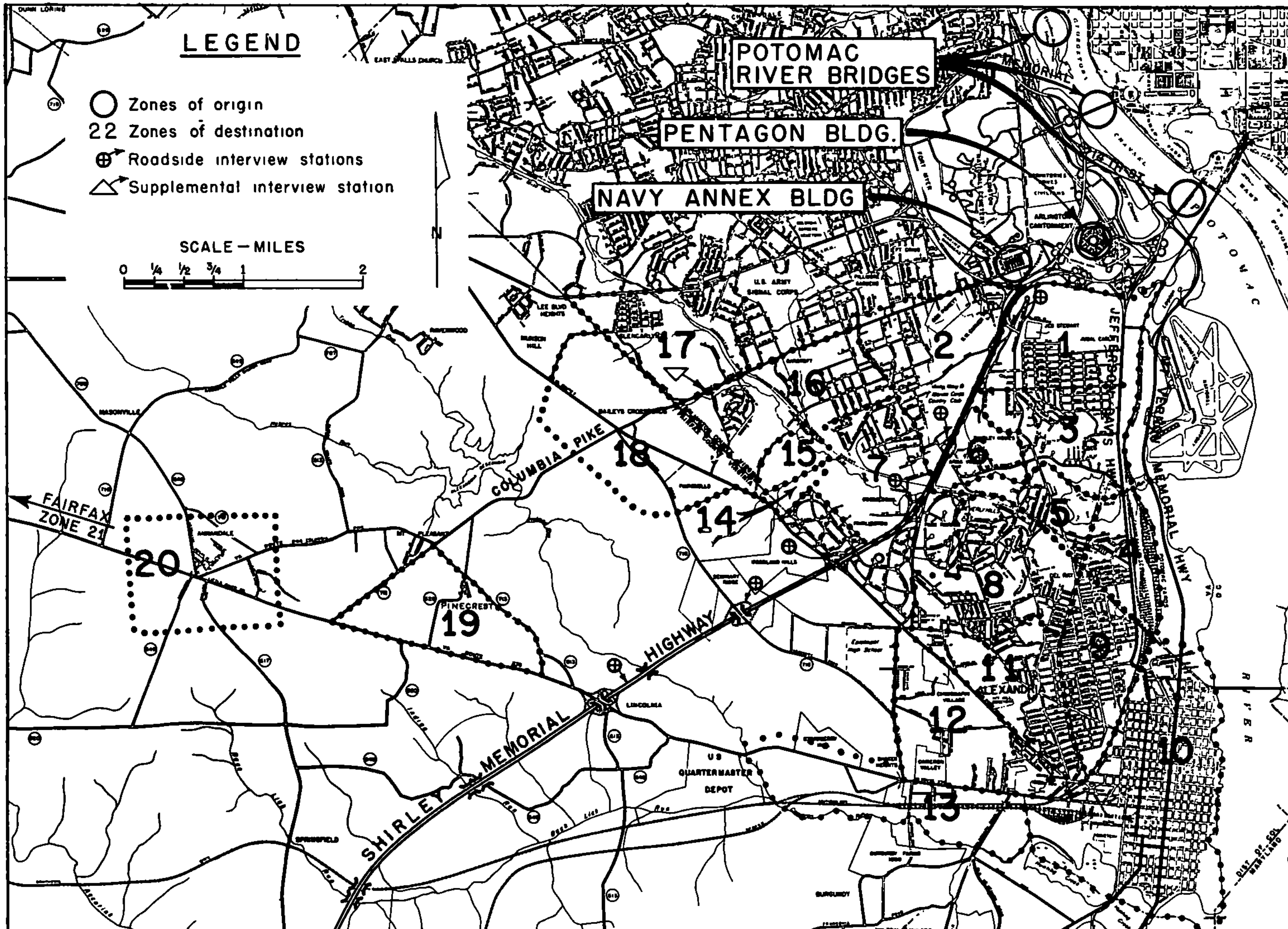


Figure 3. Map of study area.

zone-to-zone movements from the 1948 survey were uniformly increased by 20 percent. The amount of this increase was estimated from July and August traffic counts made in 1948 and in 1950 at 10 automatic recorder stations in the metropolitan area and, also, from a comparison of the travel in 1948 with that in 1950 between the city of Washington and the Fairlington apartment development. Fairlington is a large residential development, containing about 3,600 dwelling units and housing approximately 12,000 people, located directly on the Shirley Highway at the Arlington-Fairfax county line. Practically all of the dwelling units were occupied in 1948 and also in 1950, so a direct comparison of the traffic data was possible.

An increase of 15.2 percent was found at the recorder stations and an increase of 23.1 percent in the Washington-to-Fairlington traffic. It was decided to give slightly more weight to the latter, and a 20 percent increase was selected as reasonable for the uniform expansion. In addition to this expansion, certain zone-to-zone movements were increased by appropriate supplemental factors to account for unusual changes in population, employment, and commercial development known to have occurred since 1948.

The number of passenger cars using the Shirley Highway in going from one zone to another was determined from data collected at roadside interview stations. Interview stations were established on all exit ramps along the freeway from its beginning near the Pentagon to the end of the study area near the Lincolnia interchange (Virginia Route 236). This required five interview stations. At the end of the study area, just north of the Lincolnia interchange, a station was established directly on the Shirley Highway and a sample of all outbound passenger cars passing this point was interviewed. Also, to assist in determining the total travel to some of the outlying zones, a supplemental interview station was established on Columbia Pike. The location of these stations is indicated by distinctive symbols in Figure 3.

Each station was operated for 16 hr. on a weekday, 6 a.m. until 10 p.m., by an experienced crew of the Traffic and Planning Section of the Virginia Department of Highways. During the time of this study, July 19 to August 3, 1950, an average of 23,249 passenger cars passed the six interview stations along the Shirley Highway in the 16-hr. period. Interviews were obtained from the drivers of 15,667 of these vehicles, or about 67 percent.

The data were coded, punched on tabulating cards, and appropriate factors applied by hourly periods to expand the information to an average 24-hr. weekday representative of the period of the study. A tabulation was then prepared showing the zone of origin and the zone of destination of all outbound passenger car drivers using the freeway.

In order to investigate the effect of travel time on the choice of route, it was necessary to determine the time required to travel between points of origin and destination via the freeway and via the alternate routes. A comprehensive travel time map prepared for the Washington transportation survey provided much useful information in this connection. Check runs by the floating-car method were made on the freeway and on the principal alternate routes to test for differences between 1948 and 1950 travel time. The times recorded represent average peak-hour conditions on a weekday and were measured to the center of population of each zone.

As with the travel-time measurements, the distances were measured to the center of population of each zone via the freeway and via the shortest alternate route. In each case the mileage was scaled from a 1:24,000-scale map of the study area. A number of field checks made with a passenger car showed close agreement between the scaled distances and the odometer readings.

The time and distance measurements as well as the traffic volumes between points of origin and destination used in the study are shown in Table 1.

## METHOD OF ANALYSIS

Since a part of the basic data for this study was derived from a 5 percent sample of travel, it follows that zone-to-zone movements of very low volume are not suitable for use. For this reason, it was decided to consider the city of Washington and its Maryland suburbs as a single zone for purposes of this study. All trips originating therein and destined to zones in the study area must cross one of the three Potomac River bridges designated in Figure 3. Thus, for purposes of this analysis, these bridges have been considered as points of origin for all trips beginning on the Washington side of the Potomac River. While information relative to the actual bridge crossed was not available, groups of trips were assigned to the most logical crossing according to their zone of origin and zone of destination.

The Pentagon and the Navy Annex Building are major traffic generators on the Virginia side of the Potomac River and these, in addition to the three bridges spanning the Potomac River, (Fourteenth Street, Memorial, and Key) comprise the five points of origin used in the study.

By reviewing the tabulation of passenger cars that used the freeway it was possible to determine the zones in Arlington and Fairfax counties that were destinations of a substantial number of vehicles using that facility. Twenty-one such zones were tentatively selected. The findings reported in this article are based on an analysis of the travel from the 5 points of origin to these 21 zones of destination. In total, 105 different groups of trips were examined, but 15 were found to be unsatisfactory for use because of inadequate samples, uncertainties in adjustment of 1948 travel to 1950, or for some other reason, and these movements were disregarded in the analysis. Also disregarded in the analysis were trips originating outside of the Washington metropolitan area, since it was assumed that a majority of these trips would follow marked routes regardless of the attractiveness of such routes for travel. In Table 1 it will be noted that a few zone-to-zone movements of low volume were used, this being made possible through the use of the data collected at the supplemental roadside interview station on Columbia Pike.

Table 2 summarizes the total number of trips included for study and classifies them according to travel on the freeway, on alternate routes, and those that were not used.

TABLE 1

Origin, Destination, Travel Time, and Travel Distance for Trips Studied.

| Zone of destination | Number of trips | | | Travel time | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Via Shirley | | | | | | | | |
| | Total | Number | % of total | Via Shirley | Via Alternate | Ratio Shirley to Alternate | Time differential | Via Shirley | Via Alternate | Ratio Shirley to Alternate |
| | | | | Min. | Min. | | Min. | Mi. | Mi. | |
| | | | | **Origin at Fourteenth Street Bridge** | | | | | | |
| 1 | 785 | 170 | 21.7 | 6.3 | 4.6 | 1.37 | -1.7 | 2.8 | 1.9 | 1.47 |
| 2 | 890 | 52 | 5.8 | 10.3 | 7.0 | 1.47 | -3.3 | 4.4 | 3.3 | 1.33 |
| 3 | 424 | 131 | 30.9 | 7.0 | 6.0 | 1.17 | -1.0 | 3.4 | 2.4 | 1.42 |
| 4 | 332 | 19 | 5.7 | 11.0 | 7.0 | 1.57 | -4.0 | 5.1 | 3.1 | 1.65 |
| 5 | 576 | 496 | 86.1 | 8.0 | 8.8 | 0.91 | 0.8 | 3.7 | 3.2 | 1.16 |
| 6 | 634 | 370 | 58.4 | 7.3 | 8.3 | 0.88 | 1.0 | 4.0 | 3.7 | 1.08 |
| 7 | 1,192 | 1,172 | 98.3 | 6.5 | 13.5 | 0.48 | 7.0 | 3.9 | 4.9 | 0.80 |
| 8 | 860 | 478 | 55.6 | 9.5 | 10.0 | 0.95 | 0.5 | 4.9 | 4.2 | 1.17 |
| 9 | 675 | 148 | 21.9 | 12.2 | 9.9 | 1.23 | -2.3 | 5.2 | 4.3 | 1.21 |
| 10 | 2,308 | 188 | 8.1 | 18.0 | 13.0 | 1.38 | -5.0 | 7.7 | 5.2 | 1.48 |
| 11 | 467 | 193 | 41.3 | 12.0 | 13.0 | 0.92 | 1.0 | 6.2 | 4.9 | 1.27 |
| 12 | 108 | 100 | 92.6 | 12.2 | 16.4 | 0.74 | 4.2 | 6.2 | 5.9 | 1.05 |
| 13 | 176 | 43 | 24.4 | 14.0 | 21.0 | 0.67 | a/ | a/ | a/ | a/ |
| 14 | 57 | 55 | 96.5 | 9.8 | 17.2 | 0.57 | 7.4 | 5.4 | 6.9 | 0.78 |
| 15 | 89 | 84 | 94.4 | 10.0 | 17.0 | 0.59 | 7.0 | 5.5 | 6.8 | 0.81 |
| 16 | 700 | 151 | 21.6 | 12.7 | 10.7 | 1.19 | -2.0 | 4.9 | 4.3 | 1.14 |
| 17 | 177 | 18 | 10.2 | 14.7 | 11.7 | 1.26 | -3.0 | 6.9 | 4.7 | 1.47 |
| 18 | 322 | 169 | 52.5 | 12.6 | 12.9 | 0.98 | 0.3 | 6.4 | 5.4 | 1.19 |
| 19 | 72 | 60 | 83.3 | 14.6 | 18.6 | 0.78 | 4.0 | 8.4 | 8.2 | 1.02 |
| 20 | 291 | 196 | 67.4 | 17.7 | 20.2 | 0.88 | 2.5 | 10.2 | 9.4 | 1.09 |
| 21 | 60 | 37 | 61.7 | 27.3 | 29.8 | 0.92 | 2.5 | 16.3 | 15.5 | 1.05 |
| | | | | **Origin at Memorial Bridge** | | | | | | |
| 1 | 242 | 82 | 33.9 | 6.8 | 6.9 | 0.99 | 0.1 | 3.2 | 3.2 | 1.00 |
| 2 | 382 | 22 | 5.8 | 10.8 | 7.4 | 1.46 | -3.4 | 4.8 | 3.5 | 1.37 |
| 3 | 184 | 84 | 45.7 | 7.5 | 8.3 | 0.90 | 0.8 | 3.7 | 3.7 | 1.00 |
| 4 | 200 | 15 | 7.5 | 11.5 | 9.2 | 1.25 | -2.3 | 5.4 | 4.5 | 1.20 |
| 5 | 192 | 123 | 64.1 | 8.5 | 11.1 | 0.77 | 2.6 | 4.0 | 4.6 | 0.87 |
| 6 | 198 | 156 | 78.8 | 7.8 | 11.3 | 0.69 | 3.5 | 4.3 | 4.6 | 0.93 |
| 7 | 322 | 321 | 99.7 | 7.0 | 13.9 | 0.50 | 6.9 | 4.3 | 5.3 | 0.81 |
| 8 | 346 | 284 | 82.1 | 10.0 | 12.3 | 0.81 | 2.3 | 5.2 | 5.5 | 0.95 |
| 9 | 188 | 62 | 33.0 | 12.7 | 12.1 | 1.05 | -0.6 | 5.6 | 5.5 | 1.02 |
| 10 | 560 | 65 | 11.6 | 18.5 | 15.2 | 1.22 | -3.3 | 8.1 | 6.9 | 1.17 |
| 11 | 65 | 44 | 67.7 | 12.5 | 15.3 | 0.82 | 2.8 | 6.6 | 6.2 | 1.06 |
| 12 | 153 | 105 | 68.6 | 13.0 | 16.5 | 0.79 | 3.5 | 6.6 | 7.2 | 0.92 |
| b/13 | 27 | 36 | --- | --- | --- | -- | -- | -- | -- | -- |
| 14 | 28 | 28 | 100.0 | 10.3 | 17.6 | 0.59 | 7.3 | 5.7 | 7.2 | 0.79 |
| 15 | 27 | 27 | 100.0 | 10.5 | 17.4 | 0.60 | 6.9 | 5.8 | 7.1 | 0.82 |
| 16 | 406 | 60 | 14.8 | 13.2 | 11.1 | 1.19 | -2.1 | 5.3 | 4.5 | 1.18 |
| 17 | 101 | 5 | 5.0 | 15.2 | 12.1 | 1.26 | -3.1 | 7.1 | 4.9 | 1.45 |
| 18 | 377 | 169 | 44.8 | 13.1 | 13.3 | 0.98 | 0.2 | 7.2 | 5.9 | 1.22 |
| 19 | 43 | 30 | 69.8 | 15.0 | 15.9 | 0.94 | 0.9 | 9.2 | 7.3 | 1.26 |
| 20 | 281 | 199 | 70.8 | 18.1 | 20.6 | 0.88 | 2.5 | 11.1 | 9.9 | 1.12 |
| 21 | 54 | 49 | 90.7 | 27.8 | 30.3 | 0.92 | 2.5 | 17.1 | 16.0 | 1.07 |

TABLE 1 (Continued)

Origin at Key Bridge

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 184 | 66 | 35.9 | 9.3 | 8.4 | 1.11 | -0.9 | 4.2 | 3.9 | 1.08 |
| 2 | 198 | 8 | 4.0 | 13.3 | 9.9 | 1.34 | -3.4 | 5.7 | 4.4 | 1.30 |
| 3 | 105 | 23 | 21.9 | 10.0 | 9.8 | 1.02 | -0.2 | 4.6 | 4.5 | 1.02 |
| 4 | 49 | 10 | 20.4 | 14.0 | 10.8 | 1.30 | -3.2 | 6.3 | 5.2 | 1.21 |
| b/ 5 | 60 | 137 | — | — | — | — | — | — | — | — |
| 6 | 86 | 73 | 84.9 | 10.3 | 12.8 | 0.80 | 2.5 | 5.2 | 5.7 | 0.91 |
| b/ 7 | 141 | 157 | — | — | — | — | — | — | — | — |
| b/ 8 | 2 | 32 | — | — | — | — | — | — | — | — |
| 9 | 113 | 57 | 50.4 | 15.2 | 14.7 | 1.03 | -0.5 | 6.5 | 6.4 | 1.02 |
| 10 | 290 | 46 | 15.9 | 21.0 | 17.8 | 1.18 | -3.2 | 8.9 | 7.7 | 1.16 |
| 11 | 65 | 30 | 46.2 | 15.0 | 16.8 | 0.89 | 1.8 | 7.5 | 7.0 | 1.07 |
| 12 | 28 | 18 | 64.3 | 15.5 | 19.0 | 0.82 | 3.5 | 7.5 | 7.7 | 0.97 |
| b/13 | 0 | 11 | — | — | — | — | — | — | — | — |
| 14 | 20 | 20 | 100.0 | 12.8 | 18.7 | 0.68 | 5.9 | 6.7 | 7.3 | 0.92 |
| 15 | 24 | 22 | 91.7 | 13.0 | 18.5 | 0.70 | 5.5 | 6.8 | 7.2 | 0.94 |
| 16 | 115 | 17 | 14.8 | 15.7 | 12.2 | 1.29 | -3.5 | 6.1 | 4.6 | 1.33 |
| 17 | 119 | 0 | 0.0 | 17.7 | 11.0 | 1.61 | -6.7 | 8.0 | 5.8 | 1.38 |
| 18 | 23 | 11 | 47.8 | 15.6 | 15.8 | 0.99 | 0.2 | 8.0 | 6.7 | 1.19 |
| 19 | 7 | 4 | 57.1 | 17.6 | 19.2 | 0.92 | 1.6 | 10.0 | 7.3 | 1.37 |
| c/20 | — | — | — | — | — | — | — | — | — | — |
| c/21 | — | — | — | — | — | — | — | — | — | — |

