HIGHWAY RESEARCH BOARD

Bulletin No. 17

Highway Planning

SIX PAPERS

PRESENTED AT THE
TWENTY-SEVENTH ANNUAL MEETING

1948

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HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

WASHINGTON, D. C. **DECEMBER 1948**

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USE OF HIGHWAY PLANNING SURVEY DATA BY THE BUTCHER, THE BAKER, AND THE CANDLE STICK MAKER

Fred J. Herring
Engineer, Statistics and Analyses
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What becomes of all the facts and figures, maps, charts, tabulations, memoranda and 'what have you' that the State Highway Planning Surveys accumulate and produce? The many uses by the Public Roads Administration and the State Highway Departments are familiar, but what of the butcher, and the baker, and the candle stick maker? Have they profited as a result of our efforts?

The very first request I had for a county map started me to thinking about the diversified uses to which they could be put. A jolly, rather corpulent clergyman walked in one day and said that he wanted to see one of those maps that showed where all the houses and churches were, and after I explained the symbols, he grinned and said, "Just what I want! Brother Blank has been assigned to First Church, and I want to mark all the places where he can get some good chicken dinners, so that he can plan his calls in order to arrive at those places before dinner."

Had that thinking prompted action, what an interesting record of uses we might have accumulated by now! But lacking that, I have shuffled through our files and called on our memories in my endeavor to list some of those uses that have developed in Arkansas.

Unquestionably the most popular records that the Planning Surveys have produced are maps, especially the county maps.

At the start of our survey, we found that the U.S. Post Office Department was without adequate maps showing the location of rural mail routes. In order to obtain that information, our men had to go into the field and talk to the rural carriers to determine what roads the routes followed. Now we have given the Post Office Inspectors the maps they so much needed, and they are able to record all the changes and additions in the routes for us.

Rural Electric Cooperative Corporations found our maps indispensable in laying out lines, planning extensions and developing areas, and nowhere else could they have obtained the necessary information. The same statement applies to the power and light corporations, and to the telephone companies. Two of these utilities use tracing reproductions for their mapping needs.

The State Health Department uses maps in many phases of their work. The Game and Fish Commission assert that they would be unable to function effectively if they did not have these maps to use as bases for their cover maps. The Forestry Commission uses them as bases to show the wooded areas, the protected areas, and the location of fire towers. Had these Departments not used our maps, the cost of necessary surveys would have made much of their work prohibitive.

The State Department of Education uses the maps in planning school consolidations, integrated systems of school bus routes, and for other purposes; and the local authorities make extensive use, not only for their own planning, but also in sending in information to the State Department.

Aerial surveys, oil surveys, sales territories, service routes, checking travel mileage, are only a few of the unofficial uses.

We find special interest in the use of the maps by those engaged in work in the rural areas. We have received many expressions of appreciation from the Agricultural Extension, the Library Extension, Church Extension, and Rural Health workers because the efficiency of their work is markedly increased when they have the maps. One of the most inspiring and interesting men who comes into my office is the Director of Town and Country Work for the North Arkansas Conference of the Methodist Church. He approaches his work from the same angle that a business man would approach a sales problem, except he tries to select only those communities where church work is needed but where other denominations are not serving the field.

The users of our traffic data are not so numerous as are the users of our maps, yet I believe that the benefits derived from these data are greater. In fact, I sometimes am impelled to think that these data are used to far greater extent by other agencies than by the ones for whom they were designed in the original conception of the survey. About the first users that I recall were the bill poster companies -- the men who erect bill boards -- for advertising men are keenly conscious of the number who will see their advertisements. Service station companies also began asking for traffic volume data during the early stages of the survey. We find that they use the information not only for locating new stations, but also in checking comparative sales at existing stations. A sales manager came in to ask why the sales at certain stations, where the traffic flow was comparatively light, were much greater than the sales at a station which they had located along a road with high traffic volume, and it was found that the traffic at the latter station was so heavy and moved so fast that the vehicles did not have an opportunity to pull into the service station.

We have frequent requests for commodity classification data, which we can supply from our loadometer surveys. Many users want to know the proportion of trucks in the total volume, and the requests for the ratio of out-of-state passenger vehicles in the traffic pattern are numerous.

Some bankers will not loan money for the development of hotels and tourist courts until the applicant furnishes traffic data which he obtained from us.

Each month we prepare a summary statement of Monthly and Cumulative State Highway Income, Motor Fuel Taxes, and Motor Vehicle Registrations. These are mailed to a comprehensive list of users: to banks, to the associations of motor vehicle manufacturers and dealers, to oil dealers' associations, to oil companies, and others; and we know that they are being used because of the number of inquiries we get when our mailing is late, and because of the questions if there is an error. It seems that this information is pretty good, because during the last year's legislative sessions both the advocates and the opponents of several measures cited our reports as a basis for their contentions.

The Arkansas Public Expenditure Council, the Arkansas Economic Council, and the Arkansas Public Service Commission have all made extensive use of our data, and we have, at their request, prepared special analyses.

We furnish mileage figures to the many agencies who pay mileage rates for transportation, and to bus and trucking companies for use in making their schedules.

We scratch our heads many times in our endeavor to answer the inquiries which come from students: from the grade student whose teacher has told him to write a paper about Arkansas; from the high school student who is making some special study and wants information (he often doesn't know just what he wants); and from the college student who is engaged in the development of a serious thesis. We take pleasure in answering these inquiries, and in giving the questioner the information we think will be most useful.

Individuals in other states who are considering settling in Arkansas are given planning survey data if it is helpful, although generally this type of inquiry is referred to other agencies.

This partial list of the many uses of Planning Survey Data tends to show that the money expended for the planning surveys has been justified, even if the Agencies for which the data were originally prepared do not use them as fully as they could, and in the light of our experience we are led to believe that if more people only knew what we had, we would have to increase our force to answer all their questions and requests.

THE ADVANTAGES OF STANDARDIZED ROAD SECTION DESIGNATIONS FOR USE OF ROAD INVENTORY DATA

C. H. Makeever, Chief Engineer
Ohio Highway Planning Survey

SYNOPSIS

The Ohio Department of Highways supplanted an obsolete system of highway station and section marking with a system adequate for modern requirements.

The new system of marking is based on route numbers, counties, and distances from county lines. It is so designed that every point of the State System may be accurately identified. Special care was exercised that the stationing and sectioning should be adaptable to punch card recording.

The system makes available all data accumulated by the Highway Planning Survey for highway programming, cost recording, and road life studies. The system is so easily understood that it is usable by the public for accident reports, locations of pipe line and power line crossings of highways, and for locations of access to the highway by farm driveways.

Posts bearing distinguishing numbers were erected at two-mile intervals on every State Route. All sections and stations may be located from these posts.

Records are perpetuated on straight line diagrams and on punched cards. The straight line diagrams are constantly revised by the Planning Survey, as conditions change. Current straight line diagrams are kept in the hands of all interested field and office engineers of the Department of Highways. Punched cards are available in the office of the Planning Survey for use by the Survey when more extensive studies are required than may be made by use of the straight line diagrams.

When the Ohio Department of Highways was very young a method of designating various sections of the State Highway System was devised and adopted. The method was crude and cumbersome but continued in use without change in principal until 1947.

The method of designating the sections on the Highway System was never carefully thought out, but rather just grew. With a background such as this the method of designating sections had scarcely any chance of being adaptable to modern machine recording. In fact, the method of designating sections was unsuitable for one of the most ancient kinds of recording, inasmuch as many highway sections could not be accurately located on a map.

The now abandoned method of designating sections was based on an old highway numbering. Each highway on what was then known as the Inter-County Highway System was assigned a number. This number quite often was applicable only to the distance between two county seats, but sometimes applied to a road the entire distance across the State. For example, the old National Pike extending across Ohio from Bridgeport on the Ohio River to the Indiana line near Richmond was old State Highway No. 1. For many years this road has been known as US 40. Travelers on the road, contractors interested in State projects and others referred to the road as US 40, but on State Highway Department maps, correspondence, and records, it was State Highway No. 1. All other roads had this confusing system of double numbers, with a few exceptions where the old State Highway numbers and the present route numbers happened to be identical. The old state highways whose lengths were short were more confusing than the longer ones. For example, US 42, in crossing Ohio between Cincinnati and Cleveland traversed eight old state highways. Thus US 42, in Department of Highways records, was State Highway 6, 241, 332, 334, 140, 139, 97, or 25, depending upon which part of it was under consideration.

The old method of designating short sections on the state highways was even more confusing than the numbering. The sections had one or both of their terminals at township, county, or municipal boundaries or at points where projects had ended. Each section on a state highway within a county was designated by a letter of the alphabet but usually sections were not in alphabetical order. Frequently the same letter was assigned to different sections on the same highway in the same county. Since being originally established many sections had been relettered, overlapped, or sub-divided. Numerous sections were unidentifiable. The state highway system originally did not extend within municipalities so sections were not established there. Modern state highway extensions into municipalities were not sectioned.

With road section designations so indefinite, Planning Survey road inventory data could only be coordinated poorly with the Highway System and for many locations the data were unusable. To correct this situation, it was decided to establish a new system of stations and section designations which would permit an efficient and complete use of road inventory data. It was further decided that the new system of stationing and section designations should supplant the old system and be used throughout the Department of Highways.

THE NEW SYSTEM OF STATIONING AND SECTION DESIGNATION

After the decision was made to abandon the old system of stationing and section designations investigations were begun to devise a system to replace it. Conferences were held at which the engineers of the Planning Survey, Bureaus of Location and Design, Construction, Maintenance and Bridges, and Division Engineers responsible for work in the field expressed their opinions and made suggestions. These discussions developed five requirements which a new system had to fulfill to justify abandonment of the existing method of stationing and sectioning. These were:

1. It must be easily understood and used.
2. Every point on the State Highway System must be identifiable with no ambiguity.
3. It must be easily perpetuated.
4. It must be adaptable to punch card recording.
5. Old sections, where identifiable, must be tied to the new system.

THE NEW SYSTEM

The plan adopted was one basing all stations and section designations on counties and route numbers. This plan was simple and easily understood, as its basis is the route numbers which appear on highway route maps and on markers along each route.