Origin at Pentagon

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 140 | 55 | 39.3 | 4.0 | 3.8 | 1.05 | -0.2 | 1.8 | 1.5 | 1.20 |
| 2 | 141 | 19 | 13.5 | 7.8 | 6.2 | 1.26 | -1.6 | 3.4 | 2.4 | 1.42 |
| 3 | 64 | 56 | 87.5 | 4.8 | 5.8 | 0.83 | 1.0 | 2.3 | 2.1 | 1.10 |
| 4 | 29 | 6 | 20.7 | 8.5 | 7.4 | 1.15 | -1.1 | 4.1 | 2.8 | 1.46 |
| 5 | 234 | 57 | 24.4 | 6.3 | 7.3 | 0.86 | a/ | a/ | a/ | a/ |
| b/ 6 | 58 | 98 | — | — | — | — | — | — | — | — |
| b/ 7 | 220 | 424 | — | — | — | — | — | — | — | — |
| 8 | 398 | 241 | 60.6 | 7.9 | 9.2 | 0.86 | 1.3 | 3.9 | 3.8 | 1.03 |
| 9 | 75 | 40 | 53.3 | 10.5 | 9.8 | 1.07 | -0.7 | 4.3 | 4.0 | 1.08 |
| 10 | 232 | 66 | 28.4 | 15.1 | 13.6 | 1.11 | -1.5 | 6.8 | 4.8 | 1.42 |
| b/11 | 0 | 59 | — | — | — | — | — | — | — | — |
| 12 | 65 | 46 | 70.8 | 11.1 | 14.3 | 0.78 | 3.2 | 5.3 | 5.5 | 0.96 |
| 13 | 30 | 21 | 70.0 | 12.3 | 17.0 | 0.72 | 4.7 | 5.4 | 6.9 | 0.78 |
| 14 | 59 | 59 | 100.0 | 7.8 | 16.4 | 0.48 | 8.6 | 4.5 | 6.0 | 0.75 |
| 15 | 50 | 50 | 100.0 | 8.0 | 16.2 | 0.49 | 8.2 | 4.6 | 5.9 | 0.78 |
| 16 | 148 | 69 | 46.6 | 9.3 | 10.0 | 0.93 | 0.7 | 4.0 | 3.2 | 1.25 |
| 17 | 154 | 15 | 9.7 | 14.0 | 11.3 | 1.24 | -2.7 | 5.7 | 3.7 | 1.54 |
| 18 | 284 | 169 | 59.5 | 10.9 | 12.1 | 0.90 | 1.2 | 5.7 | 4.5 | 1.27 |
| 19 | 23 | 19 | 82.6 | 12.9 | 17.7 | 0.73 | 4.8 | 7.6 | 7.2 | 1.06 |
| 20 | 139 | 113 | 81.3 | 16.0 | 19.3 | 0.83 | 3.3 | 9.3 | 8.5 | 1.09 |
| 21 | 17 | 15 | 88.2 | 24.9 | 29.5 | 0.84 | 4.6 | 15.4 | 14.6 | 1.05 |

TABLE 1 (Continued)

Origin at Navy Annex Building

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 65 | 54 | 83.1 | 3.7 | 4.9 | 0.76 | 1.2 | 1.7 | 2.1 | 0.81 |
| 2 | 123 | 8 | 6.5 | 6.9 | 4.5 | 1.53 | -2.4 | 2.9 | 1.5 | 1.93 |
| b/ 3 | 17 | 28 | — | — | — | — | — | — | — | — |
| 4 | 24 | 8 | 33.3 | 8.3 | 8.0 | 1.04 | -0.3 | 3.7 | 3.6 | 1.03 |
| 5 | 67 | 41 | 61.2 | 6.1 | 8.3 | 0.73 | 2.2 | 2.5 | 3.8 | 0.66 |
| 6 | 74 | 65 | 87.8 | 5.3 | 8.0 | 0.66 | 2.7 | 2.6 | 3.2 | 0.81 |
| 7 | 143 | 140 | 97.9 | 5.0 | 11.0 | 0.45 | 6.0 | 2.6 | 3.1 | 0.84 |
| 8 | 67 | 53 | 79.1 | 7.6 | 10.7 | 0.71 | 3.1 | 3.5 | 4.0 | 0.88 |
| 9 | 49 | 39 | 79.6 | 10.2 | 11.7 | 0.87 | 1.5 | 3.8 | 4.7 | 0.81 |
| b/10 | 0 | 50 | — | — | — | — | — | — | — | — |
| b/11 | 0 | 15 | — | — | — | — | — | — | — | — |
| b/12 | 0 | 5 | — | — | — | — | — | — | — | — |
| b/13 | 0 | 6 | — | — | — | — | — | — | — | — |
| 14 | 7 | 6 | 85.7 | 8.0 | 13.0 | 0.62 | 5.0 | 4.2 | 4.9 | 0.86 |
| 15 | 11 | 11 | 100.0 | 8.2 | 12.8 | 0.64 | 4.6 | 4.3 | 4.8 | 0.90 |
| 16 | 112 | 13 | 11.6 | 8.9 | 7.5 | 1.19 | -1.4 | 3.6 | 2.3 | 1.57 |
| 17 | 65 | 0 | 0.0 | 13.5 | 8.3 | 1.63 | -5.2 | 5.2 | 2.7 | 1.93 |
| 18 | 72 | 14 | 19.4 | 10.5 | 9.6 | 1.09 | -0.9 | 5.4 | 3.5 | 1.54 |
| 19 | 2 | 2 | 100.0 | 12.5 | 15.2 | 0.82 | 2.7 | 7.2 | 6.4 | 1.13 |
| 20 | 28 | 15 | 53.6 | 15.6 | 16.8 | 0.93 | 1.2 | 8.9 | 7.7 | 1.16 |
| 21 | 5 | 2 | 40.0 | 25.3 | 26.4 | 0.96 | 1.1 | 15.0 | 13.8 | 1.09 |

a/- Not included for analysis because percentage of traffic using freeway, when related to travel time ratio, falls far out of general range of other data.

b/- Not used in analysis because of inadequate samples and uncertainties in adjustment of 1948-50 travel.

c/- Insufficient data available to make an estimate of the total zone-to-zone movement.

TABLE 2

Total Number of Trips Studied

| | Number of trips | Percentage of total |
|---|---|---|
| On freeway | 8,152 | 39.0 |
| On alternate routes | 11,604 | 55.5 |
| Subtotal | 19,756 | 94.5 |
| Not used | 1,158 | 5.5 |
| Total | 20,914 | 100.0 |

FREEWAY-USE RELATION TO TRAVEL TIME

Figure 4 shows the percentage of passenger-car traffic using the freeway for various travel-time ratios. The travel-time ratio in each case was derived by dividing the amount of time required to make the trip via the freeway by that required via the most favorable alternate route. Each symbol represents the group of trips beginning at one of the 5 points of origin and ending in one of the 21 zones of destination. For example, the small circle near the middle of the chart in the upper right quadrant (1.07 time ratio and 53-percent freeway usage) represents the group of trips beginning at the Pentagon and ending in Zone 9. Table 1 shows the total number of trips in this movement to be 75, of which 40 used the Shirley Highway. The dot to the left and slightly below the circle, but also in the upper right quadrant, represents a movement of 113 trips beginning on the Washington side of the Potomac River, crossing Key Bridge, and, as it happens, also ending in Zone 9; 57 of these trips used the Shirley Highway.

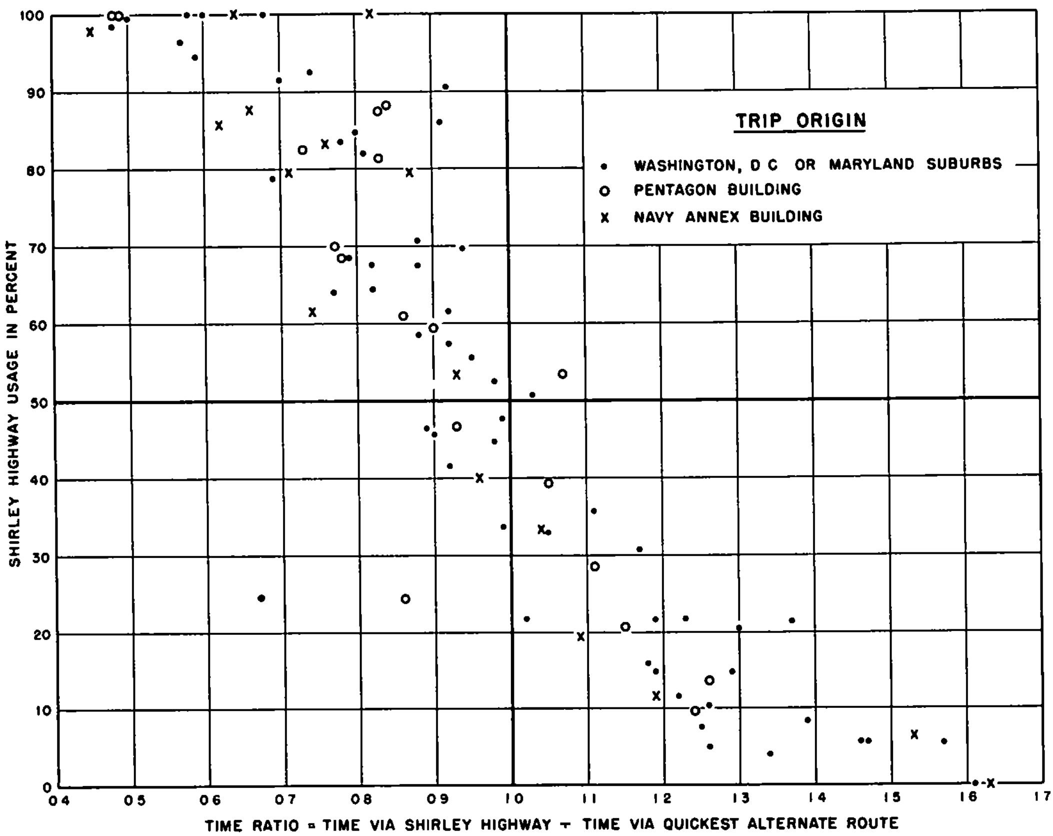


Figure 4. Freeway usage in relation to time ratio.

In total, the 56 dots on the chart represent 16,970 trips originating on the Washington side of the Potomac River, the 18 small circles represent 2,282 trips originating at the Pentagon, and the 16 crosses represent 914 trips originating at the Navy Annex Building. Included are two groups totaling 410 trips that were not used in subsequent analyses because they fall so far out of the general range of the other points. The symbols for these groups are in the 20 to 30 percent usage of the chart, to the left of 0.9 time ratio.

Although, as expected, there is some scatter in the points, they seem to fall within a reasonably close band all the way across the chart. The general pattern suggests the probability of a relation that may be expressed in terms of an S curve. No attempt was made to fit a curve to the points on this chart, however, because they represent different values insofar as the number of trips is concerned.

To arrive at a weighted mean and also to reduce the number of points the data were summarized by combining those movements which have the same travel-time ratio within increments of one tenth (for example, 0.96 to 1.05) and computing the percentage of the total trips of these combined movements that used the freeway. The results of this summarization are shown by small circles in Figure 5. The position of these circles clearly indicates a definite relation between travel-time ratios and freeway usage. While all of the circles do not fall directly on a smooth S curve, especially at each extremity, those near the center fit remarkably well. This may be due, in part, to the greater number of trips represented by those points. The position of the five circles near the center (0.8 to 1.2 time ratios) was determined from a study of 11,205 trips, while the position of the remaining seven circles was determined from 8,551 trips. The curve in Figure 5 (and all others shown in this article) was fitted by inspection.

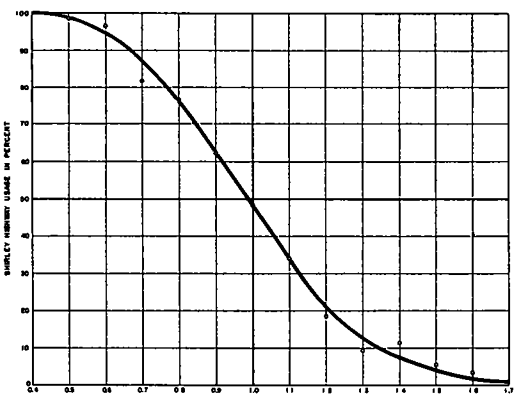

Figure 5. Curve for freeway usage in relation to time ratio.

From this curve it is apparent that practically all of the motorists use the freeway when the travel time by way of that route is less than 0.4 of that by way of the most favorable alternate route. At the other extreme, when travel time via the freeway is greater than 1.7 times that via an alternate, almost all of the motorists use the alternate route. When the travel time is the same on the freeway as that on an alternate route, approximately 48 percent of the drivers choose the freeway even though it is necessary to travel additional distance in order to do so.

FREEWAY USE RELATION TO TRAVEL DISTANCE

Figure 6 shows the percentage of passenger-car traffic using the freeway for various travel-distance ratios. The same general procedure was used in developing this chart as was used for the one shown in Figure 5. In this case, however, the scatter of the points is much greater, especially near the middle of the chart between 1.0 and 1.4 distance ratios. Even though weighted means for groups of points with so much variation have little significance, the data were summarized by one-tenth-distance ratios (shown by the small circles), and a curve fitted to these circles. Note that the shape of this curve, unlike that of the time-ratio S curve, is concave throughout.

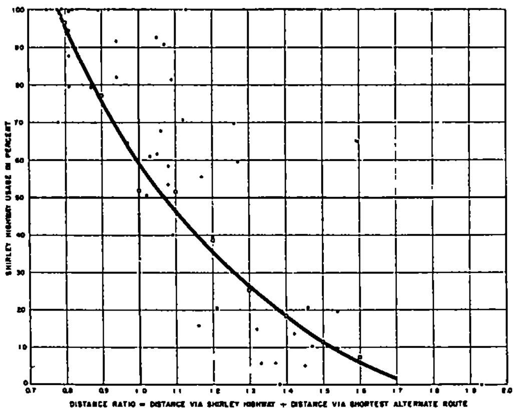


Figure 6. Freeway usage in relation to distance ratio.

It is evident from the data represented on this chart that practically all of the motorists use the freeway when the distance ratio is less than 0.8 and very few use it when the ratio is greater than 1.7. The usage when the distance ratios are between 1.0 and 1.1 varies from 22 to 92 percent. The exact reason for such a wide variation is unknown, although from a supplementary analysis it appears to be directly related to the quality of the traffic service provided by the alternate routes. The 22 movements comprising these trips were separated into two groups: (1) a choice of the freeway or an alternate providing reasonably good traffic service, and (2) a choice between the freeway or a relatively poor alternate. Of the first group, only 37.1 percent chose the freeway, while 66.6 percent of the second group chose that route. Furthermore, all except two of the eight movements included with the first group could travel via alternate routes in the same or less time than via the freeway, while all except one of the fourteen movements included with the second group could save time by using the freeway. Thus it is apparent that motorists making trips that are approximately equal in distance by the freeway and by an alternate route choose the former in greater proportions when travel time can be saved by doing so.

FREEWAY-USE RELATION TO TIME AND DISTANCE COMBINED

Since both the travel-time ratio and the distance ratio appear to bear some relation to the use of the freeway, it was decided to investigate a combination of the two. With this in mind, the distance ratio was divided by the time ratio for each group of trips, in effect giving a speed ratio, and the result plotted according to the percentage of passenger-car traffic using the freeway in each case. No correlation was found with this procedure. A second attempt was made to combine the two ratios, in which the time ratio and the distance ratio for each group of trips were multiplied and the product plotted according to the percentage of passenger-car traffic using the freeway in each case. Figure 7 shows the results of this combination after the detailed data were summarized by increments of one tenth.

The tendency is more toward a straight line than the S curve found in connection with the time ratio (Fig. 5). This is to be expected because, as a matter of mathematics, the product of the time and distance ratios tends to drop the relative position of the product curve below that of the

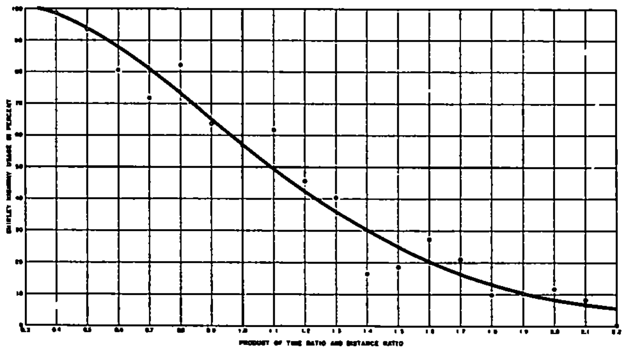

Figure 7. Freeway usage in relation to product of time and distance ratios.

time-ratio curve for each group of trips having a time ratio and a distance ratio both less than 1.0. Conversely, the tendency is to raise the relative position where either or both ratios are greater than 1.0.

While a relation between the freeway usage and the travel time-distance ratio product seems to exist, the correlation is not as good as that found with the time ratio alone. The relation shown in Figure 7 is of general interest, but it appears to be less practicable and would provide less accurate results than the time-ratio curve if used as a basis for making traffic assignments.

FREEWAY-USE RELATION TO TIME DIFFERENTIAL

Figure 8 shows the percentage of passenger-car traffic using the freeway based on the actual number of minutes motorists saved or lost by using that route as compared with an alternate. Here, as in the case of the travel-time ratio, the points fall within a reasonably close band which unmistakably suggests an S-curve relation.

The curve shown was drawn to fit the weighted means computed for each minute saved and each minute lost. As on previous charts, the weighted means are indicated by small circles. The resulting curve shows that where motorists can save 8 min. or more by using the freeway, they all choose that route. At the other extreme, a few motorists use the freeway even though they lost 4 or 5 min. by doing so. When travel time via the freeway is the same as that via an alternate route, the curve shows that approximately 48 percent of the motorists choose the freeway. This agrees properly with the percentage use shown by the time-ratio curve when the travel times are equal.

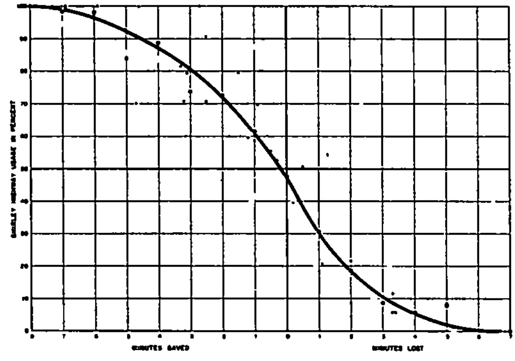

Figure 8. Freeway usage in relation to time differential.

An interesting feature of this relation is its tendency to group zone-to-zone movements according to length. The longer trips tend to fall near the extremities of the curve while the shorter trips are grouped nearer the middle. This is readily understandable, because it would be impossible to save or lose several minutes by using the freeway instead of an alternate route in making short trips of only 5 or 10 min. total duration. On the other hand, in making trips of 20 or 30 min. duration, a time differential of several minutes would not be at all unlikely.

It is this tendency of trips to fall into groups according to length that results in somewhat better correlation between freeway usage and time differential than between freeway usage and time ratio. The reason for this difference is brought out in Figure 9.

## FREEWAY USE IN RELATION TO TRIP LENGTH

Figure 9 shows the percentage of passenger-car traffic using the freeway, based on travel-time ratios, for three increments of travel distance: 4.0 mi. and less, 4.1 to 6.4 mi., and 6.5 mi. and greater. The distance by way of the freeway was used in grouping the trips into the three increments of length. The length in each case is the over-all distance between one of the five points of origin and one of the zones of destination. On this basis, the shortest trip included is 1.7 mi. while the longest is 17.1 mi.

It is evident from the position of the three curves in Figure 9 that, when the time ratio is less than 1.07, a greater percentage of the longer trips than of the shorter trips are on the freeway. When the time ratio is greater than 1.07, however, the position of the curves is reversed and a larger percentage of the shorter trips are on the freeway. For example, when the travel-time ratio is 0.7, these curves show that 89 percent of the longer trips are on the freeway and only 82 percent of the shorter ones. When the time ratio is 1.4, only 3 percent of the longer trips are on the freeway but there are 15 percent of the shorter ones.

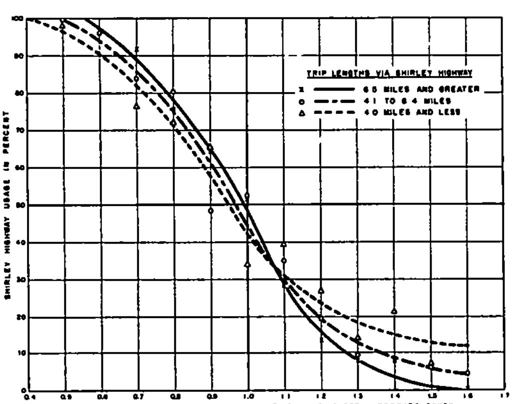


Figure 9. Effect of trip length on freeway usage.

The explanation for this relation appears to be directly connected with the actual amount of time motorists can save, or will lose, in making trips of various lengths by one route as compared with that of another. This point can best be explained by an example. Assume a long trip to require 20 min. by way of the freeway and a short one 5 min. If the time ratio is 0.7, motorists making the longer trip save 8.6 min. by using the freeway while those making the shorter trip save only 2.1 min. The actual amounts of time saved in the case of the longer trip is four times as great as that for the shorter trip. When the time ratio is 1.4 however, motorists lose 5.7 min. in making the longer trip by way of the freeway, but only 1.4 min. for the shorter one. In this case the loss in time is about four times as great for the longer trip.

Thus it seems that motorists attach significance to the actual amount of time saved or lost in traveling from one point to another in urban areas (especially when the amount is substantial) as well as to the relative travel time by way of one route compared with that of another. It is quite possible, in the case of the shorter trips, that the increment of time saved or lost is so small that it is not only insignificant but probably unknown to motorists. This might further explain the reason for the relative position of the curves in Figure 9.

If the travel-time ratio were the only criterion, the point at which the curves in Figure 9 cross each other would occur at a ratio of 1.0 instead of 1.07. The position of the curves show that, when the travel-time ratio is 1.0, the freeway is slightly more attractive to motorists making long trips than it is to those making short trips. The difference is so small in this case, however, that it could not be considered significant insofar as traffic assignment is concerned.

## FREEWAY-USE IN RELATION TO TIME AND DISTANCE RATIOS

The percentage use of the freeway in relation to travel-time ratios and to travel-distance ratios has been shown on charts, separately, in Figures 5 and 6. In Figure 10 these two ratios and the percentage use of the freeway are shown on the same chart in order that the general relation of the three variables can be visualized and explored. Each dot on the chart represents a zone-to-zone movement and the adjacent numeral indicates the percentage of that movement using the freeway. These are plotted according to the time and distance ratios for each such movement.

The four statements shown in brackets on the chart, relative to saving or losing time and distance, apply to the four quadrants formed by the heavy vertical line at time ratio 1.0 and the heavy horizontal line at distance ratio 1.0. These statements refer to trips made by way of the freeway. Note that the lower right quadrant does not contain any dots. This is proper because, in this study, the average speed of travel on the freeway exceeds that on any alternate route; consequently, any zone-to-zone movement that would have lost time on the freeway would also have lost distance.

It is of interest that, in total, the freeway was used by 17 percent of the zone-to-zone movements plotted in the upper right quadrant, by 60 percent of those plotted in the upper left quadrant, and by 90 percent of those plotted in the lower left quadrant. Interpreting these percentages further, of the motorists whose trips were studied that would have lost both time and distance by using the freeway, 17 percent chose to do so, as did 60 percent of those who would have saved time but lost distance. On the other hand, of the motorists that could have saved both time and distance by using the freeway, 10 percent did not do so. This, again, seems to indicate the presence of factors other than time and distance that influence motorists in their choice of route.

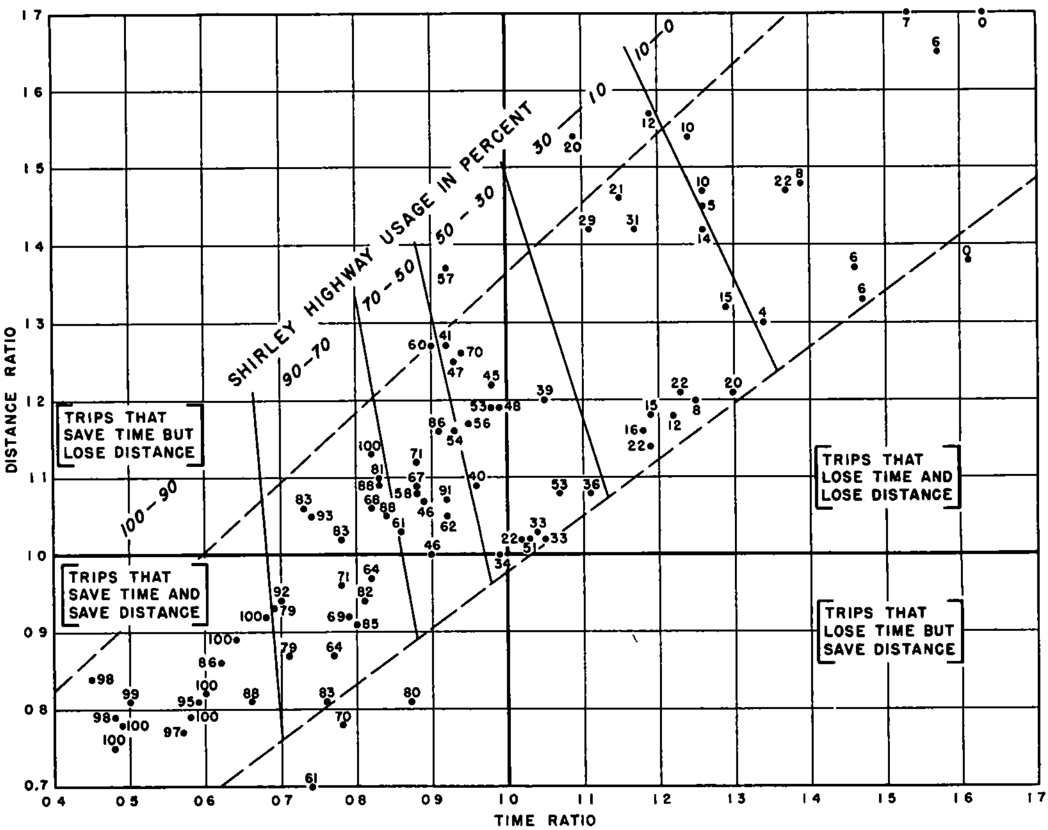


Figure 10. Freeway usage in relation to time and distance ratios.

The two dashed lines extending from the lower left to the upper right of the chart indicate the general range of time and distance ratios within which usage of the freeway occurs. The five solid lines sloping upward slightly to the left subdivide the area between the dashed lines into six segments. Each segment represents roughly a certain percentage range for use of the freeway as designated by the line of numerals extending diagonally across the chart above the upper dashed line, most of the percentages within a segment falling within the range indicated. It will be noted that the percentage of use gradually decreases from 100 percent at the lower left corner to zero at the upper right corner.

While it would have been desirable to have had more points from which to determine the slope of these five "contour" lines, the general direction of the third and fifth line from the left can be determined with reasonable accuracy from the points shown. To determine the slope of the three remaining lines, the third and fifth were extended to an intersection at a point above the chart and the remaining three lines projected back from that point of intersection as radii of a circle. This method seemed to conform with the data as nearly as any other logical one.

The slope of the resulting lines permits some interesting conjectures to be made. If all had turned out to be vertical this would have indicated that distance ratio has no effect at all on a motorist in his choice of route insofar as the factors of time and distance ratio are concerned. Conversely, had the lines assumed a horizontal position, it would indicate that time ratio has no effect. The lines as drawn suggest that both ratios affect the choice of route to some extent but, since the lines are more nearly vertical than horizontal, it follows that the time ratio is probably more significant than the distance ratio in this respect. Furthermore, since the slope of each line becomes greater as the percentage use of the freeway decreases, it suggests an increasing effect of the distance ratio as the time and distance ratios increase.

## STATISTICAL COMPARISON OF CURVES

As stated earlier, the principal purpose of this study is to show how travel time and travel distance affect the use of a freeway. The curves developed show the effects of these factors, but the correlation is not perfect in any of these cases. The points in some instances depart widely from the average relation expressed by the trend lines or curves fitted to the data. It is desirable to know the relative significance of the averages expressed by each curve before they can be used intelligently.

The standard error of estimate offers a mathematical means of making this determination. The standard error serves not only as a general index of the significance of these curves, but also as a measure of the degree of accuracy of estimates based upon them. In other words, it measures the expected variability of estimated values from the actual values.

Therefore, in order to compare the curves developed in connection with time and distance ratios and appraise their reliability for use in traffic assignment work, the standard error was computed for each curve. The results of these computations, which is the percentage variation that would not be exceeded more often than about one third of the time, are summarized in Table 3.

TABLE 3

Standard error of estimate

| Description of curve | Figure No. | Standard error |
|---|---|---|
| | | percent |
| Time ratio | 5 | 8.66 |
| Distance ratio | 6 | 17.54 |
| Product of time and distance ratios | 7 | 11.14 |
| Time differential | 8 | 8.50 |

Of the four curves, the one based on time differential has the least standard error, while the one based on distance ratio has the greatest. It will be noted that the curve based on time ratio has a standard error only slightly greater than that of the time differential curve. This clearly indicates that the curves based on time differential and time ratio are approximately of equal reliability and that time differential and time ratio show the best correlation with the percentage use of the freeway. Either of these curves, if used for purposes of assigning zone-to-zone movements of traffic to the freeway, would provide results within 8 or 9 percent of the true values in at least two thirds of the cases. This is satisfactorily within the accuracy of the basic data collected in origin-and-destination traffic studies conducted on the usual sampling basis. Moreover, the necessity of projecting traffic estimates into the future, with the attendant uncertainties, can readily introduce differences of greater magnitude than those that would result from the assignment of traffic on the basis of the time differential or travel-time curves.

# ALLOCATION OF TRAFFIC TO BYPASSES

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## SYNOPSIS

From recent experience gained in conducting before and after origin-destination studies on two Indiana bypasses, it was found that several of the current methods used for traffic assignment did not give comparable results. The traffic usages as given by various methods, including a method based on time, one based on distance, and another based on several distance factors, were compared to the known usage of the two Indiana bypasses. The results were then analyzed in an effort to verify one or more of these methods.

A new method based upon comparative travel costs which considers both time and distance factors was derived from the factual usage. This method may have a wide application to all types of facilities, and offers opportunities for easy and direct computation of highway benefits for the determination of economic justification.

IN THE DESIGN of new highway facilities, it is desirable to determine the anticipated volume and character of traffic which will use the improvement. The methods in use, however, vary considerably among the various state highway departments. Many, in fact, do not use a particular method but rely on the experience and wisdom of those associated with the planning of the facility for an estimate of the volume and character of the traffic. The problem has recently occupied the thoughts of many men, and several methods of allocating traffic on a rational basis from a consideration of various factors have been proposed and used.

A search by the authors for a method to allocate traffic to bypasses supplemented by a knowledge from before and after data of the actual usage, formed the basis for a comparison of several of the proposed methods for allocating traffic. These data were also used in the formulation of a method based upon costs of travel.

## PURPOSE

The purpose of this paper is to compare three proposed methods of allocating traffic with the actual usage encountered on two Indiana bypasses. The results of the comparison have been analyzed in an attempt to verify one or more of these methods.

An additional purpose is to present a method based upon the costs of travel. Such a method might be applicable to many types of new facilities and could be used directly and easily in determining the economic justification for the new construction.

## BYPASS STUDIES

In August, 1950, the State Highway Commission of Indiana and the Joint Highway Research Project of Purdue University initiated a cooperative traffic and engineering study of two bypasses. The locations of these bypasses, one at Lebanon, Indiana, and the other at Kokomo, Indiana, are shown in Figure 1. The major routes at the two locations and the street pattern of the two cities are shown in Figures 2 and 3. Before and after studies were conducted at each bypass.

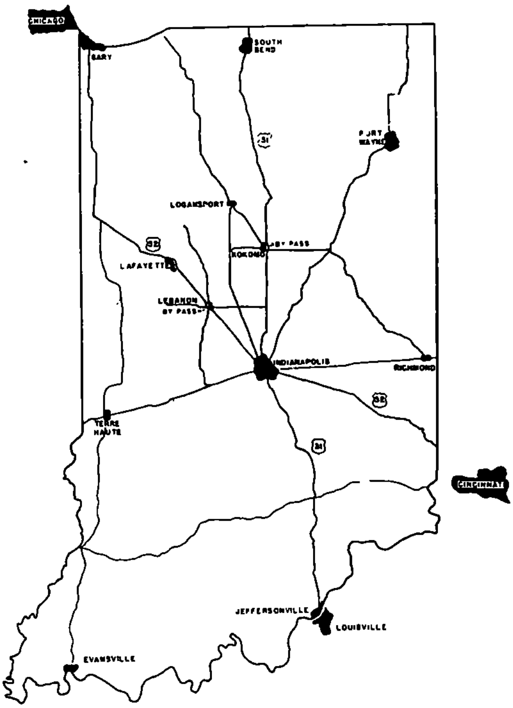

Figure 1. Principal highway routes in Indiana.

The before studies included a standard, external-cordon origin-and-destination survey conducted prior to the opening of the bypass. The cordon line in each study was placed around the urban limits of the city.

The after studies also included an origin-destination survey. In these surveys the cordon line was placed around the bypass and the traffic was intercepted as it left the bypass. The place of entry of the vehicle onto the bypass, in addition to the usual questions, was asked of each driver. These studies were conducted about six months after the opening of the bypasses.