The new stationing on each route begins with Station 0.00 at the county boundary in each county. On roads where general direction is east and west, the zero station is at the west boundary and for north-south roads, at the south boundary of the county. Each county was assigned a three letter abbreviation. In Ohio the first three letters of the county name were satisfactory, as there was no duplication. A station designation is the abbreviation of the county in which the station occurs, followed by the route number, and concluded with the distance from the county line in miles. Thus, a point in Franklin County on US 40, 12.41 miles from the county line is designated FRA-40-12.41. An exception occurs when a route originates within a county. In that case, the zero point for stationing in the county of origin is the beginning of the route.

When the routes were stationed it was realized that the lengths of routes would change due to relocations. Provision was made for this by planning for an equation in the stationing at the point where the relocation rejoined the old location.

Where the relocation shortened the route the equation is simple. For example, if US 40 were shortened 0.50 miles and rejoined the old location at FRA-40-18.21 the equation would be FRA-40-18.21 A = FRA-40-17.71 B; "A" being "ahead" and "B" being "back."

Where a relocation lengthens a route the equation is somewhat more complicated. For example, US 40 might be lengthened 3.00 miles and rejoin the old location at FRA-40-05.84. Then FRA-40-05.84 A = FRA-40-08.84 B. In such a situation there would be a duplication of stationing from FRA-40-05.84 B to FRA-40-08.84 A. From FRA-40-05.84 B to FRA-40-08.84 A the stationing must be designated by the appropriate letter.

Provision was made for over-lapping of routes. Where a state numbered route overlapped a United States numbered route the stationing of the United States route prevailed. Where a State Route overlapped a State Route or a United States route overlapped a United States route, the stationing of the route with the lower number prevailed. For example, US 62 overlaps US 40 in Franklin County for 4.72 miles. US 62 joins US 40 at FRA-62-12.68 which on US 40 is FRA-40-10.48. The records of US 62 are on the US 40 punched cards and straight line diagrams for the next 4.72 miles. Records on US 62 are resumed at FRA-62-17.40 which is the point where US 62 leaves US 40. The station of US 40 where US 62 leaves it is FRA-40-15.20.

This system of stationing is readily adaptable to punch card records.

SECTIONS

The designation for any section is the station at the beginning of that section. If the station used as an example in a preceding paragraph were the beginning of a section, that section would be known as FRA-40-12.41. The section would be identified on the Basic Inventory Card, Figure 1, by Columns 3 to 5 for the County, 8 to 10 for route numbers, and 15 to 18 for the section identification. Column 11 further describes the route number in the event that it is an alternate route or has a location description as, for example, US 30-North and US 30-South.

Sections are always terminated at the following locations:

1. County or municipal boundary.
2. Where base type changes.
3. Where surface type changes.
4. Where surface width changes.
5. Where contiguous sections of like type and width were constructed at different times.

The average rural section length by the new system of section is 2.65 miles. By the old method, the average length of urban sections is 0.25 miles. Under the old system urban sections were not identified. The shortest rural section established by the new method is 0.01 miles and the shortest urban section also 0.01 miles. The longest rural section is 24.36 miles.

SURFACE AND BASE TYPES

For determining section terminals and other uses, 18 surface types and 21 base types were classified. The classifications were sufficiently refined as to be adequate for maintenance and construction reports and records, cost records, pro-

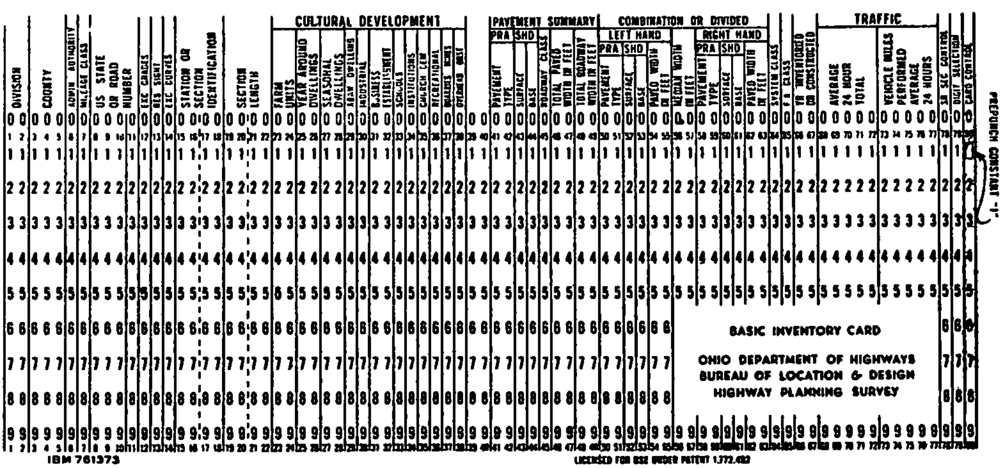


Figure 1. IBM Punch Card (approx. 3/4 actual size)

STANDARD SURFACE & BASE CLASSIFICATIONS

SURFACE

Code	Description
A	(1) Combination Surface
B	(2) Mono-Brick
C	Brick other than Monolithic
D	(2) Reinforced Concrete
E	(2) Plain Concrete
F	Dense graded tar concrete, such as T-136
G	Dense grade asphaltic concrete, such as T-35 or T-50
H	Kentucky Rock or open graded bituminous course (plant mix) such as T-40, T-60, or T-61
I	Penetration Macadam, such as T-33
J	(2) W B Macadam with Bituminous surface treatment
K	Open graded road mix or pugmill mix, such as T-32 or T-34
L	(3) Surface seal with cover, such as T-31
M	Oil Mat
N	(2) Stabilized
O	(2) Traffic Bound-Graded and Drained (See note below)
P	(2) Traffic Bound-Not graded and drained
Q	(2) Earth-graded and drained
R	(2) Earth-Unimproved

Note: Traffic Bound Graded and Drained is construed as Traffic Bound built to a uniform section

(1) A combination surface is one, the wearing course of which consists of two or more individual types, each being of sufficient depth (combined with base) as to be classed logically as part of the traffic bearing road surface rather than as surfaced shoulders Widenings of 2 feet or less shall be ignored and the width included as a part of the predominating type

(2) No base entry necessary

(3) To be recorded as wearing surface only on Stabilized or Traffic Bound

BASE

Code	Description
Z	(4) Combination-Rigid
Y	Road or pugmill mix over combination-rigid
X	(5) Combination-Rigid and Flex
W	Road or pugmill mix over Combination-Rigid and Flex
V	Mono-Brick
U	Road or pugmill mix over Mono-Brick
T	Brick-Rigid Base
S	Road or pugmill mix over Brick-Rigid Base
R	Brick-Flex Base
Q	Road or pugmill mix over Brick-Flex Base
P	Reinforced concrete
O	Road or pugmill mix over Reinforced Concrete
N	Plain Concrete
M	Road or pugmill mix over Plain Concrete
L	Plant Mix bituminous concrete or penetration macadam such as B-33, B-34, or B-35
K	Macadam other than penetration
J	Road or pugmill mix over Macadam
I	Stabilized
H	Road or pugmill mix over Stabilized
G	Traffic Bound
F	Road or pugmill mix over Traffic Bound

(4) Combination Base-Rigid, is a base composed of two individual rigid types According to the type classifications these could only include the following combinations:

Mono-Brick and Concrete (Plain or Reinforced)
Brick and Concrete (Plain or Reinforced)
Brick and Mono-Brick

(5) Combination Base-Rigid and Flex is a base composed of a rigid type and a flexible type, for example:

Reinforced Concrete, B-35

Figure 2

gramming, and road life records. Each surface and base type was assigned an alphabetical code letter. The code is recorded in Column 43 or 44 on the punch card shown in Figure 1. The types with code letters are shown in Figure 2.

FIELD WORK

Forces of the Division Engineer in each division located old section terminals where identifiable and points which became section terminals under the new system. A conspicuous stake was driven at each point, white stakes for old section points and red stakes for new section points.

Crews from the Road Inventory Section of the Planning Survey drove the entire State Highway System in automobiles equipped with carefully calibrated odometers graduated to 0.01 of a mile. Every section point was recorded in terms of the new system of stationing.

A cross-index of old and new sections was prepared. This index is in book form and provides a ready transposition of old sections into the new designations and vice versa.

FIELD IDENTIFICATION

To insure that all points on the State Highway System might be easily located, posts were set every two miles. These posts are of steel, extend three feet above ground and are set as near the right-of-way line as possible and yet be visible. Each post carries on it the distance from the county line. That is, the fifth post being 10 miles from the county line carries the number "10." Any point on the State System may be accurately located by measuring from the nearest post, which at no place is at a distance greater than one mile. At locations where it was not practicable to set a post, as in an intersection or in front of a residence, an off-set post was set. The off-set post carries in addition