The field data for the Kokomo before study was collected in September and October 1950. A total of 95.7 percent of the total traffic which passed through the interview stations was interviewed. The 22,107 interviews accounted for 82 percent of all the traffic which entered or left the city during an average weekday. The average 24 hr. weekday traffic in, out, and through Kokomo was 24,674 trips of which 12.4 percent was through traffic. The principal origins and destinations are shown in Figure 4.

The after study at Kokomo was conducted in May 1951. A total of 12,881 vehicles was intercepted and interviewed. Included in this total was 82 percent of the vehicles which used all or a portion of the bypass. The average 24 hr. traffic using the bypass was 7,316 trips of which 1,071 trips used the entire length (7.11 mi. of the bypass, and 6,245 trips used only a portion of the bypass. The average 24 hr. traffic volume on the central section of the bypass was 4345 vehicles.

The before study of the Lebanon bypass was conducted in October

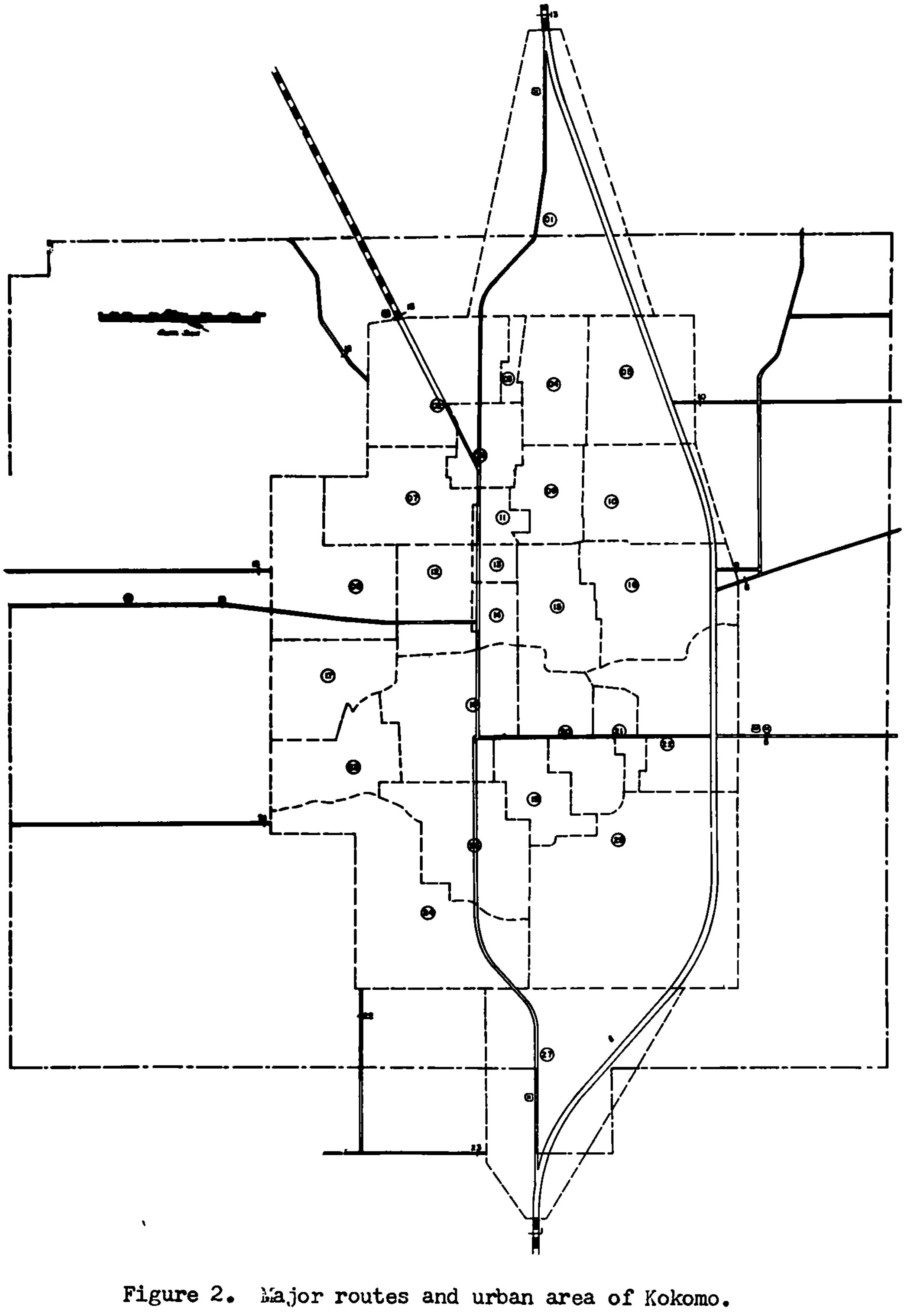

Figure 2. Major routes and urban area of Kokomo.

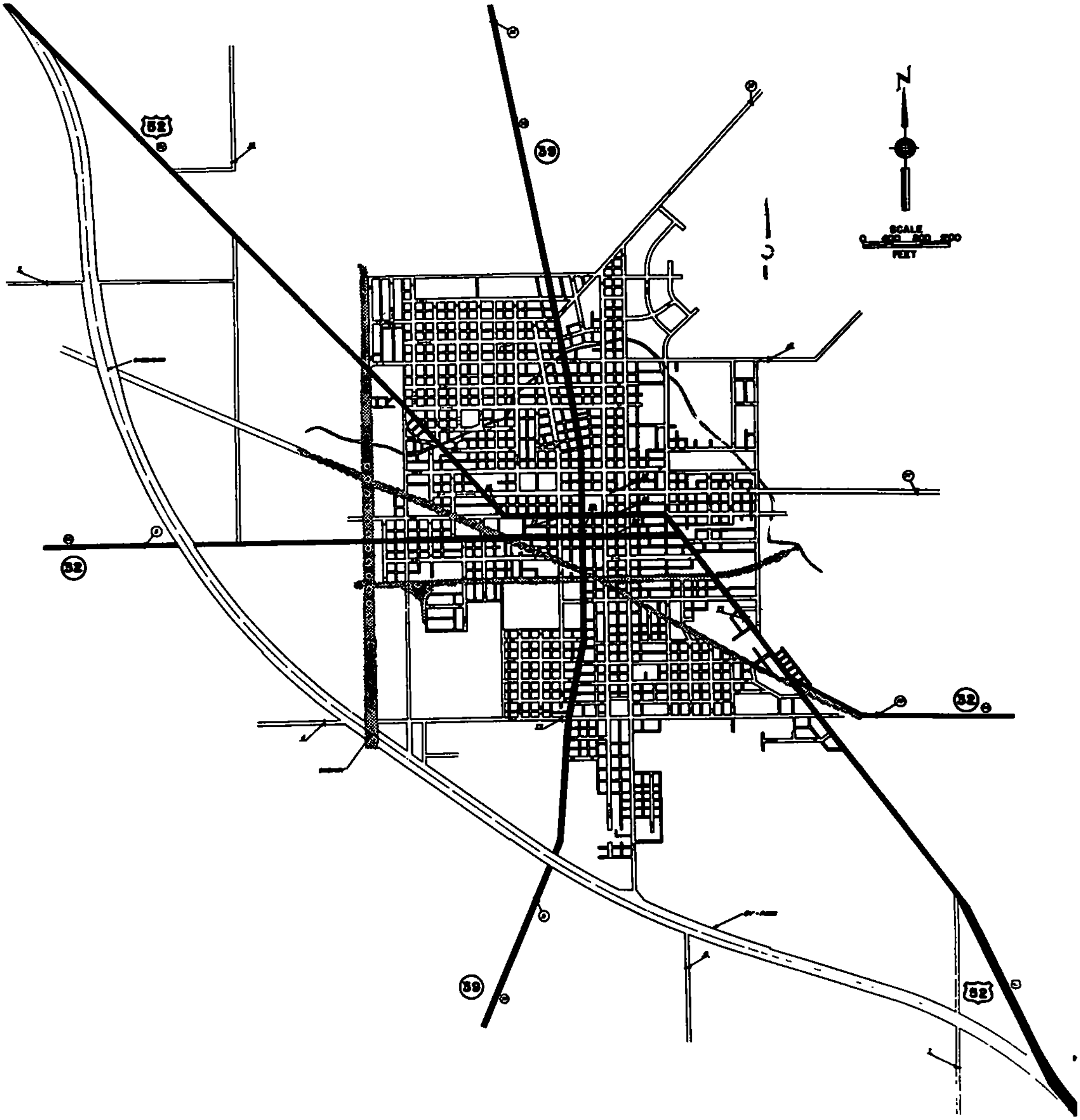


Figure 3. Major routes and urban area of Lebanon.

1950. A total of 96 percent of the total traffic which passed through the interview stations was interviewed. The 13,170 vehicles interviewed accounted for 83 percent of the average daily traffic entering or leaving Lebanon. The average 24 hr. weekday traffic in, out, and through Lebanon was 14,233 trips of which 59.3 percent was inbound or outbound from the city, and 40.7 percent was through traffic. The principal origins and destinations are shown in Figure 5.

The field data for the Lebanon-after study were collected in October 1951. A total of 9,153 vehicles was intercepted and interviewed. Included

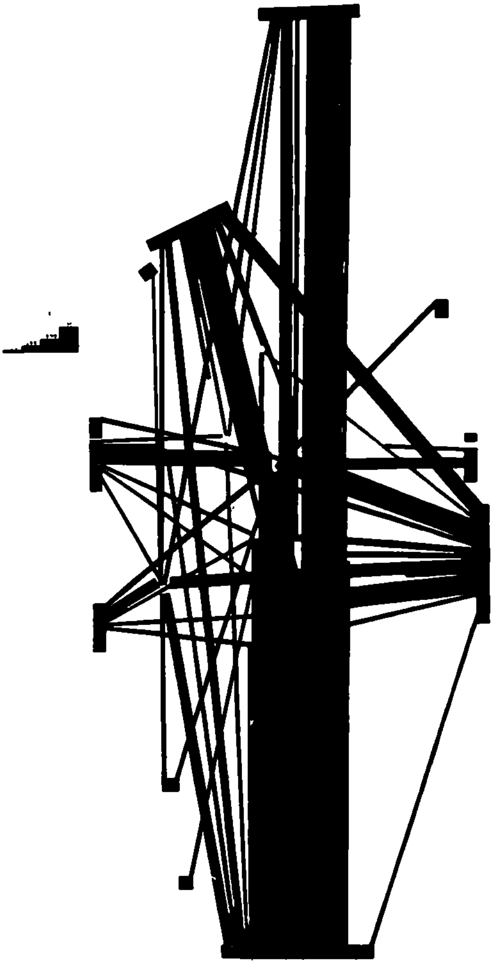

Figure 4. Origin-and-destination desire line map, automobiles and trucks, Kokomo.

in this total was about 90 percent of the vehicles which used all or a portion of the bypass. The average 24 hr. traffic volume on the central section of the bypass was 5,283 vehicles. This bypass is 5.14 mi. long.[1]

SOME CURRENT METHODS OF TRAFFIC ALLOCATION

The first portion of this section includes a brief description of some of the presently used methods of assigning traffic to new facilities. The latter portion presents the application of the data obtained in the before and after surveys at Lebanon and Kokomo to the various methods.

INDIANA METHOD

In a paper presented to the Highway Research Board in 1947, R. M. Brown of the State Highway Commission of Indiana introduced a proposed method for determining vehicular usage for expressways (1). This method was based upon the following factors: (1) Expressway Distance (F1) - length of the expressway portion of the trip; (2) Access Distance (F2) - the length of the city streets used to enter and leave the expressway in connection with the trip; and (3) Adverse Distance (F3) - the increased distance required for the trip via the expressway as compared to a more direct route using existing city streets.

Speeds on the expressway were assumed as twice those on city streets.

The following equation expresses the predicted percent of expressway usage (F) for a given trip:

$$F = \frac{(F1 + F2) \times F3}{100}$$

1/ - NOTE: The Lebanon bypass is apparently a two-lane road and should not be compared to an expressway. - Editor.

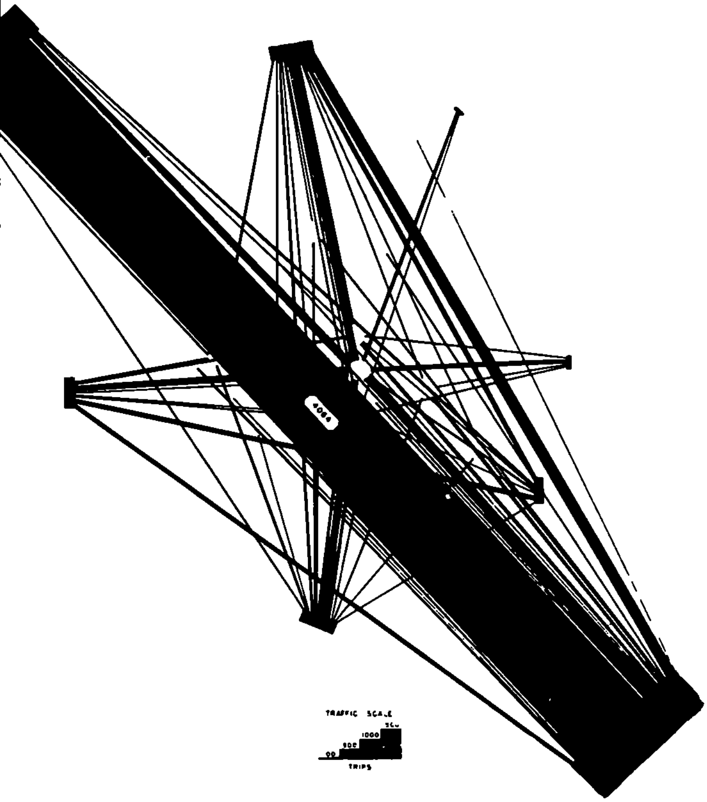

Figure 5. Origin-and-destination desire line map, automobiles and trucks, Lebanon.

After trial and experiment, Brown considered that F3 (adverse distance factor) rated equal in importance to the combination of F1 and F2. It was also considered that F1 (expressway distance factor) was more important than F2 (access distance factor) by a ratio of 7:3. Therefore, optimum value for F1 was 70, F2 was 30, and F3 was 100.

Three distances scaled from a map that are measured to determine the factors are: (1) Expressway Distance (a) - the length in miles of the expressway portion of the trip; (2) Access Distance (b) - the length in miles of the city street portion of the trip when using the expressway; and (3) Street Distance (c) - the total length of trip in miles by most advantageous route using only city streets.

The relationship between actual expressway distance and the expressway distance factor is:

$$F1 = -2.8a^2 + 30.24a - 11.65$$

(For values of "a" between 0.4 and 5.4 miles - For lesser and greater values of "a", F1 retains its respective minimum (0) and maximum (70) values.)

The relationship between actual access distance and the access distance factor is:

$$F2 = 33.3 \frac{a}{a + b} - 3.3$$

The relationship between actual adverse distance (v) and adverse distance factor is:

$$F3 = 100 - 240 (v/a)^2 \quad \text{where } v = a + b - c$$

The derivations of these formulas are given in the paper (1). Laborious calculations involved in the application of the formulae are eliminated by the use of a mechanical device developed by Brown.

## DISTANCE RATIO METHOD

Earl Campbell of the Highway Research Board staff proposed a method of assigning traffic to proposed expressways in 1949 (2) Campbell's method is based upon three fundamental principles: (1) 100 percent vehicular usage of the new facility when the distance by existing routes is equal to or greater than the route via the new highway facility; (2) 50 percent vehicular usage when the cost of travel by existing routes is equal to the cost of travel via the new highway facility; and (3) 0 percent usage when the time of travel by existing routes is equal to or less than the time of travel via the new highway facility.

Campbell suggested that these three points, equal distance, equal cost, and equal time be adjusted to 95 percent, 60 percent, and 5 percent respectively, so as to allow for such intangibles as safety, relief from congestion, comfort, beauty, force of habit, and investigative desire.

In this method, Campbell suggested using the ratio of the expressway distance used (a) to the pure street distance (P) of city streets used. Pure street distance is computed as follows:

$P = c - b$

where

c = mileage of city streets used without using expressway.

d = mileage of city streets used by using expressway.

## TIME RATIO METHOD

Of the many factors affecting selection of routes, the saving of time appears to be one of the most important to the traveling public. A method of assigning traffic to a new highway facility has been developed in which the time ratio was used for determining vehicular usage. The characteristics of this curve have been partially established by data collected in several after studies on expressways and boulevards (3, 4, 5). Time ratio is defined as the ratio of time via the expressway to the time via city streets.

## OTHER METHODS

K. A. MacLachlan of the state highway department in California has presented a method of determining vehicular usage of new highway facilities (6). The application of this method is presented in an origin-and-destination survey of Sacramento, California (7). A special type of desire line chart similar to a contour map is constructed. To make such an analysis, however, it is necessary to subdivide the internal area into extremely small tracts and to use special IBM equipment.

Certain states have found that the judgment of several experienced individuals is able to duplicate with accuracy in a short period of time present mathematical means of route selection and traffic assignment (2).

## APPLICATION OF BYPASS DATA TO PRESENT METHODS

The Kokomo and Lebanon bypass data were applied to the Indiana, the distance-ratio, and the time-ratio methods. A comparison of the derived percentage usage by these three methods with the actual usage is shown in Tables 1 and 2. The data are shown separately for each bypass and for automobiles and trucks. Only trips between origins and destinations having a total volume of twenty or more were used in these calculations. Through trips are shown first in the tables and then trips from or to locations within the city.

### APPLICATION TO BYPASSES

In the use of the Indiana method, a few changes were made in the basic formulas as given earlier in this paper (1). Brown, in his proposal, considered that because of the difficulty of getting on or off an expressway-type facility, the factor F1 would be zero unless ½ mi. or more of the facility could be used. It was felt that this assumption would not hold true for bypasses where the difficulty of exit or entry would be small. Consequently, an F1 based on zero usage at 0 mi. of bypass traveled was computed and used in this study. The formula for this new F1 is:

$F1 = -2.8a^2 + 28a$ where the variables are as given earlier and for values of "a" between 0 and 5.0 mi.

The formulas as proposed by Brown were based on a speed ratio of 2:1 between the expressway route and the old route. In these bypass studies, the average speed ratios were about 5:3 for automobiles and 8:5 for trucks. Hence, the factor F3 in the Indiana method was revised. The formulas given by these ratios are:

$$\text{For automobiles, } F3 = 100 - 356 \left(\frac{v}{a}\right)^2$$

$$\text{For trucks, } F3 = 100 - 425 \left(\frac{v}{a}\right)^2$$

In the use of the distance-ratio method, a curve was plotted separately for automobiles and trucks. The three fundamental points (equal distance, equal cost, and equal time) were established on the basis of the average speeds which were attained on the streets and bypasses of Kokomo and Lebanon and by the use of a cost of travel per mile which considered the changing costs due to speed of travel. This curve is shown in Figure 6. The values for predicted usage were then taken from this curve.

The time-ratio percentages were taken from several curves which were published in Circular No. 139, Highway Research Correlation Service (8). These curves are shown in Figure 7. The average value as given by these curves was taken as the value given by this method. Time by the various routes was determined from a series of time-delay studies made on typical streets in all sections of Kokomo and Lebanon.

TABLE 1

COMPARISON OF ALLOCATION METHODS FOR LEBANON BY-PASS

Passenger Cars

| Origin Station or Tractor | Dest. Station or Tract | Total Actual Volume | Predicted Usage: Indiana Method | Predicted Usage: Distance Ratio | Predicted Usage: Time Ratio | Actual Usage |
|---|---|---|---|---|---|---|
| | | | % | % | % | % |
| 8 | 1 | 1206 | 99 | 95 | 82 | 95 |
| 1 | 8 | 1035 | 99 | 95 | 82 | 94 |
| 10 | 1 | 26 | 55 | 67 | 50 | 30 |
| 1 | 10 | 23 | 55 | 67 | 50 | 22 |
| 3 | 8 | 55 | 87 | 95 | 88 | 74 |
| 8 | 3 | 58 | 87 | 95 | 88 | 83 |
| 14 | 8 | 118 | 48 | 94 | 50 | 70 |
| 8 | 14 | 112 | 48 | 94 | 50 | 76 |
| 10 | 3 | 59 | 5 | 17 | 34 | 0 |
| 3 | 10 | 78 | 5 | 17 | 34 | 0 |
| 1 | 5 | 22 | 88 | 95 | 86 | 82 |
| 5 | 1 | 16 | 88 | 95 | 86 | 81 |
| 8 | 5 | 20 | 67 | 95 | 93 | 95 |
| 5 | 8 | 14 | 67 | 95 | 93 | 93 |
| 012 | 1 | 20 | 56 | 89 | 70 | 15 |
| 1 | 012 | 15 | 56 | 89 | 70 | 27 |
| 014 | 1 | 26 | 41 | 61 | 40 | 8 |
| 1 | 014 | 22 | 41 | 61 | 40 | 0 |
| 015 | 1 | 119 | 31 | 15 | 19 | 7 |
| 1 | 015 | 152 | 31 | 15 | 19 | 3 |
| 017 | 1 | 22 | 37 | 51 | 20 | 5 |
| 1 | 017 | 21 | 37 | 51 | 20 | 0 |
| 021 | 1 | 20 | 35 | 5 | 30 | 20 |
| 1 | 021 | 11 | 35 | 5 | 30 | 18 |
| 004 | 8 | 34 | 43 | 81 | 5 | 23 |
| 8 | 004 | 39 | 43 | 81 | 5 | 3 |

Passenger Cars

| Origin Station or Tract | Dest. Station or Tract | Total Actual Volume | Predicted Usage: Indiana Method | Predicted Usage: Distance Ratio | Predicted Usage: Time Ratio | Actual Usage |
|---|---|---|---|---|---|---|
| | | | % | % | % | % |
| 009 | 8 | 31 | 44 | 79 | 30 | 42 |
| 8 | 009 | 29 | 44 | 79 | 30 | 24 |
| 010 | 8 | 72 | 43 | 77 | 40 | 21 |
| 8 | 010 | 82 | 43 | 77 | 40 | 15 |
| 014 | 8 | 21 | 48 | 23 | 50 | 29 |
| 8 | 014 | 20 | 48 | 23 | 50 | 15 |
| 015 | 8 | 175 | 41 | 67 | 56 | 20 |
| 8 | 015 | 207 | 41 | 67 | 56 | 23 |
| 019 | 8 | 30 | 57 | 93 | 82 | 33 |
| 8 | 019 | 33 | 57 | 93 | 82 | 100 |
| 021 | 3 | 21 | 4 | 5 | 13 | 10 |
| 3 | 021 | 25 | 4 | 5 | 13 | 0 |

TRUCKS

| Origin Station or Tract | Dest. Station or Tract | Total Actual Volume | Predicted Usage: Indiana Method | Predicted Usage: Distance Ratio | Predicted Usage: Time Ratio | Actual Usage |
|---|---|---|---|---|---|---|
| 8 | 1 | 795 | 99 | 95 | 82 | 98 |
| 1 | 8 | 901 | 99 | 95 | 82 | 98 |
| 14 | 8 | 57 | 47 | 95 | 25 | 61 |
| 8 | 14 | 56 | 47 | 95 | 25 | 66 |
| 10 | 3 | 22 | 0 | 72 | 45 | 5 |
| 3 | 10 | 27 | 0 | 72 | 45 | 0 |
| 014 | 8 | 22 | 47 | 77 | 56 | 73 |
| 8 | 014 | 29 | 47 | 77 | 56 | 25 |
| 015 | 8 | 35 | 39 | 89 | 60 | 26 |
| 8 | 015 | 33 | 39 | 89 | 60 | 21 |
| 016 | 8 | 21 | 49 | 93 | 82 | 52 |
| 8 | 016 | 23 | 49 | 93 | 82 | 22 |

TABLE 2

COMPARISON OF ALLOCATION METHODS FOR KOKOMO BY-PASS

| Passenger Cars | | | | | | |
|---|---|---|---|---|---|---|
| Origin Station or Tract | Dest. Station or Tract | Total Actual Volume | Predicted Usage: Indiana Method | Predicted Usage: Distance Ratio | Predicted Usage: Time Ratio | Actual Usage |
| | | | % | % | % | % |
| 5 | 1 | 57 | 87 | 95 | 90 | 86 |
| 1 | 5 | 99 | 87 | 95 | 90 | 80 |
| 1 | 13 | 458 | 99 | 95 | 80 | 85 |
| 13 | 1 | 446 | 99 | 95 | 80 | 87 |
| 5 | 13 | 47 | 98 | 95 | 90 | 77 |
| 13 | 5 | 68 | 98 | 95 | 90 | 67 |
| 002 | 1 | 33 | 72 | 64 | 55 | 3 |
| 006 | 1 | 66 | 45 | 13 | 26 | 6 |
| 007 | 1 | 38 | 45 | 13 | 33 | 5 |
| 008 | 1 | 25 | 58 | 26 | 55 | 16 |
| 011 | 1 | 27 | 48 | 17 | 42 | 7 |
| 012 | 1 | 48 | 26 | 5 | 3 | 8 |
| 013 | 1 | 55 | 54 | 25 | 49 | 7 |
| 014 | 1 | 351 | 45 | 13 | 29 | 5 |
| 015 | 1 | 51 | 72 | 68 | 66 | 21 |
| 018 | 1 | 120 | 9 | 5 | 5 | 9 |
| 019 | 1 | 233 | 21 | 44 | 17 | 16 |
| 020 | 1 | 59 | 58 | 52 | 57 | 22 |
| 022 | 1 | 31 | 84 | 95 | 83 | 65 |
| 023 | 1 | 126 | 13 | 5 | 7 | 6 |
| 025 | 1 | 104 | 0 | 5 | 2 | 6 |
| 026 | 1 | 29 | 52 | 53 | 73 | 31 |
| 002 | 5 | 48 | 68 | 95 | 81 | 48 |
| 006 | 5 | 61 | 30 | 95 | 70 | 15 |
| 007 | 5 | 38 | 30 | 92 | 68 | 18 |
| 009 | 5 | 27 | 39 | 95 | 82 | 33 |
| 011 | 5 | 26 | 32 | 95 | 78 | 26 |
| 012 | 5 | 43 | 22 | 64 | 76 | 21 |
| 013 | 5 | 32 | 33 | 95 | 79 | 31 |
| 014 | 5 | 366 | 27 | 74 | 73 | 17 |
| 015 | 5 | 65 | 36 | 95 | 72 | 56 |
| 016 | 5 | 38 | 34 | 72 | 78 | 47 |
| 019 | 5 | 265 | 25 | 88 | 67 | 11 |
| 025 | 5 | 60 | 18 | 47 | 63 | 13 |

| Passenger Cars | | | | | | |
|---|---|---|---|---|---|---|
| **Origin Station or Tract** | Station or Tract | Total Actual Volume | Predicted Usage: Indiana Method | Predicted Usage: Distance Ratio | Predicted Usage: Time Ratio | Actual Usage |
| | | | % | % | % | % |
| 026 | 5 | 30 | 33 | 95 | 76 | 47 |
| 002 | 13 | 53 | 42 | 20 | 3 | 4 |
| 004 | 13 | 41 | 52 | 53 | 5 | 17 |
| 006 | 13 | 42 | 32 | 5 | 17 | 10 |
| 007 | 13 | 49 | 25 | 5 | 4 | 10 |
| 011 | 13 | 35 | 0 | 5 | 3 | 6 |
| 012 | 13 | 58 | 21 | 5 | 6 | 2 |
| 013 | 13 | 28 | 50 | 21 | 8 | 4 |
| 014 | 13 | 233 | 49 | 21 | 9 | 10 |
| 015 | 13 | 57 | 60 | 80 | 69 | 37 |
| 016 | 13 | 25 | 72 | 95 | 84 | 56 |
| 018 | 13 | 75 | 47 | 21 | 22 | 11 |
| 019 | 13 | 120 | 76 | 75 | 69 | 62 |
| 020 | 13 | 27 | 88 | 90 | 78 | 52 |
| 023 | 13 | 93 | 52 | 31 | 34 | 10 |
| 025 | 13 | 53 | 63 | 42 | 22 | 13 |
| TRUCKS | | | | | | |
| 5 | 1 | 32 | 88 | 95 | 92 | 97 |
| 1 | 5 | 42 | 88 | 95 | 92 | 86 |
| 13 | 1 | 152 | 99 | 95 | 82 | 95 |
| 1 | 13 | 166 | 99 | 95 | 82 | 89 |
| 5 | 13 | 32 | 98 | 95 | 91 | 90 |
| 13 | 5 | 35 | 98 | 95 | 91 | 97 |
| 008 | 1 | 24 | 46 | 80 | 61 | 4 |
| 013 | 1 | 34 | 37 | 25 | 57 | 32 |
| 014 | 1 | 65 | 0 | 13 | 37 | 6 |
| 018 | 1 | 24 | 44 | 5 | 6 | 0 |
| 019 | 1 | 40 | 0 | 86 | 21 | 10 |
| 023 | 1 | 29 | 0 | 5 | 8 | 7 |
| 025 | 1 | 30 | 88 | 5 | 2 | 3 |
| 014 | 5 | 55 | 26 | 92 | 63 | 29 |
| 019 | 5 | 57 | 24 | 94 | 73 | 5 |
| 008 | 13 | 24 | 2 | 5 | 2 | 0 |
| 014 | 13 | 30 | 42 | 74 | 9 | 14 |
| 019 | 13 | 30 | 74 | 75 | 71 | 43 |

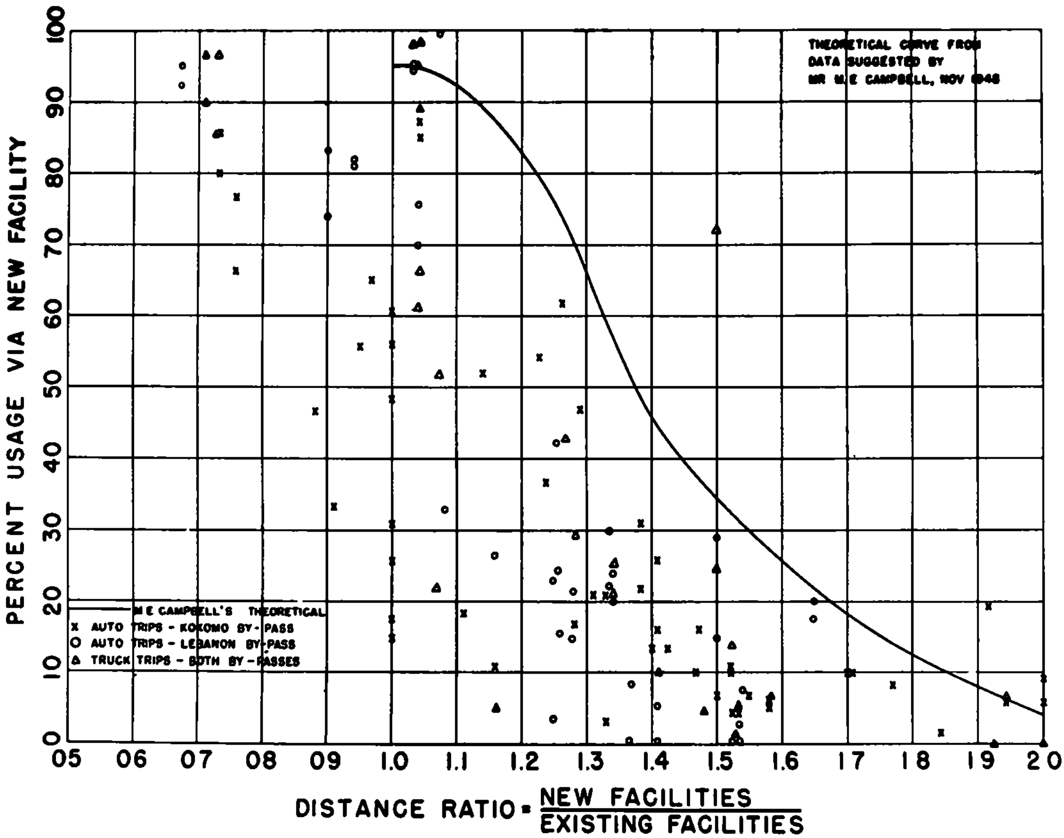


Figure 6. Percent diversion of traffic based on comparative travel distance.

## COMPARISON OF RESULTS

The indices as computed for the various methods are shown in Tables 3 and 4. From these indices the points were plotted on Figures 6 and 7. A comparison of the values in Tables 1 and 2 and the plot of points in Figures 6 and 7 indicate the following conclusions:

1. The three methods give results which are not similar in value in many cases. Only at very few points do the methods closely agree.

2. The three methods give results that are too high in practically every case. This may be accounted for by the lower-type facility (a bypāss) than an expressway for which the methods were primarily designed.

3. The Indiana method gives the best results when a very short distance of the bypass (less than 1 mi.)is used.

4. The values as given by the time-ratio method appear to fall more closely to the actual usage than do those by the other two methods.