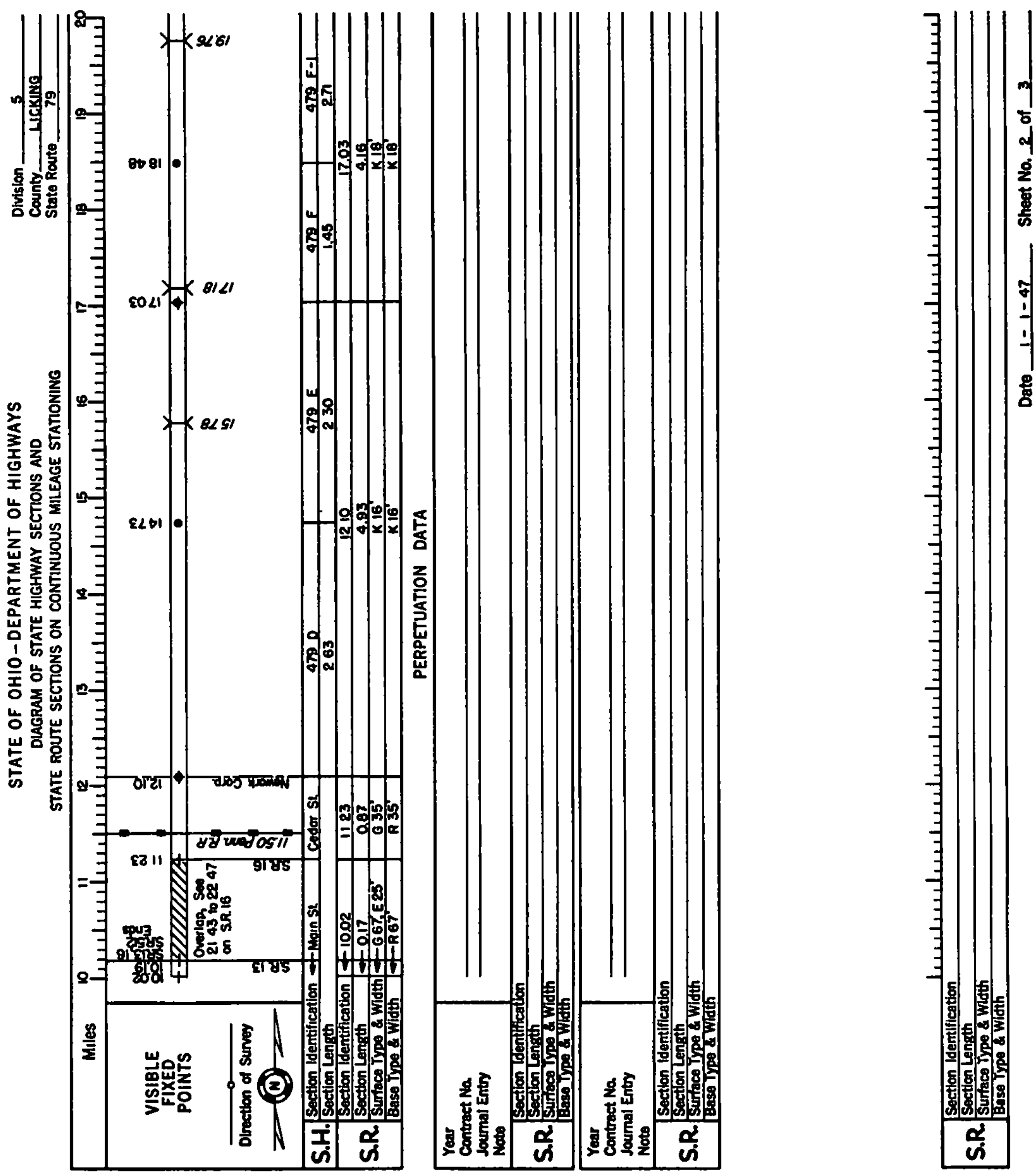


Figure 3

to the mileage number the off-set distance, in small figures. As a warning, off-set posts are designated by a red band painted a short distance above the ground.

The two-mile distance between posts was selected because it was believed that a post within one mile of any point was sufficiently close, and also for reasons of economy.

STRAIGHT LINE DIAGRAMS

Straight line diagrams were prepared under the new system of sectioning for the entire State Highway System. A typical diagram and legend sheet are shown in Figures 3 and 4.

When any change occurs on a highway, it is recorded on the appropriate diagram

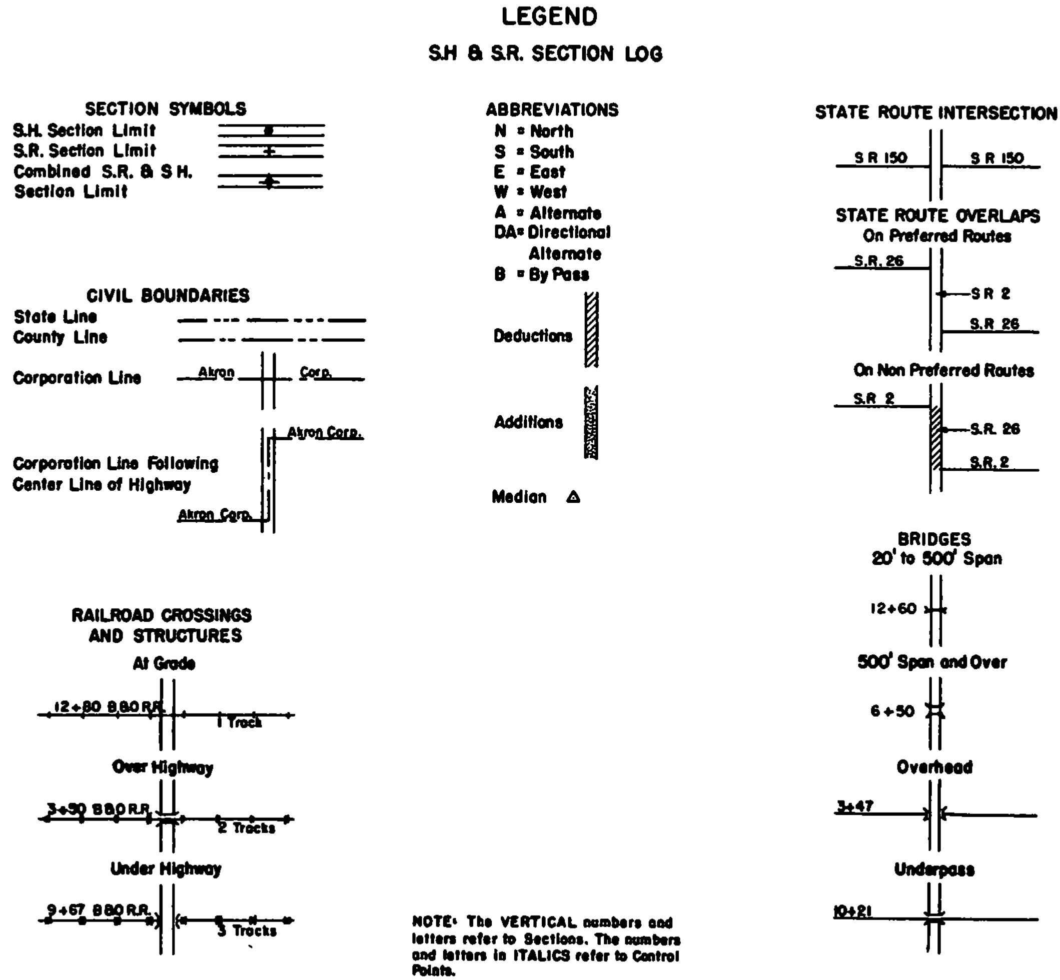


Figure 4

in the spaces provided under "Perpetuation Data." The straight line diagrams are the ordinary source of reference for engineers in the field and office, with the punched cards available for extensive studies. Each of the four regional planning engineers in Ohio have complete sets of straight line diagrams for their respective regions. Each of the 12 division engineers has a set for his division, a county engineer for his county, and numerous other engineers have sets covering the territory in which they are interested.

The Planning Survey has been assigned the responsibility of keeping the straight line diagrams up-to-date. When a change occurs on a highway, the change is recorded on the appropriate original tracing in the space provided for the perpetuation of data. Reproductions of the revised tracing are sent to each engineer who maintains a file of straight line diagrams.

USE OF STANDARDIZED SECTIONS

Ohio Highway Planning Survey data have never been used by the remainder of the Department of Highways to the extent their value indicates they should have been used. The reason for this scant use was the inability of engineers outside of the Planning Survey to identify information furnished by the Survey with specific locations on the highways. This serious defect was eliminated by the establishment of the system of station and section designations previously described. Various uses of road inventory data made accessible by the standardized designations will be discussed.

COST RECORDS

It is planned that in the future there will be maintained by the Ohio Department of Highways detailed cost records on punched cards based on the new system of section designations. This system of cost recording is not yet in operation.

For construction records it is thought that it will be advantageous to punch a card for each item of each contract. These cards will record quantities, estimated unit prices, unit prices bid, and other desirable data. A tabulation from these cards will reveal quantities and costs of various items by sections, routes, counties, or highway divisions. A comparison of costs of like items in different sections of the State will be readily available and of great potential value.

For each individual contract it is proposed that a card be punched. This card will record, among other data, the name of the contractor, the number of bids received, the estimated prices, the actual bid prices, time required for completion, over-run on time, and other pertinent data.

For maintenance records it is proposed that for each section two cards be punched for each principal item, one for labor and one for material. These cards will afford a comparison of maintenance costs by items for any section, county, or division.

Systems of card recording will be developed for office and field engineering. These cards will record expenditures for materials and engineering services by sections and contracts.

PROGRAMMING

Since the establishment of the Planning Survey in 1935, several attempts have been made to use Planning Survey road life data in formulating a program for highway improvements. These attempts failed because of the inability of engineers to identify data with specific locations on the highways. Thus, the potential value of road inventory data for planning was not utilized. Since the revision of stations and sections all engineers in the Department of Highways are using one system. All Planning Survey data have become available for programming highway improvements. This is possibly the greatest advantage of the new sectioning system.

That Planning Survey data may be used efficiently for programming, it is proposed that a system be devised whereby an index number is assigned for each road characteristic for each section of the State Highway System. These road characteristics will consist of width of pavement, gradients, sight distances, safety records, curvature, riding qualities, structural strength, maintenance costs, and probably others. Each characteristic will be assigned an index number reflecting the variance of the characteristic from a standard adequate for that section. It is now proposed that a completely inadequate characteristic be designated zero, with a large finite number assigned for a completely adequate characteristic.

With this system the cards for a route, division, or the entire Highway System can be run through the tabulators and the indexes added mechanically. The section with the smallest total of indexes should, theoretically at least, be first on the program of improvements. It is realized that one characteristic rated zero might make a section impassible, but other characteristics with high index numbers might make the section appear satisfactory when, in fact, it required attention immediately. Such instances will require exercise of judgment. At no place is it assumed that the index can supplant engineering judgment, but it can always serve as a program guide.

ROAD LIFE

On the straight line diagrams, Figures 3 and 4, are recorded the surface and base types and dates of construction and retirement. Eventually an easily understood, graphic record of the life of each type will evolve.

Further, the date of construction, length, width, and date of retirement for each surface and base type will be recorded on punch cards. A sort of the cards by pavement type, with a tabulation of the pertinent data, will provide the material for computation of the weighted average life of each type of surface and base.

The surface and base types are represented by an alphabetical code on the straight line diagrams and punched cards. The alphabetical code and classifications are shown by Figure 2.

ACCIDENT RECORDS

Heretofore accident records have been of less use than was desirable, as no way was available to record exactly where an accident occurred. The State Highway Patrol reported accidents with location referred to nearby municipal boundaries, road intersections, or conspicuous land marks. With varying degrees of success the Department of Highways coordinated these reports with their confusing system of section designations.

With the new system of designations the Highway Patrolman drives from the scene of an accident to the nearest two-mile post and reports the distance as shown by his speedometer. The highway section and the station are thus definitely known. These will be recorded on punch cards, along with code numbers describing pertinent details of the accident.

Ohio is not fortunate enough to have compulsory reporting of highway accidents. When and if a report of accidents is required by law the new system of section designations will become more valuable. Without doubt the prescribed forms for the reports would provide spaces for locating the scene of an accident with reference to a section post. These data, along with those from the report of the Highway Patrol, would be recorded on punch cards.

A tabulation of the accident record cards readily discloses the accident prone locations on the State System.

OLD SECTIONS

All abstracts of Department of Highways real estate and records of old contracts are based on the old system of section designations. To allow continued use of the old designations where necessary, a cross-index of the old and new sections was prepared. This cross-index is in book form. Also, the index for each division is bound separately, making 12 smaller books. All identifiable old sections are easily transposed into the new sections and vice versa.

The cross index will continue in use indefinitely by the engineers and lawyers interested in rights-of-way and real estate. The cross index books are now used extensively by other field and office engineers, but as they become familiar with the new designations it is expected the use of the cross index will be nearly discontinued.

USE BY PUBLIC

The nature of the old system of designations was such that they could be of no use to anyone outside of the Department of Highways. Access to Highway Department records and some research was usually involved in identifying a section.

Heretofore proposed contracts were described as being located on certain State Highways and sections, old numbering. Nothing in the field or on an ordinary map indicated where the project was located. A proposed project is now described by the familiar highway route number and the new section designation. An interested contractor may drive along the route indicated and locate a section post. From there he can locate the site of the proposed project by his speedometer.

Comments by the Public are now made at times with accurate place locations. As the Public becomes aware of the meaning of the two-mile posts it is believed this practice will improve. A communication to a Division Engineer describing a situation which has developed at a definite distance from a designated post is a vast improvement over a communication attempting to locate a position by describing it as being near a certain farm, cross-roads, or land mark.

All permits are now being issued according to the new section designations. Previously they were located by a general description which was transcribed into the section designations which only the Department of Highways recorded or understood. Now a public utility desiring a power line or pipe line installation across a highway, or a farmer requesting an access to a highway can describe the location in the same terms as those used by the Department of Highways.

VOICE OF EXPERIENCE

As was to be expected, if Ohio were installing the sectioning system with the experience now available, the decisions in some instances would vary from those made at the beginning of the project.

In Ohio the routes were driven by automobiles and the data recorded for the straight line diagrams and cross-index. The straight line diagrams and the cross-index of new sections and identifiable old sections were then made. Crews later went into the field to set the two-mile marker posts. In some locations cumulative errors caused the sectioning already recorded on the straight line diagrams and in the cross-index to be at variance with the post locations. It was necessary to redraw some straight line diagrams and correct the cross-index. If the work were to be performed in the light of present knowledge, the section posts would be set first and all later work referenced to them. No attempt would be made in the entire State to use the new sectioning for any purpose until all posts were set, all straight line diagrams completed and distributed, and the cross-index completed.

The present steel posts erected near the right-of-way line are inconspicuous in some locations. Consideration should be given to heavier, higher posts, possibly located nearer the pavement. The present posts have only one figure on them, except the off-set posts, and this figure faces the highway. For example, a post 10 miles from a county line carries only the figure "10." There would be many advantages to a post which carried also the County abbreviation and the route number. This would be especially advantageous on overlaps, on roads which are on County lines, or on roads which repeatedly cross a county boundary. Consideration should be given to having the numbers face traffic, or possibly use a square post set diagonally and place the figures on two sides to be read by traffic of both directions.

USES OF PLANNING SURVEY DATA IN CONNECTION WITH HIGHWAY SAFETY

Burton Marye, Jr.
Traffic & Planning Engineer
Virginia Department of Highways

Highway Planning Survey data can and should be used extensively in connection with highway safety.

Facts and figures accumulated by the Planning Surveys can be used to good advantage in both short and long range safety programs and are applicable to construction, maintenance and operation.

In 1936, when the survey was started in Virginia, all highway safety work was handled by a Safety Engineer who also was responsible for employee safety, damage claims, etc. In fact, it can be stated with candor that the first duty of the Safety Engineer was employee safety and that because of limitations of personnel available to him, highway safety was forced to run a rather poor second.

Our Safety Engineer, however, being an unusually intelligent and resourceful fellow -- so much so that he has long since left the Department for greener fields -- was quick to recognize the value of the data beginning to be gathered by the Planning Survey and was probably the first official in the Highway Department to ask for and put to practical working use information of peculiar value to his particular phase of work.

If I remember correctly, the data first requested were traffic counts at certain intersections which data were used to determine the justification, if any, for traffic signal control. That was way back in the latter part of 1936 and was the beginning of the use of survey data in connection with highway safety.

Although, by digging back through eleven years of correspondence, the exact chronological sequence of the uses of Survey data in highway safety work could probably be ascertained, such sequence is of no particular moment or interest. Suffice it to say that among the early uses were the following:

1. The use by the Division of Surveys and Plans of straight traffic counts, later refined to directional movements, in the determination of intersection design.
2. The use by the State Police of Traffic Maps in the assignment of personnel used to patrol the highways.
3. The joint use by the Department of State Police and the Safety Engineer of the Highway Department of traffic flow data in the determination of accident frequency.
4. The use by the Maintenance Division of traffic data in the determination of locations for pavement marking.

The above early direct uses were, of course, supplemented by many indirect uses, as in the determination of geometric design.

It was not until 1943, however, that the Planning Survey was really given the opportunity to "spread its wings," so to speak, in highway safety work. In that year, the Virginia Highway Department employed a firm of personnel specialists to study its organization and procedures, and to recommend changes, if any. These specialists were quick to recognize the closely related, in fact, almost inseparable work of the Planning Survey with that of highway safety. The result was a recommendation, immediately adopted, that all highway traffic safety work previously handled by the Safety Engineer be combined with the responsibilities of the Planning Survey and that a new departmental division, called The Division of Traffic and Planning, be created.

Among the additional duties assigned to the new division were those of field inspection of construction plans, and general responsibility for the design and location of signs, signals and pavement markings.

It is highly significant that although additional responsibilities and considerably more work were assigned to the Planning Survey, it was only necessary to establish one new position within the organization of the Planning Survey in order to carry out the added duties. This does not mean that no additional persons were employed -- there were. It does mean that the qualifications of the normal Planning Survey personnel are so peculiarly adapted to Traffic Engineering work that the added duties can be carried out with a very minimum increase in key positions. More field work is, of course, necessary and additional statistical, clerical and drafting work is required. However, this can be accomplished either by the personnel presently employed or by new personnel in the same grades and possessing generally the same qualifications.

In our organization in Virginia, an Associate Traffic Engineer, reporting directly to the Traffic and Planning Engineer (Manager of Planning Survey) is in direct charge of traffic safety work. He has two full time assistants and a secretary. For detailed traffic surveys and clerical and drafting work the Associate Traffic Engineer calls on the particular staff member of the Planning Survey who has charge of that particular phase of work.

The following uses are being presently made of Planning Survey data in the Traffic Engineering and safety work of the Highway Department:

1. Traffic volumes and types govern the classification of the highway system, which classification determines the design speed, maximum curvature, minimum sight distance, number of lanes, lane width, etc.
2. Directional volume counts, by type of vehicle, are used to determine intersection design.
3. Directional volume counts, vehicular and pedestrian, supplemented by examination of accident records, are used to determine the justification, if any, for signal control at intersections.
4. Cultural development supplemented by volume counts, speed determination, and accident records are used in the establishment, or elimination of restricted speed zones.
5. Data on degree of curvature are used in the marking of the safe speed on curves.
6. Data on vehicle miles of travel, supplemented by accident records, are used in the determination of "high accident frequency" stretches of highway.
7. Data on vehicle and pedestrian volumes are used to determine need for sidewalks.
8. Grade crossing survey data are used to establish priority in formulating grade crossing elimination or protection programs.
9. Bridge inventory data are used to govern the erection of all clearance signs and markings.
10. Inventory data are used in connection with the routing and issuance of special trip permits for overweight and oversize vehicles.
11. Volume data are used in establishing priority of construction and reconstruction of State Highways.
12. Accident data are used in designing special treatment for accident prone locations.

While this list may be regarded as generally covering the routine usage of Planning Survey data by the highway safety section, it is by no means all inclusive of the full value of such data in the much broader field of traffic facilitation. The average Traffic Engineering Bureau has nearly always in the past been considered as an organization established to deal with the day to day problems of highway operation, such as traffic control by signs, markings, and signals. Our organization is established on a much broader concept in which day to day operation control comprises but one segment. Long range planning and active direct assistance to the administrator of all highway activities are other equally important segments.

A great deal of Planning Survey data, that are not otherwise related to highway safety or operation, are usually necessary to efficient top level highway administration in planning its future facilities. Any efficient highway administration, like an efficient traffic engineering section, must anticipate and plan for contingencies, which may not arise for years. In this long range planning, every available fact is a necessity and an efficient traffic engineering section to serve the top management as a strong right arm is essential. The history of highway development is certainly not replete with instances of overdesign of facilities, --for every such case there are hundreds of instances of underdesign. These latter have almost invariably resulted from a lack of facts or knowledge of trends of moving traffic. Hence, a strong traffic engineering arm, properly organized to anticipate future trends and capable of evaluating their effects, is vital to the highway administration determined to avoid perpetuating existing evils or the creation of new hazards and bottlenecks. Similarly, the strong traffic engineering organization to discharge its responsibility must have the benefit of every fact gathered by the Planning Survey in order for its conclusions to be well balanced and logical.

Our experience in Virginia is that the Traffic Division is a necessary division of highway administration, and that Planning Survey data is the fuel with which it operates not only in the day to day problems of traffic control but in the far reaching field of long range planning as well.

It is realized that the foregoing discussion has strayed somewhat from the direct subject assigned to us of evaluating Planning Survey data directly with highway safety. This has been done purposely in order that the influence of highway planning data on the whole field of highway administration might be brought sharply into proper focus, for we believe that highway safety is inseparable from efficient highway administration.