TABLE 3

INDICES FOR PERCENT USAGE
BY VARIOUS METHODS-LEBANON BYPASS

Passenger Cars

| Origin Station or Tract | Destination Station or Tract | Actual Volume | Actual Usage | Distance Ratio | Time Ratio | Cost Index |
|---|---|---|---|---|---|---|
| | | No. | % | | | |
| 8 | 1 | 1206 | 95 | 1.03 | .68 | .80 |
| 1 | 8 | 1035 | 94 | 1.03 | .68 | .80 |
| 10 | 1 | 26 | 30 | 1.33 | .97 | 1.04 |
| 1 | 10 | 23 | 22 | 1.33 | .97 | 1.04 |
| 3 | 8 | 55 | 74 | .90 | .55 | .66 |
| 8 | 3 | 58 | 83 | .90 | .55 | .66 |
| 14 | 8 | 118 | 70 | 1.04 | .96 | .94 |
| 8 | 14 | 112 | 76 | 1.04 | .96 | .94 |
| 10 | 3 | 59 | 0 | 1.53 | 1.02 | 1.05 |
| 3 | 10 | 78 | 0 | 1.53 | 1.02 | 1.05 |
| 1 | 5 | 22 | 82 | .94 | .60 | .72 |
| 5 | 1 | 16 | 81 | .94 | .60 | .72 |
| 8 | 5 | 20 | 95 | .67 | .39 | .47 |
| 5 | 8 | 14 | 93 | .67 | .39 | .47 |
| 012 | 1 | 20 | 15 | 1.16 | .83 | .93 |
| 1 | 012 | 15 | 27 | 1.16 | .83 | .93 |
| 014 | 1 | 26 | 8 | 1.37 | .98 | 1.05 |
| 1 | 014 | 22 | 0 | 1.37 | .98 | 1.05 |
| 015 | 1 | 119 | 7 | 1.54 | 1.10 | 1.17 |
| 1 | 015 | 152 | 3 | 1.54 | 1.10 | 1.17 |
| 017 | 1 | 22 | 5 | 1.41 | 1.09 | 1.14 |
| 1 | 017 | 21 | 0 | 1.41 | 1.09 | 1.14 |
| 021 | 1 | 20 | 20 | 1.65 | 1.03 | 1.22 |
| 1 | 021 | 11 | 18 | 1.65 | 1.03 | 1.22 |
| 004 | 8 | 34 | 23 | 1.25 | 1.31 | 1.42 |
| 8 | 004 | 39 | 3 | 1.25 | 1.31 | 1.42 |
| 009 | 8 | 31 | 42 | 1.26 | 1.03 | 1.14 |
| 8 | 009 | 29 | 24 | 1.26 | 1.03 | 1.14 |
| 010 | 8 | 72 | 21 | 1.28 | .99 | 1.02 |
| 8 | 010 | 82 | 15 | 1.28 | .99 | 1.02 |
| 014 | 8 | 21 | 29 | 1.50 | .97 | 1.02 |
| 8 | 014 | 20 | 15 | 1.50 | .97 | 1.02 |
| 015 | 8 | 175 | 20 | 1.34 | .94 | .86 |
| 8 | 015 | 207 | 23 | 1.34 | .94 | .86 |
| 019 | 8 | 30 | 33 | 1.08 | .67 | .70 |
| 8 | 019 | 33 | 100 | 1.08 | .67 | .70 |
| 021 | 3 | 21 | 10 | 2.11 | 1.15 | 1.18 |
| 3 | 021 | 25 | 0 | 2.11 | 1.15 | 1.18 |

TABLE 3 (continued)

TRUCKS

| Origin Station or Tract | Destination Station or Tract | Actual Volume | Actual Usage | Distance Ratio | Time Ratio | Cost Index |
|---|---|---|---|---|---|---|
| | | No. | % | | | |
| 8 | 1 | 795 | 98 | 1.03 | .66 | .68 |
| 1 | 8 | 901 | 98 | 1.03 | .66 | .68 |
| 14 | 8 | 57 | 61 | 1.04 | 1.06 | .86 |
| 8 | 14 | 56 | 66 | 1.04 | 1.06 | .86 |
| 10 | 3 | 22 | 5 | 1.53 | .98 | .98 |
| 3 | 10 | 27 | 0 | 1.53 | .98 | .98 |
| 014 | 8 | 22 | 73 | 1.50 | .93 | .96 |
| 8 | 014 | 29 | 25 | 1.50 | .93 | .96 |
| 015 | 8 | 35 | 26 | 1.34 | .92 | .94 |
| 8 | 015 | 33 | 21 | 1.34 | .92 | .94 |
| 016 | 8 | 21 | 52 | 1.08 | .68 | .72 |
| 8 | 016 | 23 | 22 | 1.08 | .68 | .72 |

TABLE 4

INDICES FOR PERCENT USAGE
BY VARIOUS METHODS-KOKOMO BYPASS

Passenger Cars

| Origin Station or Tract | Destination Station or Tract | Actual Volume | Actual Usage | Distance Ratio | Time Ratio | Cost Index |
|---|---|---|---|---|---|---|
| | | No. | % | | | |
| 5 | 1 | 57 | 86 | .73 | .45 | .542 |
| 1 | 5 | 99 | 80 | .73 | .45 | .542 |
| 5 | 13 | 47 | 77 | .76 | .46 | .555 |
| 13 | 5 | 68 | 67 | .76 | .46 | .555 |
| 1 | 13 | 458 | 85 | 1.04 | .70 | .803 |
| 13 | 1 | 446 | 87 | 1.04 | .70 | .803 |
| 002 | 1 | 33 | 3 | 1.33 | .94 | 1.020 |
| 006 | 1 | 66 | 6 | 1.58 | 1.05 | 1.130 |
| 007 | 1 | 38 | 5 | 1.58 | 1.03 | 1.130 |
| 008 | 1 | 25 | 16 | 1.48 | .94 | 1.068 |
| 011 | 1 | 27 | 7 | 1.55 | .89 | 1.140 |
| 012 | 1 | 48 | 8 | 1.77 | 1.60 | 1.260 |
| 013 | 1 | 55 | 7 | 1.50 | .97 | 1.084 |
| 014 | 1 | 351 | 5 | 1.58 | 1.04 | 1.154 |
| 015 | 1 | 51 | 21 | 1.31 | .87 | .979 |
| 018 | 1 | 120 | 9 | 2.00 | 1.33 | 1.400 |
| 019 | 1 | 233 | 16 | 1.41 | 1.12 | 1.170 |
| 020 | 1 | 59 | 22 | 1.38 | .93 | 1.056 |
| 022 | 1 | 31 | 65 | .97 | .64 | .763 |
| 023 | 1 | 126 | 6 | 1.94 | 1.25 | 1.340 |
| 025 | 1 | 104 | 6 | 4.50 | 1.69 | 1.640 |
| 026 | 1 | 29 | 31 | 1.38 | .80 | 1.084 |
| 002 | 5 | 48 | 48 | 1.00 | .69 | .795 |

TABLE 4 (continued)

| Origin Station or Tract | Destination Station or Tract | Actual Volume | Actual Usage | Distance Ratio | Time Ratio | Cost Index |
|---|---|---|---|---|---|---|
| | | No. | % | | | |
| 006 | 5 | 61 | 15 | 1.00 | .84 | .872 |
| 007 | 5 | 38 | 18 | 1.11 | .84 | .847 |
| 009 | 5 | 27 | 33 | .91 | .67 | .841 |
| 011 | 5 | 26 | 26 | 1.00 | .74 | .847 |
| 012 | 5 | 43 | 21 | 1.33 | .76 | .962 |
| 013 | 5 | 32 | 31 | 1.00 | .71 | .830 |
| 014 | 5 | 360 | 17 | 1.28 | .79 | .952 |
| 015 | 5 | 65 | 56 | 1.00 | .80 | .873 |
| 016 | 5 | 38 | 47 | 1.29 | .74 | .837 |
| 019 | 5 | 265 | 11 | 1.16 | .85 | .905 |
| 025 | 5 | 60 | 13 | 1.40 | .88 | .859 |
| 026 | 5 | 30 | 47 | .88 | .76 | .832 |
| 002 | 13 | 53 | 4 | 1.53 | 1.46 | 1.410 |
| 004 | 13 | 41 | 17 | 1.00 | 1.29 | 1.270 |
| 006 | 13 | 42 | 10 | 1.70 | 1.12 | 1.230 |
| 007 | 13 | 49 | 10 | 1.71 | 1.38 | 1.350 |
| 008 | 13 | 32 | 19 | 1.92 | 1.26 | 1.590 |
| 011 | 13 | 35 | 6 | 2.00 | 1.45 | 1.460 |
| 012 | 13 | 58 | 2 | 1.84 | 1.26 | 1.300 |
| 013 | 13 | 28 | 4 | 1.52 | 1.23 | 1.270 |
| 014 | 13 | 233 | 10 | 1.52 | 1.20 | 1.240 |
| 015 | 13 | 57 | 37 | 1.24 | .84 | .931 |
| 016 | 13 | 25 | 56 | .95 | .64 | .736 |
| 018 | 13 | 15 | 11 | 1.52 | 1.08 | 1.130 |
| 019 | 13 | 120 | 62 | 1.27 | .84 | .944 |
| 020 | 13 | 27 | 52 | 1.14 | .72 | .830 |
| 023 | 13 | 93 | 10 | 1.47 | 1.01 | 1.100 |
| 025 | 13 | 53 | 13 | 1.42 | 1.08 | 1.030 |

TRUCKS

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 1 | 32 | 97 | .73 | .44 | .449 |
| 1 | 5 | 42 | 86 | .73 | .44 | .449 |
| 5 | 13 | 32 | 90 | .71 | .45 | .454 |
| 13 | 5 | 35 | 97 | .71 | .45 | .454 |
| 13 | 1 | 152 | 95 | 1.04 | .66 | .668 |
| 1 | 13 | 166 | 89 | 1.04 | .66 | .668 |
| 008 | 1 | 24 | 4 | 1.48 | .90 | .888 |
| 013 | 1 | 34 | 32 | 1.50 | .93 | .950 |
| 014 | 1 | 65 | 6 | 1.58 | 1.00 | 1.018 |
| 018 | 1 | 24 | 0 | 2.00 | 1.30 | 1.290 |
| 019 | 1 | 40 | 10 | 1.41 | 1.08 | 1.090 |
| 023 | 1 | 29 | 7 | 1.94 | 1.25 | 1.240 |
| 025 | 1 | 30 | 3 | 4.50 | 1.57 | 1.580 |
| 014 | 5 | 55 | 29 | 1.28 | .88 | .875 |
| 019 | 5 | 57 | 5 | 1.16 | .80 | .800 |
| 008 | 13 | 24 | 0 | 1.92 | 1.72 | 1.720 |
| 014 | 13 | 30 | 14 | 1.52 | 1.20 | 1.200 |
| 019 | 13 | 30 | 43 | 1.27 | .82 | .822 |

5. The variation of results appears to be greatest in the distance-ratio method.

6. There appears to be very little necessity for separate curves for trucks and automobiles for the distance and the time ratio methods.

7. There appears to be only limited continuity between the actual results and those given by any of the three methods. This would indicate that all of the methods consider too few of the factors that are apparently involved.

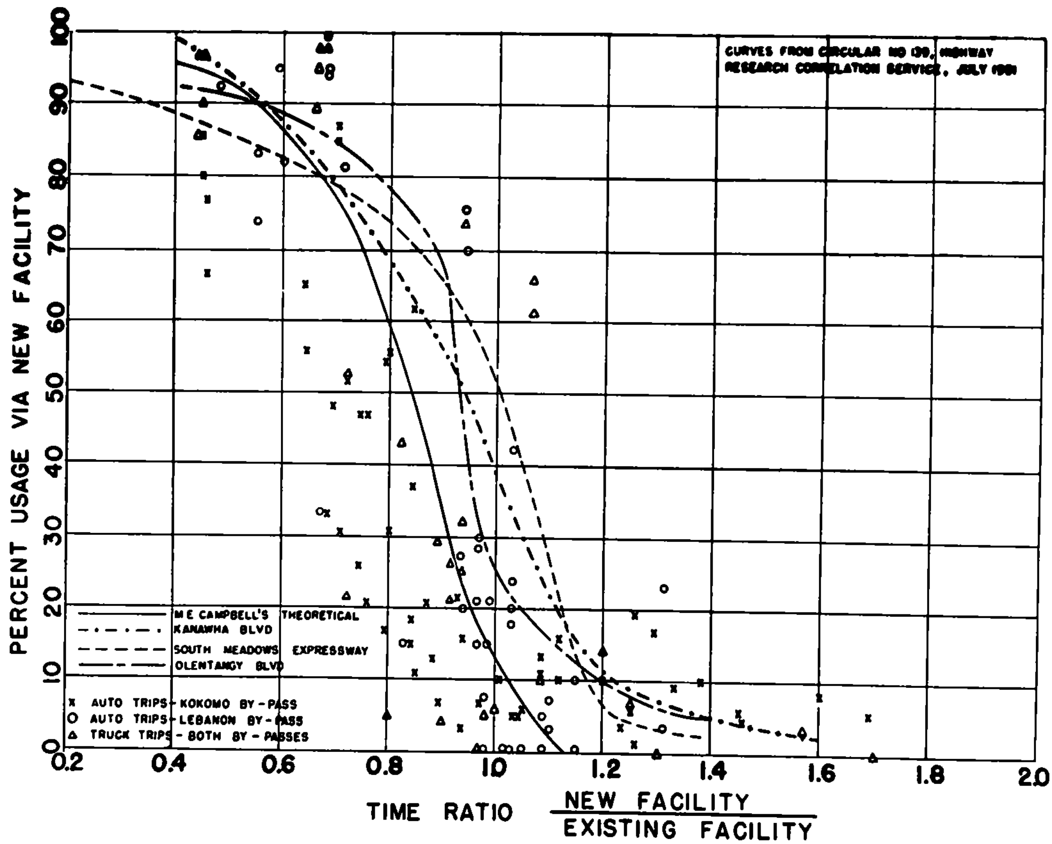


Figure 7. Percent diversion of traffic based on comparative travel time.

## COST INDEX METHOD

A search for a more accurate method of allocation resulted in a consideration of the various factors as they may be reflected in the cost of travel. It is doubtful whether the individual decides to use a new facility based upon a complete cost tabulation; however, an appreciation of cost may contribute to the drivers' decision. The dollar sign is a standard system by which most benefits can be evaluated, and the public is receptive to monetary values.

It is well established that the cost of travel varies with the speed that can be attained and the number of stops and starts that are necessary. Therefore, the streets of the two cities and the highways within the internal areas were classified as open highways, arterial streets, local streets, or congested streets. This classification was based upon speed, quantity, and quality of impedances; road surface condition; and type of traffic. These factors were evaluated from speed and delay studies on the principal routes and from an inventory of the physical conditions.

Distance as a factor in the cost of travel was evaluated by measuring the distance of each type of street for each route from a scale map of the city.

Time also is a factor in the cost of travel, especially for trucks. The value of time for the truck operator as well as for the truck itself was taken from a study made by Lawrence Lawton and reported in "Traffic Quarterly" for January 1950 (9). These costs were based on the operator's wage and on the cost of operating the truck per hour considering administrative, overhead, and operating costs other than gasoline on an hourly basis. The value of time for automobile occupants was also taken from the article by Lawton. A value of $1.10 per hour was determined by the average value placed on time from a study of payments made by users of toll facilities (9). This value of $1.10 per hour per vehicle is in agreement with the frequently used value of one cent per minute per occupant, since the average vehicle on the bypasses contained 1.9 occupants.

Operational costs of automobiles and trucks were tabulated for the various classes of streets from data collected by Lawton. These costs were corrected to 1950 costs by using the wholesale price index published by the U. S. Department of Commerce (10). The total costs, operating and time, were thus determined for the passenger car and for the composite truck on a per mile basis. Time value was changed to a per mile basis by evaluating the average speeds on the four classes of streets. A composite truck is assumed to be the average weighted size of all the trucks that were found in the Kokomo and Lebanon surveys. A compilation of the costs per mile is shown in Table 5.

An example of how these values were determined follows:

For a passenger car for an ordinary street.
Average speed of travel = 30 mph.
Average gasoline consumption = 14.9 mi. per gal. (9)

From this data and from the basic price data shown in Table 5 the total costs were evaluated on a per mile basis.

| | |
|---|---|
| Gasoline | 1.76 |
| Oil | 0.21 |
| Tires & Tubes | 0.31 |
| Maintenance | 0.67 |
| Depreciation | 0.83 |
| Total (Operational) | 3.78 |
| Time | 3.66 |
| Total | 7.44 |

TABLE 5

VEHICULAR OPERATIONAL COSTS ON VARIOUS TYPES OF STREETS CENTS PER MILE

| Item | Bypass | Class A | Class B | Class C |
|---|---|---|---|---|
| | | Passenger Cars | | |
| Speed (mph) | 50 | 40 | 30 | 20 |
| Total Operations | 3.31 | 3.55 | 3.78 | 5.07 |
| Time (1.83¢/min) | 2.20 | 2.74 | 3.66 | 5.50 |
| Totals | 5.51 | 6.29 | 7.44 | 10.57 |
| | | Trucks* | | |
| Speed | 40 | 30 | 25 | 15 |
| Gasoline | 5.09 | 6.20 | 7.66 | 12.84 |
| Other Operational Costs | 7.13 | 9.50 | 11.40 | 19.00 |
| Time | 5.25 | 7.00 | 8.40 | 14.00 |
| Totals | 17.47 | 22.47 | 27.44 | 45.84 |

*Average weighted truck using bypasses.

Basic prices used:
Gasoline - 27 ¢ per gallon
Oil - 35¢ per quart (6 qt. per 1,000 mi.)
Tires & tubes - $24.00 for one (30,000-mi. life)
Maintenance - $100 per year (2/3 because of actual use, 10,000 mi. per year)
Depreciation - Total cost $2,200 (1/3 because of actual use, 8-yr. life, 10 percent value at end)

Operators Time:

| | | | |
|---|---|---|---|
| Passenger cars | 1.10 per hr. | Medium truck | 1.68 per hr. |
| Light truck | 1.20 per hr. | Heavy truck | 2.37 per hr. |

Most trips will involve various classes of roads and the total cost can be arrived at by simply determining the mileage of each class of road, the cost for each class of road, and adding these various costs. A comparison of the cost by using the new facility with the cost by way of only city streets gives a ratio called cost index.