Earlier, the routine usage of Planning Survey data by the highway safety section of our division was outlined. It is beyond the scope of this paper to attempt to enumerate all of the many special uses made of the data in specific cases arising from day to day and week to week. The point to be emphasized is that the traffic engineering section could not function without much of the basic data normally gathered by the Planning Surveys. This is not meant to imply that all of the data that is normally gathered by the Planning Surveys can be used for strictly traffic engineering purposes. On the other hand, it is hardly necessary to point out that it would be repetitious to have two different organizations collecting the same facts.

Accordingly, for any State contemplating organization of a traffic engineering bureau, it is strongly recommended that the Planning Survey activities be combined with the traffic engineering functions and the reorganized division placed on an equal footing with the old line highway departmental divisions such as maintenance, construction, etc.

REPORTING HIGHWAY TRAFFIC DATA

D. K. Shepard, Traffic Manager
Texas Highway Planning Survey

Inasmuch as the reliability of any traffic report depends upon the accuracy of the data contained therein, any discussion of reporting traffic data must necessarily include some discussion of the methods used in acquiring these data.

REPORTING TRAFFIC VOLUMES

Our 1947 Texas traffic survey covers volume counts on 198,831 miles of rural roads. Both State and county systems are included. This means a total of 32,000 single 24-hour coverage counts. Our control counts consist of 208 count stations of a week's duration and 230 24-hour count stations. Both types of count stations are repeated seasonally. These repeat counts supplement the control data furnished by eighty-nine permanently installed automatic traffic recorders.

We recently received from the Public Roads Administration a discussion of the relative values in accuracy of the 24-, the 48-, and the 72-hr. coverage counts. The conclusions were in favor of the 48-hr. count, and it was suggested that we adopt the 48-hr. count in our survey of at least a section of the State. We have seriously considered this suggestion. Inasmuch as this would involve acquiring twice as many mechanical counters to permit a workable schedule, we believed that a more thorough investigation of this theory in our section of the country was justified.

A study was made to obtain information which would help determine the relative accuracy of the 24- and the 48-hr. counts at coverage stations. The immediate purpose of this study was to determine how single 24-hr. coverage counts and 48-hr. successive counts made on week days compared with the true average week day traffic during the month in Texas.

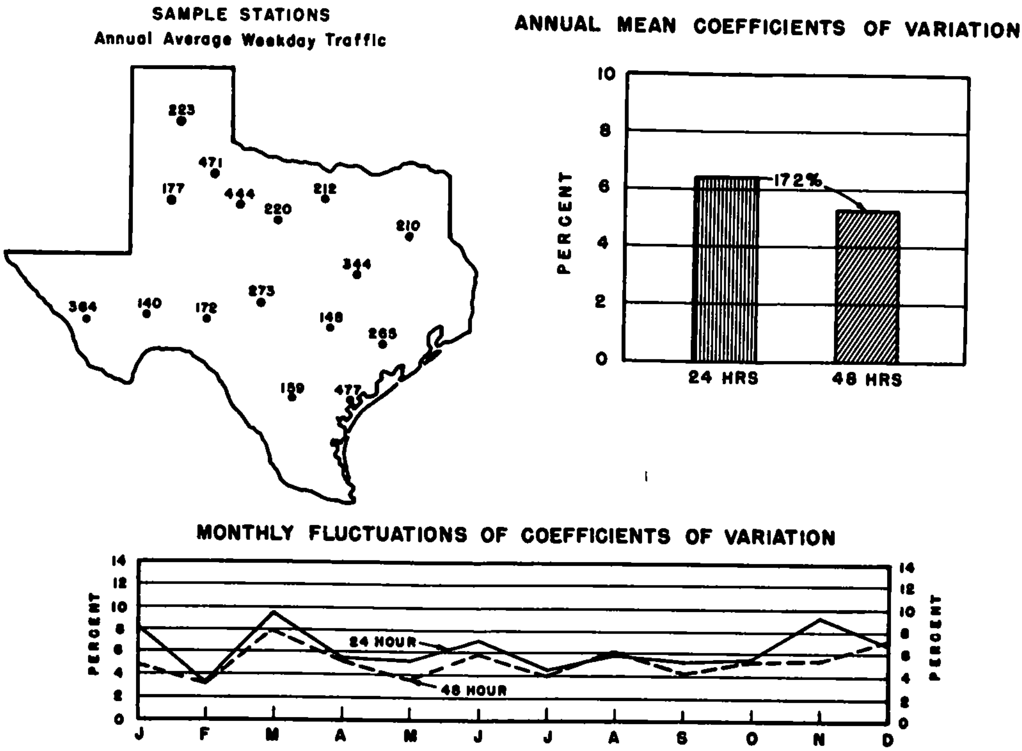
The methods used were identical in part to those presented by Mr. Petroff in his paper, "Some Criteria for Scheduling Mechanical Traffic Counts," presented at the Twenty-Sixth Annual Meeting of the Highway Research Board, Washington, D. C., December 6, 1946.

We selected sixteen permanent automatic traffic recorder stations, with average daily volumes of less than 500 vehicles, which were representative of all sections of the State. Coefficients of variation were employed as the means of comparing the 24- and the 48-hr. counts with the average week day traffic. In the first study of one-day counts, the second and fourth Tuesday of each month were used. In the second study, the arithmetic mean of the second Tuesday and Wednesday, and of the fourth Tuesday and Wednesday was used. The differences were computed in percentages of variation from the known average week day traffic for each station for each month. Then the arithmetic means of the coefficient of variation were computed for all sixteen stations.

Table 1 shows the "Monthly Fluctuation of Coefficients of Variation": Figure 1 shows these data graphically. It also shows the annual mean coefficients of variations.

The improvement in accuracy of the 48-hr. count over the 24-hr. count at the stations used in our study is not as great in Texas as that indicated in Mr. Petroff's analysis for the country as a whole. We plan further investigation along this line, but we do not believe the slight improvement indicated in the study we have made warrants any change in the field procedure.

Our reports on traffic volumes consist of three sets of traffic maps. These are the State Traffic Map, the District Traffic Map, and the County Traffic Map. We use figures on a straight-line diagram for showing traffic volumes on the State Traffic Map. We have found that this type of map is preferred by our engineering department.



RELATIVE ACCURACY OF 24-HOUR AND 48-HOUR TRAFFIC VOLUME COUNTS ON LOW VOLUME ROADS IN TEXAS

Figure 1

TABLE I

MONTHLY FLUCTUATIONS OF COEFFICIENTS OF VARIATION

Months	24-Hour Percent	48-Hour Percent
January	8.2	4.8
February	3.3	3.4
March	9.5	8.0
April	5.5	5.3
May	5.1	3.6
June	7.1	5.9
July	4.6	4.0
August	5.9	6.1
September	5.3	4.3
October	5.5	5.3
November	9.3	5.4
December	6.9	7.2
Mean	6.4	5.3

We have prepared flow band maps of the State system for display purposes, but they have not been available for distribution.

The State highway system has expanded to the extent that it has become practically impossible to show all the roads with the traffic figures on one map. We have, therefore, left off the farm to market system on the State Traffic Map and prepared District Traffic Maps, which include the farm to market roads. This method permits us to issue maps which are more legible. The County Traffic Map is a general highway map with traffic volumes indicated by figures. Figure 2 is a sample of the District Traffic Map on which we are indicating the volume of commercial traffic by a flow band superimposed on the total volume flow band.

We also issue monthly graphs and tabulations indicating the variations in traffic volumes, the graphs showing the relation of commercial to total traffic and the variations in week day, Saturday and Sunday traffic. These graphs have apparently been found useful as we have quite a lengthy mailing list and are constantly receiving

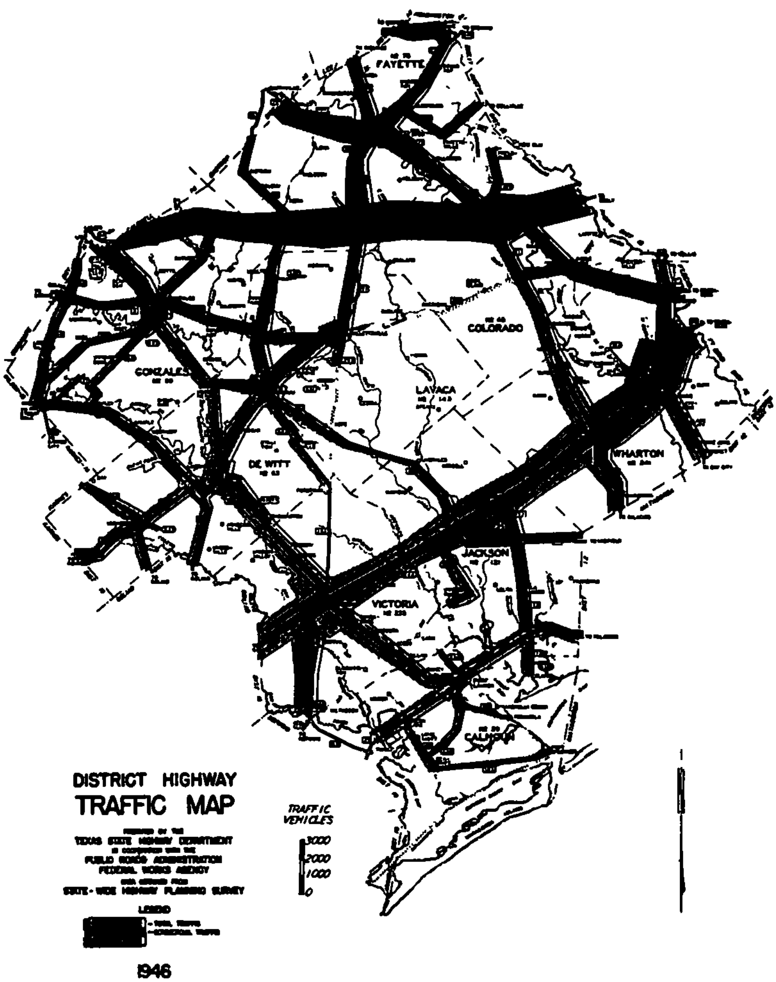


Figure 2

new requests for this type of information.

REPORTING CLASSIFICATION AND WEIGHT DATA

We have kept current on traffic volumes on our State highways and we are bringing up to date the data on our county roads, but I do not think we have paid sufficient attention to the classification of traffic and the loads our roads are carrying. We are now in the process of expanding our State system by the addition of approximately 25,000 miles of low traffic roads. We have practically no knowledge of the loads that these roads will carry. Figure 3 indicates that this is a condition that we should well consider. Due to change in load limit regulations and lack of enforcement, the loads have increased at an alarming rate. We are reviving our 1937 loadometer study and are now operating sixty stations monthly. The schedules are arranged to include night operations.

It has been suggested by the Public Roads Administration that we can determine from our loadometer study the typical weights and dimensional characteristics of the various classes of commercial vehicles. This would indicate that we may assume that a specific type of truck or combination loaded with a known commodity can be classified within a known weight grouping.

We are now giving careful study to the

idea, recently discussed with Mr. O'Flaherty of the Public Roads Administration, of extending this study by establishing interview stations where one recorder would obtain data as to the origin and destination of the trip, the route traveled and the commodity carried. At such a station the recorder could obtain most of the pertinent data except the actual weight and measurements. We believe this procedure would economically expand our weight study.

definite information as to the frequency of critical axle loads to be anticipated. In Figure 4 we have attempted to illustrate the frequency of axle loads by weight groups on various types of roads as determined by our present survey. I believe this or a similar method of bringing to the attention of our designing engineers the axle loads to be expected on the various types of roads can be developed into a very useful factor in design.

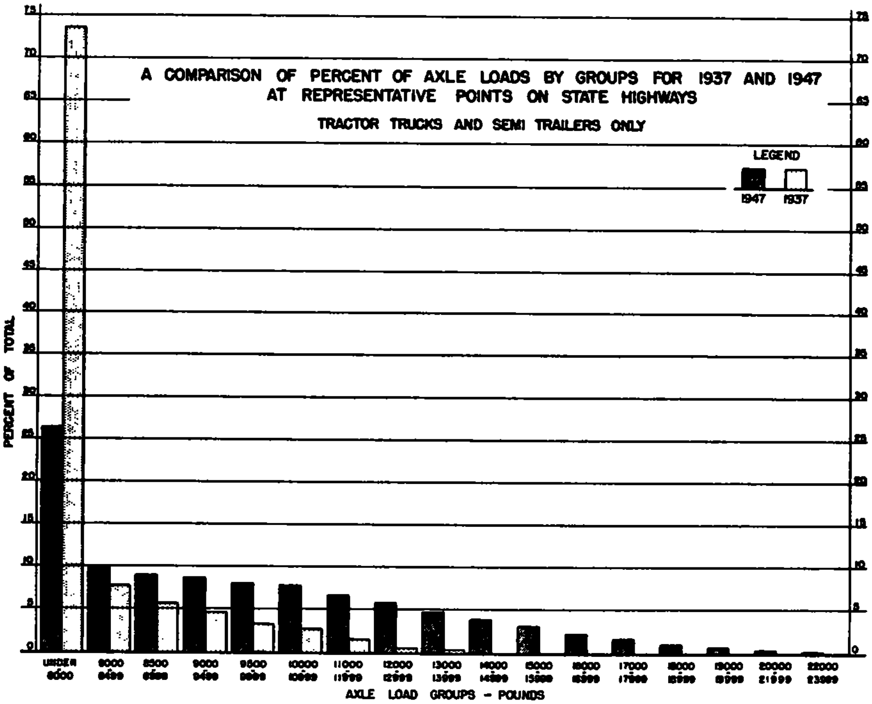


Figure 3

Before this plan is put into execution a careful analysis of our loadometer reports will have to be made to determine the range of weights by type of vehicle as well as by commodity carried. A superficial study does indicate that there exists a similarity in loaded weights of such commodities as motor fuel, citrus fruits and produce. The mere classification report as a method of estimating loads is deficient in that it does not distinguish between empty or loaded trucks or specify the commodity carried.

The damage to our roads during the war years, caused by unrestricted loading, clearly demonstrated the need for more

COUNTY ROAD IMPROVEMENT PLAN

One of the most useful and progressive methods of reporting traffic data that we have undertaken is in the preparation of county road improvement plans. We have made 44 such plans, all of which were requested by county officials. The response to this service provided by the planning survey has been most gratifying. This sort of report really includes more than traffic data in that it actually embraces an economic study of the various sections of the county, the cultural features and in some counties the costs of improvements. In some counties we borrowed the services

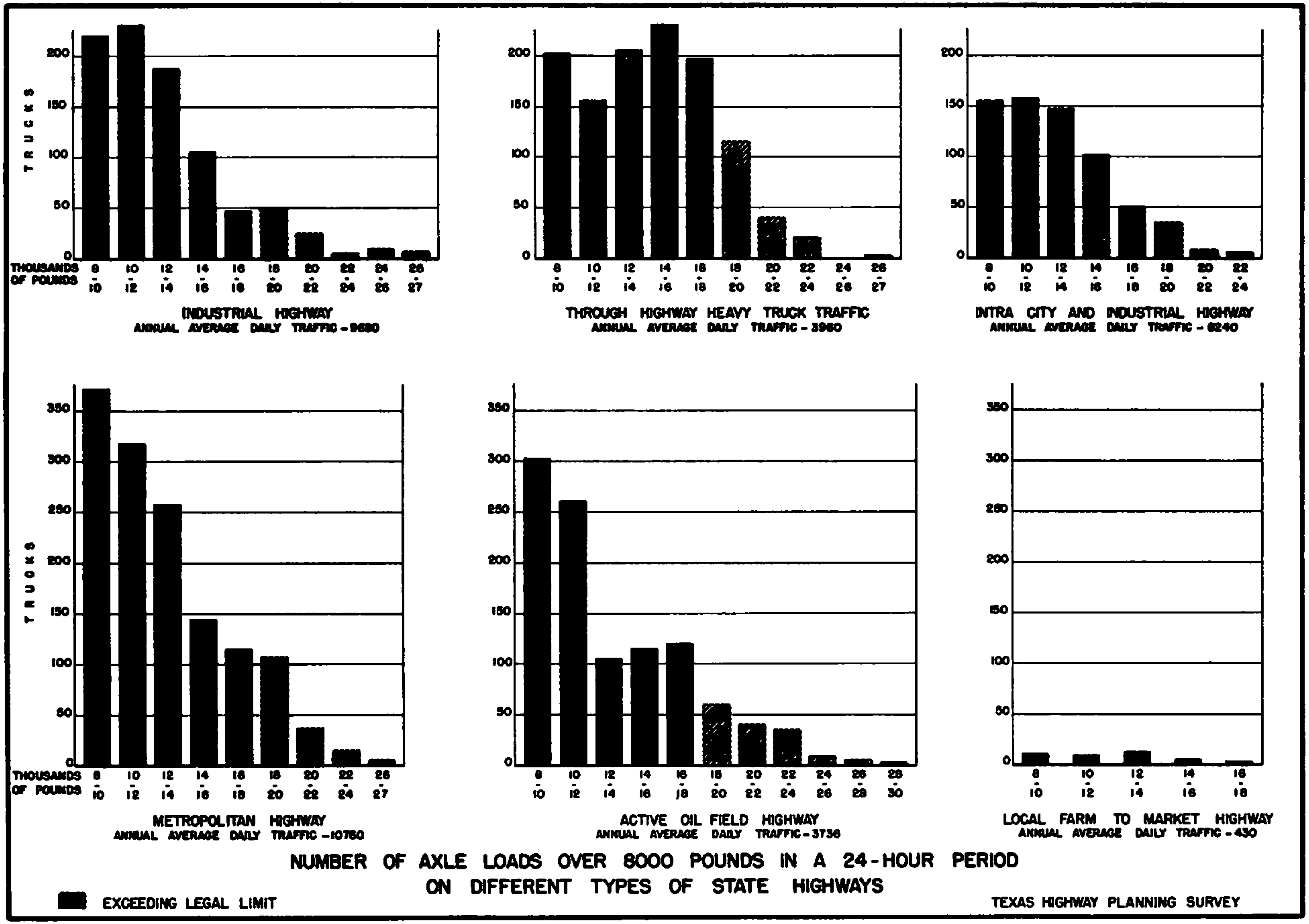

TRUCKS
THOUSANDS OF POUNDS
INDUSTRIAL HIGHWAY
ANNUAL AVERAGE DAILY TRAFFIC - 9680
THROUGH HIGHWAY HEAVY TRUCK TRAFFIC
ANNUAL AVERAGE DAILY TRAFFIC - 3960
INTRA CITY AND INDUSTRIAL HIGHWAY
ANNUAL AVERAGE DAILY TRAFFIC - 8240
METROPOLITAN HIGHWAY
ANNUAL AVERAGE DAILY TRAFFIC - 10760
ACTIVE OIL FIELD HIGHWAY
ANNUAL AVERAGE DAILY TRAFFIC - 3736
LOCAL FARM TO MARKET HIGHWAY
ANNUAL AVERAGE DAILY TRAFFIC - 430
NUMBER OF AXLE LOADS OVER 8000 POUNDS IN A 24-HOUR PERIOD
ON DIFFERENT TYPES OF STATE HIGHWAYS
EXCEEDING LEGAL LIMIT
TEXAS HIGHWAY PLANNING SURVEY

Figure 4

of personnel from the engineering department, to make a physical, on the ground, study of the existing road system and to make recommendations as to types of improvements with cost estimates.

For the most part, traffic volume or road usage has been the deciding factor in selecting the roads for improvement. Special attention was given to providing all-weather roads from isolated communities to trading centers, and, whenever feasible, to provide facilities for intercommunication between these communities. Consideration was also given to connections with the road systems in adjacent counties. Most of these counties have reported that they are using the plan as the guide for their road construction and maintenance programs. We learn that they have also been found very useful by the county officials as a defense against small pressure groups demanding improvement of roads of very minor importance.

THE FARM TO MARKET SYSTEM

Another method of reporting traffic data is in the application of traffic volumes in the selection of roads for the farm to market system. The task of selecting an 18,000-mi. addition to the State system was assigned to the traffic section of the planning survey. This, as in the preparation of the county road plans, involved more than the study of traffic volumes. An equable area distribution, economy of construction, and cultural development were all factors. However, in the final analysis, road usage was generally the deciding factor in the selection and in the assignment of priorities.