The following example may clarify this method:

a. Via bypass - A passenger car makes a trip via the bypass of a total distance of 9 mi. of which 6 mi. are on the bypass, 2 mi. are on Class A (arterial streets), and 1 mi. on Class B (local streets).

b. Via existing streets - A passenger car makes the same trip by existing city streets only. The total distance is 8 mi. of which 2 mi. are on class A streets, 4 mi. are on Class B streets, and 2 mi. are on Class C (congested streets).

c. Computations (costs per mile from Table 5).

| | Bypass | Class A | Class B | Class C | Total Cost |
|---|---|---|---|---|---|
| Via bypass | 6 x 5.51 | 2 x 6.29 | 1 x 7.44 | -------- | 53.08 |
| Via existing streets | ------- | 2 x 6.29 | 4 x 7.44 | 2 x 10.57 | 63.48 |

$$\text{Cost Index} = \frac{53.08}{63.48} = 0.836$$

From the cost index as calculated for the various trips and shown in Tables 3 and 4, points were plotted against actual usage and a curve drawn. This curve is shown in Figure 8.

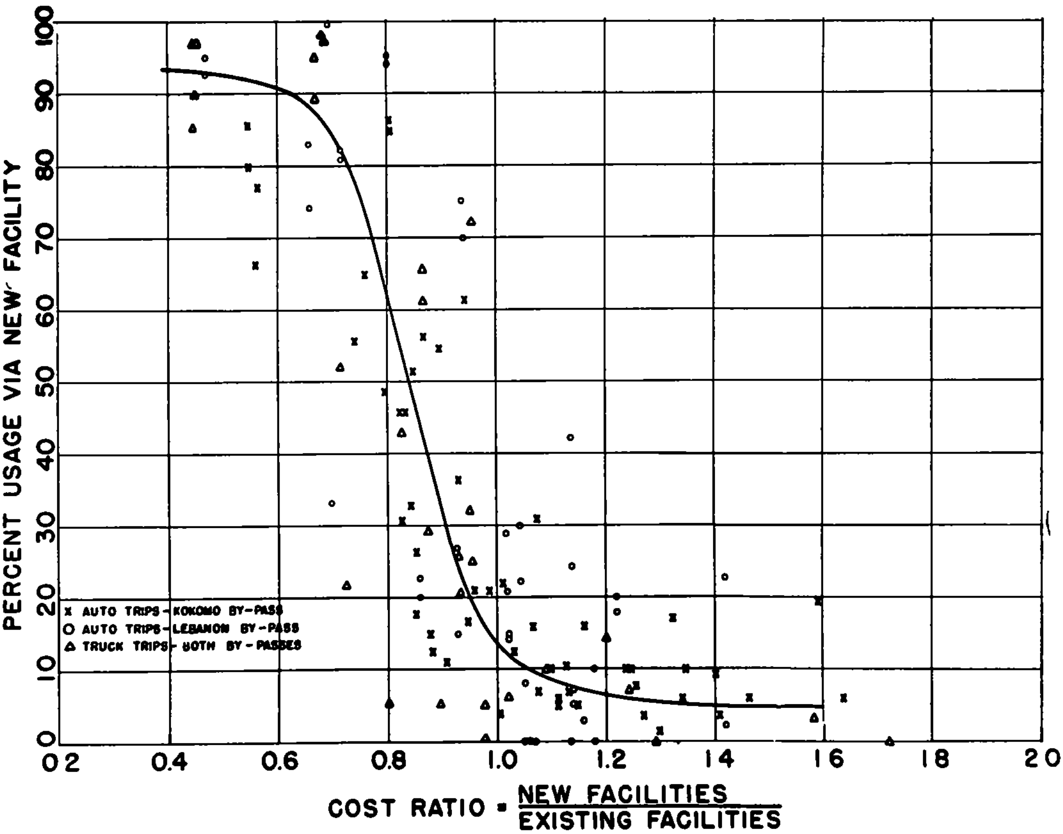


Figure 8. Percent diversion of traffic based on comparative travel cost.

## OTHER USES OF COST INDEX METHOD

In the construction of a public facility such as a highway, studies are desirable that determine on a monetary basis the cost of the facility as compared to the benefits derived from its construction. Since costs of travel have been computed by existing routes and via the proposed facility, the savings to the highway user may be easily determined. In addition, a further breakdown concerning the savings to the various types of traffic, such as auto and truck, local and foreign, or recreation and business, can be determined with very little effort.

For example, in the Lebanon survey, it was estimated from this method that passenger car users saved $185 per day while the truck users saved $625 per day. These benefits were obtained directly from the cost-index calculations with very little additional computation. A similar computation for all the trips using the facility would give the total benefits of the facility. From these data the benefit-cost ratio could be determined for an economic justification of the facility.

Much speculation has been made as to the value the public places upon such factors as safety, beauty, added convenience, etc. Although exact values cannot be placed on individual factors from the cost-index method, this method may offer a means of determining the value that the public places on all these factors. In cases where certain volumes of traffic use new facilities even though the cost of travel is greater than by existing routes, a value for these intangible factors may be possible of determination.

## CONCLUSIONS

The following conclusions are presented for the purpose of discussion:

1. The cost-index method appears to give a smaller dispersion of points from the central curve than do the other methods investigated.

2. The cost-index method indicates an S-type curve with a lower limit of 5 percent usage and an upper limit of 95 percent.

3. A cost index of 1.00 gives a usage of about 13 percent while 50 percent usage occurs at about 0.85 cost index.

4. From about a cost index of 0.65 to a cost index of 1.05 a change in percent usage from 90 percent to 10 percent is shown. This indicates that a careful evaluation of the comparative travel costs in this range is necessary.

5. It appears that the data from both bypass studies as well as the data for automobiles and trucks give approximately the same curve.

6. The calculations for the cost-index are relatively simple and provide data for a quick and easy determination of the benefits from the improvement for the various types of users.

7. The better accuracy of the cost-index method may be because consideration has been given to both the time and distance factors.

8. The cost-index method may offer opportunities for the evaluation of the intangible factors in highway use.

## RECOMMENDATIONS FOR FURTHER STUDY

Although the cost-index method appears to give a smaller dispersion of points from the central curve than do the other methods investigated, there is still a greater variation than is desirable. Additional study is being made on factors other than time and distance that may enter into the problem. From preliminary work it appears that several other factors must be considered: (1) proximity of the origin or destination to the facility; (2) length of facility that can be used to advantage;(3) exceptional usage at any one time, such as trips to and from work in an industrial area; (4) indicational signs, such as routing of state routes over the facility; and (5) natural or man-made barriers with only a limited number of crossings. An evaluation of these factors is under study.

A mathematical study to fit a curve to the actual data is also being made. Preliminary results of this study show: (1) the Gompertz, integrated normal, or logistic curves have the properties that appear to be present and (2) the logistic curve is relatively easier to fit than the other two mentioned.

Additional study to determine the mathematical equation of the logistic curve which fits the data is being deferred until the evaluation of the factors other than time and distance has been completed.

Other investigations that the authors believe would be a contribution to the improvement of techniques for allocating highway traffic to new facilities are: (1) application of cost-index method to other facilities; (2) a study of of the value of time to the highway user by type of vehicle and type of trip; and (3) a study of vehicle operating costs by type of vehicle and type of road or street.

## ACKNOWLEDGEMENTS

The authors wish to express their appreciation to those who have made this study possible, particularly K. B. Woods, associate director of the Joint Highway Research Project; A. K. Branham, research associate; R. M. Brown, in charge Metropolitan Area Traffic Survey Unit of the State Highway Commission of Indiana; M. E. Campbell, engineer of traffic and operations, Highway Research Board, for his helpful correspondence; and Paul Irick, Purdue Statistical Department, for his curve-fitting investigations.

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# TRIP-FREQUENCY STUDIES FOR NEW YORK STATE THRUWAY

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PROPOSALS for an annual permit valid for unlimited use on the New York State Thruway were the stimulus for investigating certain aspects of traffic which have not been generally explored in previous surveys. Since revenues under the permit plan would depend not only on the number of trips made, but more particularly on the number of different vehicles using the project, it was necessary to obtain information on the frequency of travel by individual vehicles making specific trips.

In conjunction with the origin-and-destination survey conducted throughout New York, therefore, drivers were asked the question "How many times a year do you make this trip?"

Some 376,000 replies were obtained to the questionnaire, representing a 25-percent sample of the 1,520,000 vehicles actually counted as passing the survey stations during the periods of the check. The replies were obtained principally by interviewing drivers in their vehicles, and the survey sample covered week-day and Sunday traffic under different seasonal conditions.

The stations selected for the survey were all outside of cities on main state highways, the principal routes covered being US 20, NY 5 and NY 17 across New York, US 9W between Albany and the City of New York area, and all the Hudson River crossings between New York city and Albany. In all, 49 locations were covered simultaneously, including 41 highway stations, five bridges and three ferries.

The results may therefore be considered indicative of typical conditions on main rural highways connecting large cities, but they do not reflect urban characteristics.

All trips considered as potential throughway users were analyzed in detail. These include most of the trips traveling along the main highways for at least a few miles, but very short trips and trips whose principal direction was across the main highway were eliminated. As a result of the trip frequency analysis of potential throughway traffic, two striking conclusions stand out: (1) a very small number of regular drivers on a particular highway account for a very substantial portion of the total traffic volume and (2) the overwhelming majority of individual vehicles on a particular highway during the course of a year are making occasional trips.

Passenger-car trips traveling along the main highways covered and considered potential to the throughway, were at the estimated annual rate of 59,700,000. Of these about 15,100,000 trips were found to be made by cars traveling with commuting frequencies of five times a week or more. The number of individual vehicles in this group was only 28,000, which was less than 1 percent of all the individual automobiles represented but they accounted for about 29 percent of all the passenger-car trips covered by the study.

The great majority of individual vehicles using the main highways in New York were found to be occasional travelers making trips occurring only one to four times a year. In order to give quantitative expression to this fact, it is necessary to use a term designating all trips made by an individual vehicle between two particular points during the course of a year. The term "vehicle run" has been adopted to apply to this value. A vehicle run may represent 1 trip or 500 trips between any two points by one vehicle. Obviously a single vehicle may make several vehicle runs on a given highway in a year, but it is unlikely that more than one of these will be of very high frequency.

Of a total of approximately 5,130,000 different vehicle runs per year estimated to be made by potential passenger car users of the New York Thruway, nearly 3,665,000 runs consisted of one round trip each. These unrepeated trips encompassed about 71 percent of all passenger-car runs, but they accounted for only 12 percent of the total traffic volume covered. Another 16 percent of all passenger-car runs represented only two to four round trips per year each, accounting for about 8 percent of the total trip volume.

Once a vehicle starts to travel a given route with a frequency of one or more trips a month, it begins to play a greater-than-average role in the traffic picture on that highway. Weekly trips, for example, accounted for over 15 percent of the passenger-car volume recorded in the survey, although less than 2 percent of the vehicle runs were in this category.

All trips made more often than once a week, including commuters, accounted for 45 percent of the traffic volume but only 1.3 percent of the passenger-car runs. Trips with commuting frequencies of five times a week or more, producing 29 percent of the traffic volume, involved only 0.5 percent of the total vehicle runs. This rather startling result illustrates the tremendous ability of a few vehicles, traveling regularly, to pile up large traffic volumes. Stated in the simplest terms, one car traveling daily makes 365 trips a year, but it requires 365 different cars making one trip a year to reach an equivalent total.

A more detailed breakdown of the trip-frequency groupings is shown in Table 1.

It is seen from the Table that the 59,706,000 trips are fairly well distributed among the 12 trip-frequency groupings. For the average day, taking into account both week days and Sundays, this distribution of trip frequencies would be fairly typical.

The distribution of vehicle runs, however, is extremely unbalanced, with the great concentration being in the low-frequency brackets. In the course of a year, each vehicle making only one trip annually must have 364 counterparts to account for one trip per day. Likewise, it requires about 120 vehicles making three trips a year to build up one trip a day. At the other end of the scale, each regular commuter very nearly accounts for a trip each day. As a result, the 14,000-most-frequent travelers made more trips in a year than were recorded by all the 3,665,000 vehicle runs which consisted of only one trip each.

TABLE 1

PASSENGER-CAR TRIPS IN EACH TRIP-FREQUENCY BRACKET
COMPARED WITH NUMBER OF DIFFERENT PASSENGER-CAR RUNS

| No. of Trips Per Year | Total One-Way Trips | | Number of Different Vehicle Runs | |
|---|---|---|---|---|
| | Number | % of Total | Number | % of Total |
| 1 | 7,329,000 | 12.3 | 3,665,000 | 71.4 |
| 2-4 | 4,958,000 | 8.3 | 826,000 | 16.1 |
| 5-8 | 2,073,000 | 3.5 | 173,000 | 3.4 |
| 9-17 | 5,534,000 | 9.2 | 231,000 | 4.5 |
| 18-34 | 3,806,000 | 6.4 | 76,000 | 1.5 |
| 35-70 | 9,086,000 | 15.2 | 95,000 | 1.8 |
| 71-135 | 5,063,000 | 8.5 | 25,000 | 0.5 |
| 136-225 | 4,772,000 | 8.0 | 14,000 | 0.3 |
| 226-280 | 4,971,000 | 11.7 | 14,000 | 0.3 |
| 281-325 | 4,854,000 | 8.1 | 8,000 | 0.1 |
| 326-375 | 2,225,000 | 3.7 | 3,000 | 0.05 |
| Over 375 | 3,035,000 | 5.1 | 3,000 | 0.05 |
| TOTALS | 59,706,000 | 100.0 | 5,133,000 | 100.0 |

In Figure 1,the left-hand circle shows the distribution of annual trips, whereas the right-hand circle deals with the corresponding vehicle runs. The striking preponderance of low-frequency vehicle runs points up the importance of the occasional user on the highway. At the same time, the disproportionately large share of the total traffic volume built up by regular travelers and commuters is brought out.

The number of individual commuters and frequent travelers covered by the survey, estimated at about 28,000, may seem very small in proportion to the total volume of traffic involved. Since these vehicles made approximately 29 percent of the total trips moving along the highways surveyed, it would require only about 100,000 vehicles traveling with similar frequencies to account for all the traffic. This would obviously be an absurd assumption, since it is common knowledge that many occasional trips occur, and yet even 100,000 vehicles are a small percentage of the total number operating in the area covered by the survey. This area, incidentally, does not include the New York city commuting territory, as no survey stations were located there. It does cover the areas surrounding most of the other important cities of the state.

The over-all picture of passenger-car travel on main rural highways appears to be as follows. Something over one quarter of all paasenger-car trips are made by regular users constituting less than 1 percent of the individual vehicles traveling over a given stretch of highway. Roughly another quarter of the trips are made occasionally, from once to a few times a year, but these trips account for about seven eighths of all individual passenger-car runs. In between, nearly half of all trips are accumulated by noncommuting drivers traveling with some frequency, ranging from about once a month to three or four times a week. This group of trips represents about 12 percent of the different passenger-car runs.

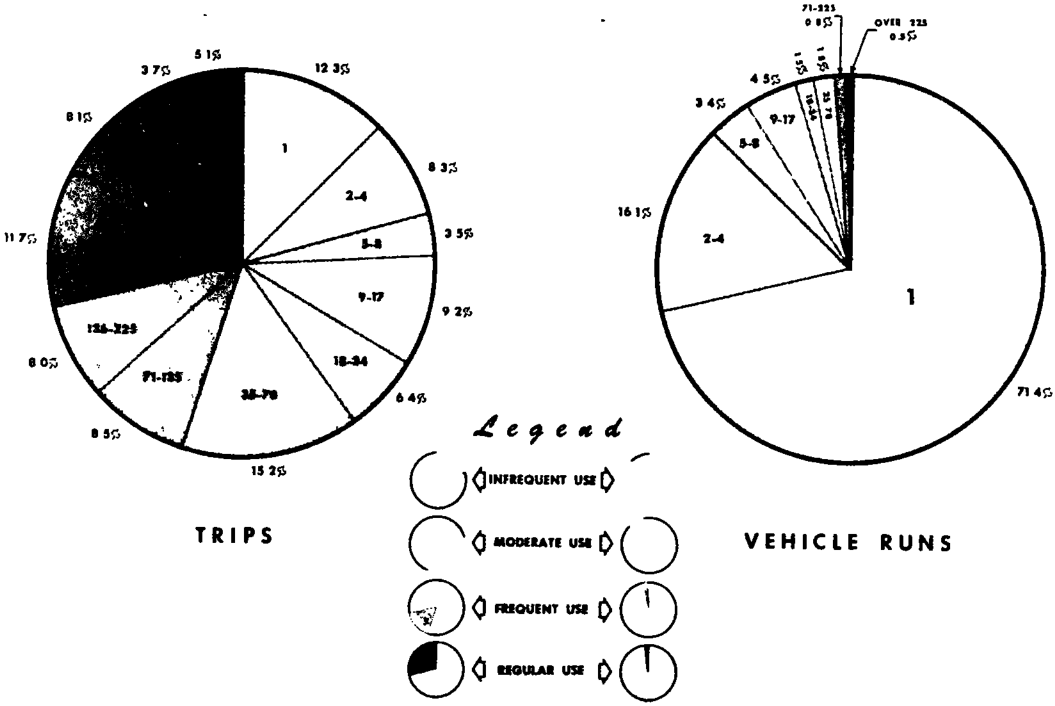


Figure 1. Trips and vehicle runs potential to throughway by trip-frequency groups (passenger cars, 1950).

## TRIP FREQUENCIES OF COMMERCIAL VEHICLES

Similar studies for light and heavy trucks also reveal some interesting characteristics, which apply to main highway traffic potential to the throughway but not necessarily to local or strictly urban movements.