No arbitrary minimum traffic volume for the State as a whole could be used for eligibility of a road for inclusion. Different areas of the State varied so widely in road usage that in some of the sparsely settled counties of West Texas a much lower minimum traffic volume was used as a basis for selection than in the more densely populated areas. In making these selections, consideration was given to the service that the existing State system was providing to the county under study. This service was measured in terms of the ratio of vehicle miles on the State highways to the total vehicle miles traveled on all the rural roads in the county. In general, the allotment of mileage to the counties was based on the rural population, the area, and the vehicle mileage traveled on both State and county systems, excluding the primary Federal-aid system.

Our selection of these roads has met with general approval. However, as is true whenever a plan embraces so great a coverage, we have received some criticism and requests for substitutions. Our lack of intimate knowledge of local conditions, such as potentially good agricultural sections but poorly developed because of the lack of roads, caused us to neglect or overlook some roads which we would have selected had we been more familiar with these facts. Situations like this bring home the fact that while traffic volume is a major consideration, it is not the sole criterion.

SPECIAL STUDIES AND REPORTS

We have made thirty-eight external urban origin and destination studies, three internal traffic studies using the license tag method, and one parking study combined with the external origin and destination study. When these surveys were requested by the design department or the district engineers, we are confident that the information furnished has been of value and has been used to advantage. The response to the studies which were requested by city administrators has not been particularly gratifying. This may be due to several causes. Perhaps we have not presented our reports in such a manner as to awaken the interest of the local officials. Perhaps the study was made where no real need for this type of survey existed, but which was requested because it was a free service provided by the Highway Department. I believe that had we made a more thorough study of the problem in each case before making the origin and destination survey, we would have been better equipped to offer a solution. As a matter of fact, we have apparently been too hesitant in offering any solution. We have with some exceptions been content to show the results of our fact-finding survey without attempting any application of these facts to the needs of the city under study.

As an example, we often find that the

through traffic generated by the highways forms a relatively minor part of the traffic on the highway routes through the city. Had we extended our survey to include data on traffic volumes, classification, and where needed, turning movement counts on the highway routes and adjacent streets through the congested area, we would have been better prepared to supplement our reports with recommendations which would have been helpful. We have adopted this policy in the recent urban studies that we have made.

Occasionally we find that city officials will request an origin and destination survey with only a vague idea as to what the term implies. They are aware of the traffic congestion in their business district and having learned that the Highway Department will provide this service, request it with the hope that it will in some miraculous manner solve all their problems. In many cases, what is actually needed is the elimination of curb or center street parking in the business district. This is not the answer they want; it is one they will eventually be compelled to accept. It may take several years of an educational program and a more critical traffic congestion to bring this type of relief about. To the extent that city and county governments become traffic conscious and informed as to the real causes of their traffic problems, to that extent may we expect to receive their cooperation in working out solutions to these problems.

Some of our studies have clearly shown that if the volume of through traffic were diverted from the center of the business district, considerable relief would be provided to the traffic congestion. Figure 5 is representative of our usual method of graphically showing the movement of traffic into and through the city. Figure 6 shows the percent of through traffic in towns of varying populations. We should, before long, be able to make a fairly accurate estimate of the amount of through traffic by a careful study of the type of town and the type of highways that pass through it.

In preparing a report on traffic data, the knowledge as to who will use the report should govern to some extent the manner in which the data are presented. We recently made a rather extensive origin and destination study in the Rio Grande Valley. The situation here is rather unique in that our study included ten towns, on an average of 3.2 miles apart, all located on one highway. There are numerous business establishments between the towns on one side of the highway and a railroad on the other side. The existing facility is a three-lane road with daily traffic volumes from 4,500 to 10,000 vehicles. The situation is not at present extremely critical, but the increasing accident rate has alarmed the public spirited citizens and they are calling for advance planning for relief from a situation which they anticipate will soon become intolerable. These towns range in population from two

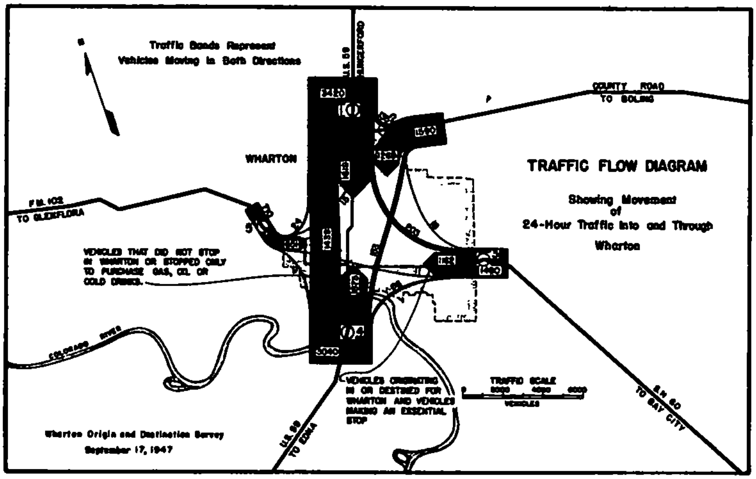


Figure 5

PERCENTAGE OF THROUGH TRAFFIC AS DETERMINED BY ORIGIN AND DESTINATION SURVEYS

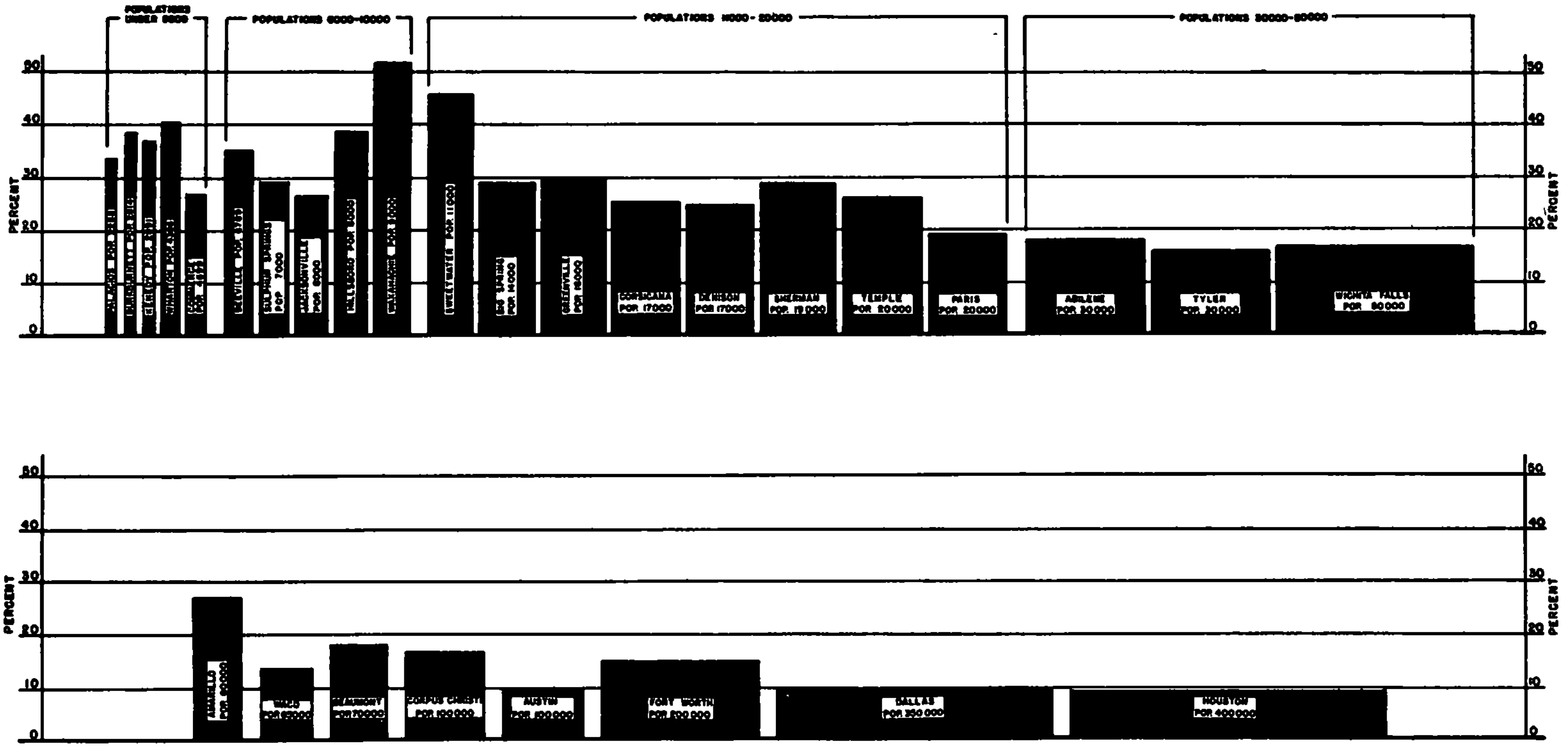


Figure 6

thousand to twenty-five thousand, and the highway actually serves as a forty-mile-long main street of a highly developed industrial and agricultural area with a population of about two hundred thousand. The field work for the survey consisted of the operation of an interview station near the city limits of each of the towns. The stations were operated on successive week days. The analysis while somewhat complicated was not particularly difficult. The method of showing graphically the results of the study presented quite a problem. Keeping in mind that the survey was requested by the Chamber of Commerce, we were anxious to make it as easy to interpret as possible. We tried several methods. We first indicated by flow bands the travel, through and local, from Harlingen to the east end of the area through McAllen at the west end. We found this display difficult to interpret. We then attempted a graphic presentation of the travel by trip lengths. This also became somewhat complicated. We finally adopted the method shown in Figures 7 and 8. (Similar sketches were shown for each of the cities.) We are not entirely satisfied with this manner of presenting the traffic data and it has met with some criticism.

We have just completed an origin and destination survey in the City of Corpus Christi. This study included an external origin and destination survey, and an internal origin and destination survey in which interviews were obtained from the operators of vehicles which parked in the central business district.

The procedure followed in this study was quite similar to that described in the parking survey manual issued by the Public Roads Administration in 1946. The report is now being prepared. We believe that we have obtained sufficient field data to enable us to offer suitable recommendations to the city. We have more confidence in this type of survey than in any we have made in that it does provide more complete information. Figure 9 indicates the traffic movements between Corpus Christi and the external zones of the trade area. Figure 10 shows the number of cars parked, the number of available spaces, and the parking demand in each block of the central business district of Corpus Christi.