About 48 percent of all movements by heavy trucks were found to be repeated from once a week to four times a week. This reflects normal operating practices for over-the-road truckers. More frequent trips accounted for 33 percent of the total volume, whereas occasional trips made less than once a week tallied up to only 19 percent of the total.

Light commercial vehicles in the delivery-truck class show a greater tendency to highly repetitive trips. The survey showed that 42 percent of all trips were made five times a week or more, with some vehicles traveling the same route two or three times a day. Another 37 percent of the trips were repeated from one to four times a week, but the balance of occasional trips still accounted for 21 percent.

In spite of the tendency of commercial vehicles to travel on regular routes, they do make substantial numbers of occasional trips. During the course of a year, about five out of eight truck runs on the main highways are unrepeated, and another one out of eight runs is made only two to four times a year. Nevertheless, more than four fifths of all trucking trip volumes are built up by the runs repeated once a week or more. These truck runs include only 9 percent of those made by all trucks.

A breakdown of the number of one-way trips and vehicle runs in each frequency bracket is shown in the following table:

TABLE 2

COMMERCIAL VEHICLE TRIPS AND VEHICLE RUNS IN EACH TRIP FREQUENCY BRACKET

| No. of Trips Per Year | LIGHT TRUCKS Trips Number | LIGHT TRUCKS Trips % of Total | LIGHT TRUCKS Vehicle Runs Number | LIGHT TRUCKS Vehicle Runs % of Total | HEAVY TRUCKS Trips Number | HEAVY TRUCKS Trips % of Total | HEAVY TRUCKS Vehicle Runs Number | HEAVY TRUCKS Vehicle Runs % of Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 153,000 | 4.3 | 76,500 | 61.4 | 235,000 | 4.1 | 117,500 | 61.7 |
| 2-4 | 111,000 | 3.1 | 18,500 | 14.8 | 172,000 | 3.0 | 28,700 | 15.1 |
| 5-8 | 82,000 | 2.3 | 6,800 | 5.5 | 94,000 | 1.7 | 7,800 | 4.1 |
| 9-17 | 201,000 | 5.6 | 8,400 | 6.8 | 283,000 | 5.0 | 11,800 | 6.2 |
| 18-34 | 193,000 | 5.4 | 3,900 | 3.1 | 287,000 | 5.1 | 5,700 | 3.0 |
| 35-70 | 475,000 | 13.3 | 4,900 | 3.9 | 831,000 | 14.7 | 8,700 | 4.5 |
| 71-135 | 380,000 | 10.6 | 1,900 | 1.5 | 889,000 | 15.7 | 4,400 | 2.3 |
| 136-225 | 476,000 | 13.3 | 1,400 | 1.1 | 1,021,000 | 18.0 | 3,100 | 1.6 |
| 226-280 | 336,000 | 9.4 | 700 | 0.6 | 514,000 | 9.1 | 1,000 | 0.5 |
| 281-325 | 531,000 | 14.9 | 900 | 0.7 | 558,000 | 9.8 | 900 | 0.5 |
| 326-375 | 274,000 | 7.7 | 400 | 0.3 | 300,000 | 5.3 | 400 | 0.2 |
| Over 375 | 361,000 | 10.1 | 400 | 0.3 | 480,000 | 8.5 | 500 | 0.3 |
| TOTAL | 3,573,000 | 100.0 | 124,700 | 100.0 | 5,664,000 | 100.0 | 190,500 | 100.0 |

TRAVEL DISTANCES

Analysis of the origins and destinations of traffic traveling along main state highways and potential to the New York State Thruway afforded an opportunity to determine the distances traveled by various classes of vehicles, and also to correlate travel distances with trip frequencies.

As has been noted by numerous previous surveys, most trips are short. Over 60 percent of all passenger-car trips were for less than 25 mi., and 74 percent were for under 50 mi. Less than 12 percent of passenger car trips along the main highways extended for more than 100 mi., and less than 6 percent were for over 200 mi.

Light trucks have even shorter trip characteristics than passenger cars, but heavy trucks make many more long trips. Approximately 21 percent of all heavy-truck trips were found to be for distances over 200 mi., and only 41 percent were for less than 50 mi.

Table 3 shows the distribution of travel distance for passenger cars, light and heavy trucks, as determined by the New York State Survey:

TABLE 3

TOTAL TRAVEL DISTANCES OF POTENTIAL THROUGHWAY TRIPS
AS DETERMINED BY 1950 TRAFFIC SURVEY

| Total Distance Traveled (Miles) | Passenger Car Trips | | Light Truck Trips | | Heavy Truck Trips | |
|---|---|---|---|---|---|---|
| | Number | Percent of Total | Number | Percent of Total | Number | Percent of Total |
| 0-50 | 43,971,000 | 73.6 | 3,011,000 | 84.3 | 2,335,000 | 41.2 |
| 50-100 | 9,136,000 | 15.3 | 373,000 | 10.4 | 1,341,000 | 23.7 |
| 100-150 | 2,127,000 | 3.6 | 54,000 | 1.5 | 395,000 | 7.0 |
| 150-200 | 1,365,000 | 2.3 | 43,000 | 1.2 | 402,000 | 7.1 |
| 200-300 | 1,299,000 | 2.2 | 33,000 | 0.9 | 478,000 | 8.4 |
| 300-400 | 1,046,000 | 1.7 | 28,000 | 0.8 | 406,000 | 7.2 |
| over 400 | 762,000 | 1.3 | 31,000 | 0.9 | 307,000 | 5.4 |
| TOTALS | 59,706,000 | 100.0 | 3,573,000 | 100.0 | 5,664,000 | 100.0 |

RELATION OF TRAVEL DISTANCES TO TRIP FREQUENCIES

It is logical to expect that long trips will be made infrequently, and that frequently repeated trips will be short. A correlation between travel distances and trip frequencies has been developed for trips expected to be diverted to the New York State Thruway, and the results are depicted graphically in Figure 2. The traffic covered in this chart does not include all potential trips, but only those expected to be throughway users.

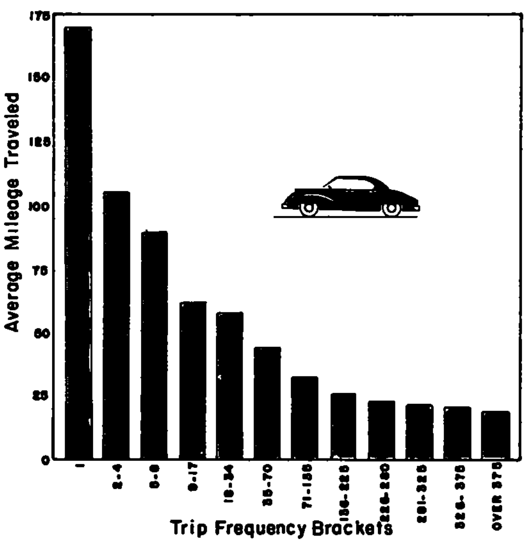


Figure 2. Average total travel distance of throughway passenger-car trips in frequency brackets.

In the lowest-frequency bracket of unrepeated trips, the average trip distance is 170 mi. Trips made from two to four times a year average 105 mi., and as the frequency increases the distance steadily decreases. In the high-frequency brackets of five trips a week or more, the average travel distance is about 20 mi. These mileage figures refer to the total travel distances of trips now being made, but expected to be diverted to the throughway when it is opened.

SUMMARY

As a result of the analysis of potential New York State Thruway trips, four principal characteristics of main-highway traffic stand out:

1. A very small percentage of the individual vehicles on the road accounts for a substantial portion of the total traffic.

2. Most of the individual vehicles traveling along a particular highway during the course of a year are engaged in occasional trips.

3. The great majority of trips on main highways are short, but a small percentage of passenger cars and a considerably larger percentage of trucks make longer trips.

4. Length of trip decreases as frequency increases.

# THE NEED FOR FURTHER RESEARCH ON TRAFFIC ASSIGNMENT

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Connecticut Highway Department

THE PROPER assignment of traffic to various proposed facilities has been the objective of highway planners for a number of years. The development of comprehensive traffic volume data by the highway-planning surveys in the 1930's was probably the spark that flamed to make this type of activity possible. Our basic traffic records, starting in the thirties and continued on the skeletonized basis since, provide a fund of information about traffic-volume changes. The origin-destination and economic studies undertaken in connection with major bridge or expressway plans have been most helpful in this work. How crude our first efforts in analyzing existing traffic and making assignments therefrom have been is easily determined by anyone who reviews the preliminary traffic estimates 10 years after the facility is in operation. The need for refinement is definitely in order. We must increase our knowledge of driver habits if we are to be able to make better, more-reliable predictions of the uses to be made of the facilities we propose.

Connecticut has tried to obtain information concerning factors relating to facility choice by the motorist. The South Meadows Expressway studies, undertaken in 1946, raised more questions than it answered. The variables were too numerous to isolate. Although a number of our technicians have tried, none were satisfied with the results.

At the 1947 meeting of the Highway Research Board, Roy E. Jorgensen presented a paper entitled "Influence of Expressways in Diverting Traffic from Alternate Routes and in Generating New Traffic." Since that time, Connecticut has begun little new research on the subject, but we have brought the data included in Jorgensen's paper up to date. In the Table below you will find a continuation, to 1951, of Table 4 in the earlier paper:

TABLE 1

| (Jorgensen's Table 4) | | Hartford-Terminating Traffic Using Expressway % |
|---|---|---|
| November | 1945 | 23 |
| March | 1946 | 33 |
| October | 1946 | 37 |
| April | 1947 | 44 |
| October | 1947 | 50 |
| April | 1948 | 53 |
| October | 1948 | 52 |
| April | 1949 | 52 |
| October | 1949 | 52 |
| April | 1950 | 52 |
| October | 1950 | 51 |
| April | 1951 | 52 |

It is interesting to note that the maximum amount of divertible traffic did not move over to the expressway immediately upon its opening. It was almost 3 years before the percentage of traffic diverted reached the percentage at which it has stabilized. Similarly, we have extended below Table 5 and 6 of Jorgensen's paper. These give the traffic generated by the Merritt Parkway and the Wilbur Cross Parkway, both in vehicles per day and the percentage which these vehicles are of the quantity to be expected, had the state-wide trend in traffic been realized on these parkways.

TABLE 2

(Jorgensen's Table 5 - Traffic Generated by the Merritt Parkway in Greenwich)

| Year | Vehicles per Day | Over Trend % |
|---|---|---|
| 1938 | 5500 | 28 |
| 1939 | 5500 | 26 |
| 1940 | 5300 | 24 |
| 1941 | 6000 | 25 |
| 1946 | 2300 | 10 |
| 1947 | 2600 | 10 |
| 1948 | 3000 | 12 |
| 1949 | 5100 | 19 |
| 1950 | 6200 | 21 |
| 1951 | 6400 | 19 |

TABLE 3

(Jorgensen's Table 6 - Traffic Generated by the Wilbur Cross Parkway in Orange)

| | | % |
|---|---|---|
| 1941[a] | 3600 | 23 |
| 1942 | 2500 | 20 |
| 1946 | 2500 | 17 |
| 1947 | 3800 | 23 |
| 1948 | 4300 | 25 |
| 1949 | 5300 | 29 |
| 1950 | 6700 | 34 |
| 1951 | 8300 | 39 |

a/ - Before completion.

While Jorgensen's figures, ending in 1947, indicated a stabilizing of the percentage over the trend of 10 percent and 20 percent respectively at the two locations, the four additional annual figures indicate that the percentages achieved by 1947 were not stable, because the Merritt Parkway figures for the past 3 years have been about 20 percent and the Wilbur Cross Parkway (formerly about 20 percent) has, in the last year, risen to 39 percent.

It is our belief that the increase in this generated traffic, over and above the state-wide trend, is probably due to the additional lengths of limited-access parkways and highways which have been opened for use in the years since Jorgensen's paper was presented. Route 15 has been assigned to the continuous route across Connecticut, which includes the Merritt and the Wilbur Cross Parkways.

Studies of this major east-west route east of the Connecticut River, where very great increases in traffic volumes have also been noted, raises the interesting question: "Where did the traffic come from?" In the northeastern part of the state, Route 15 passes through typically rural areas and is little used by commuter or suburban traffic. On this section, which was opened in November 1941, we had expected traffic volumes to follow the normal state-wide trend. The prewar volume on this route prior to its reconstruction as a limited access highway was 4,000 cars a day, and by normal traffic growth should have reached some 5,700 this past year. We find, however, that the volume on Route 15 for the year 1951 is not the 5,700 anticipated, but 9,800! This is 72 percent over the trend, if the trend is based on the 1946 postwar traffic volume of 4,050 cars per day.

It was first thought by our analysts that the phenomenon was the result of diversion from other parallel routes. An investigation was made, therefore, of the four major east-west routes east of the Connecticut River. The Table below gives the detailed traffic volumes on each of these routes and also shows the gasoline consumed in the state for each of the years to compare with the traffic volumes. The second section of the Table develops the traffic volumes which would have been realized had these been matched with the gasoline-consumption trend for the year 1946.

TABLE 4

AVERAGE DAILY TRAFFIC IN THOUSANDS

On Major East-West Routes East of the Connecticut River

| Years | Gas Consumed 100 Million Gallons | US 44 | US 6 | US 1 | Conn 15 | Three US Routes | Four Route Total |
|---|---|---|---|---|---|---|---|
| 1939 | 337.6 | 1160 | 2020 | 3910 | 3560 | 7090 | 10650 |
| 1940 | 363.6 | Data not | | 4150 | 3940 | — | — |
| 1941 | 394.3 | available | | 4880 | 4860 | — | — |
| 1946 | 367.9 | 1370 | 1820 | 4010 | 4050 | 7200 | 11250 |
| 1947 | 402.7 | 1240 | 2050 | 4350 | 4980 | 7640 | 12620 |
| 1948 | 422.1 | 1510 | 2220 | 4620 | 5420 | 8350 | 13770 |
| 1949 | 446.4 | 1520 | 2180 | 5060 | 6680 | 8760 | 15440 |
| 1950 | 482.2 | 2050 | 2890 | 4900 | 8070 | 9840 | 17910 |
| 1951 | 521± | 2100 | 3270 | 4700 | 9800 | 10070 | 19870 |
| | | If 1946 volume is equated to the trend these volumes would have been realized: | | | | | |
| 1947 | 1.09 | 1490 | 1980 | 4370 | 4410 | 7840 | 12250 |
| 1948 | 1.15 | 1580 | 2090 | 4610 | 4660 | 8280 | 12940 |
| 1949 | 1.21 | 1660 | 2200 | 4850 | 4900 | 8710 | 13610 |
| 1950 | 1.31 | 1790 | 2380 | 5250 | 5300 | 9420 | 14720 |
| 1951 | 1.41 | 1930 | 2570 | 5650 | 5710 | 10150 | 15860 |

TABLE 4 (continued)

Percentage over Trend

| | | | | | | |
|---|---|---|---|---|---|---|
| 1947 | -17 | 3 | 0 | 13 | -3 | 3 |
| 1948 | - 4 | -2 | 0 | 16 | 1 | 6 |
| 1949 | - 8 | -1 | 4 | 36 | 1 | 13 |
| 1950 | 14 | 21 | -7 | 52 | 4 | 21 |
| 1951 | 9 | 27 | -17 | 72 | -1 | 25 |

It will be noted in the foregoing table that in the column headed "Three US Routes" the traffic volume on the sum of these three parallel alternates has varied from the trend only between -3 and +4 percent and none of the separate US routes has lost more than 17 percent of its original traffic during this period. We have come to the realization, therefore, that the unpredicted traffic growth on Connecticut Route 15 (4,000 cars per day) equal to the total volume on the route as late as 1946, was not diverted from other routes. We must look elsewhere for the explanation.

Relating the increases in volumes of traffic on this route to the lengths of limited-access sections as they opened up indicates that the traffic growth is undoubtedly generated by the availability of considerable lengths of modern, limited-access highways. Listed below are the number of miles of limited access sections available for travel at the close of various years on Route 15.

TABLE 5

TOTAL LENGTHS OF LIMITED-ACCESS SECTIONS ON ROUTE 15
OPEN FOR TRAFFIC AT THE CLOSE OF VARIOUS YEARS

| Year | Miles |
|---|---|
| 1941 | 42 |
| 1943 | 62 |
| 1947 | 77 |
| 1948 | 99 |
| 1949 | 106 |

In 1941, when the first 4 mi. of Route 15 in the northeastern part of the state were constructed, the only limited access section of Route 15 open to traffic was the 38-mi. section of parkways in the opposite corner of the state. It was not until 1948 that the northeastern section of Route 15 was connected directly by a limited-access highway to the parkway sections and the expressway sections in the Hartford area.

No origin-and-destination survey would have indicated the spectacular growth in traffic volumes that has been found on Route 15. No time and delay studies would have shown the superiority of this facility over that which it replaced. Some diversion from distant, parallel routes might have been expected, but as the table above indicates, such diversion as did take place must have been accompanied by generated traffic using the alternate routes, because their sum is shown to be very close to the trend of traffic based on state-wide gasoline consumption.

It is believed that we know too little about the factors affecting motor-vehicle operation. We should continue to search our records and to make new studies in order to add to the store of knowledge which we may later apply to these fundamental questions of traffic quantities so necessary for the design of highway facilities.

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