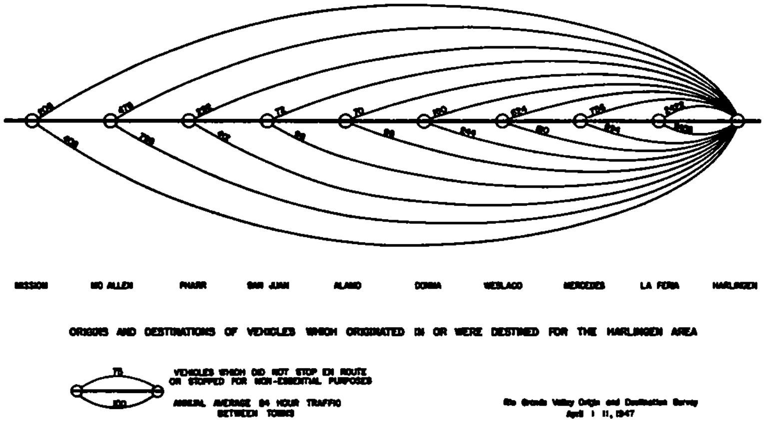


Figure 7

In the City of Amarillo two routes through the city had been proposed for U.S. Highway 66. We were assigned the task of estimating the amount of both through and local traffic which could logically use each route. We had made an external origin and destination survey and an internal survey, using the license tag method. Figures 11 and 12 show the method of indicating graphically the use that could be made of each of the competing routes. This display is subject to criticism. We were handicapped by the data obtained from the survey to this extent. We were able to estimate the volume of traffic which desired to go from each zone to each other zone, but we did not know just where on the proposed route this traffic would enter or leave. We therefore had to divide the route into sections and break our flow bands at the section boundaries. At best it is only indicative and

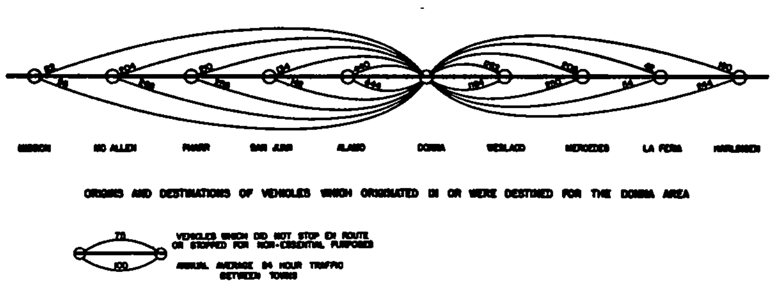


Figure 8

its reliability would depend on existing conditions, while any city street improvement program would change the pattern.

We are daily receiving requests for traffic information from all types of commercial concerns as well as other governmental agencies. Our usual procedure in complying with these requests is to cut a

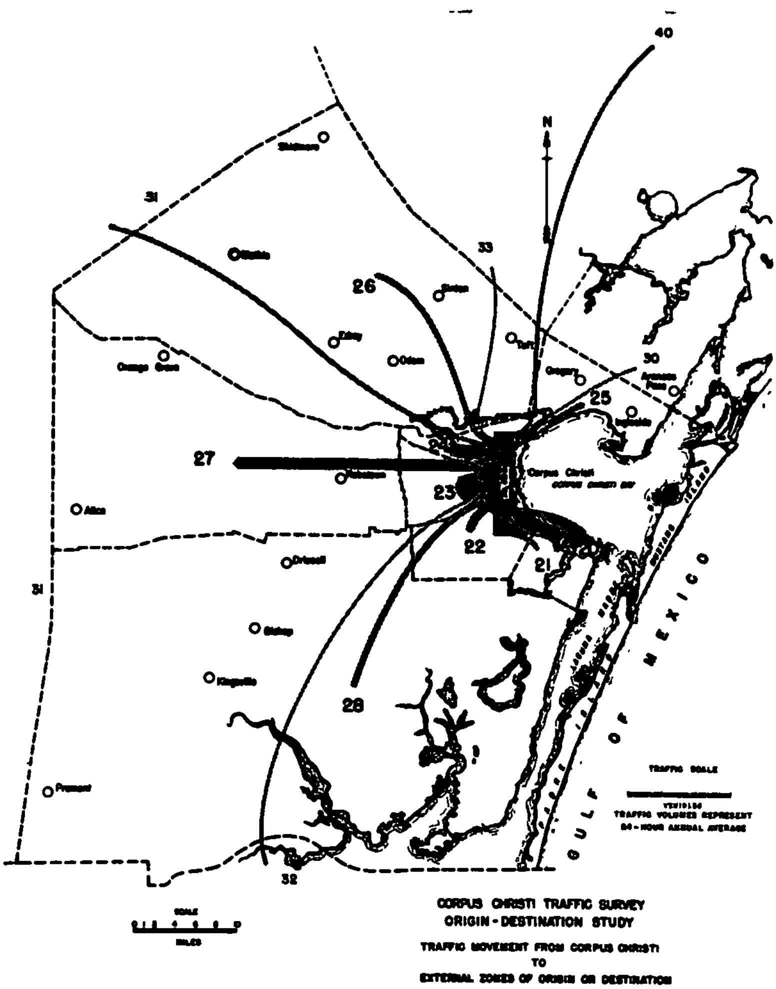


Figure 9

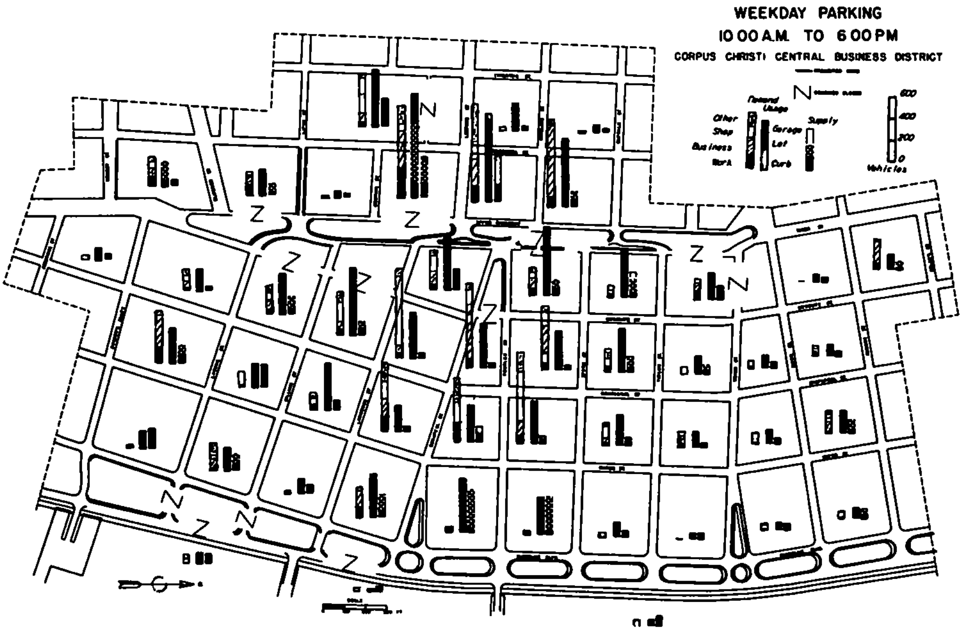


Figure 10

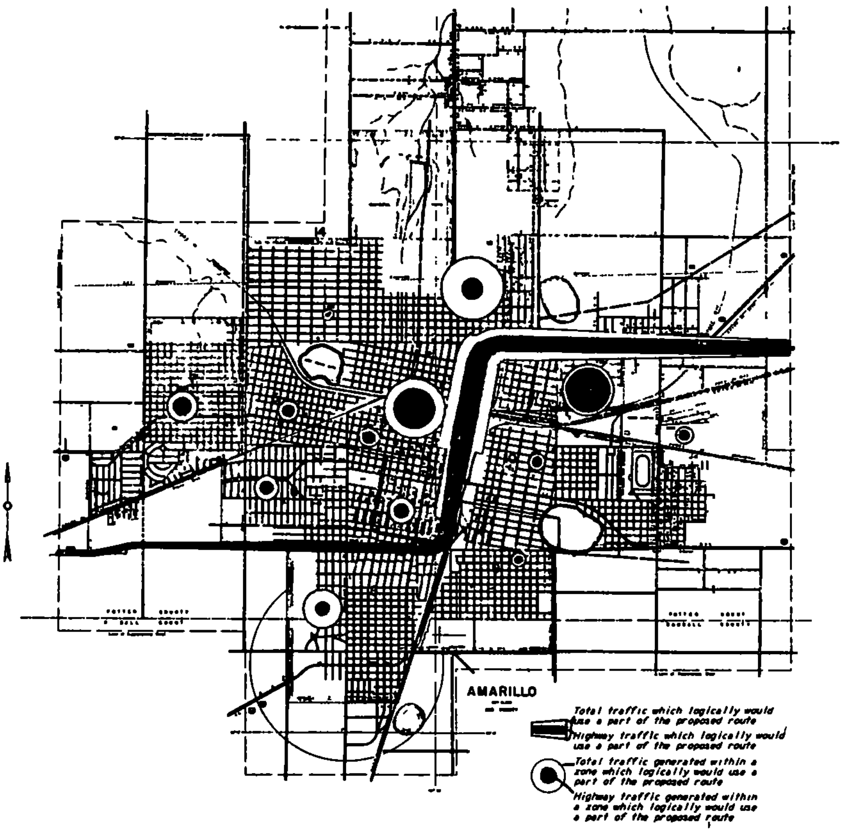


Figure 11

letter size section from the General Highway County Map showing the area of the desired information and indicating in red figures the traffic volumes.

In view of the increasing interest the Federal and State governments are taking in urban traffic problems, it behooves us to take stock of our past performance and become alert to the projects that will be assigned to us. The easy way out is to contract the large urban survey or the and the analysis. It has been done; the Jacksonville, Florida Report is a good example. The Public Roads Administration has issued complete outlines for procedure in all phases of the surveys and their representatives are always willing and ready to assist us when called on. We have found their cooperative assistance very valuable. An exchange of original ideas in reporting and graphically showing traffic data would be a stimulant to the various

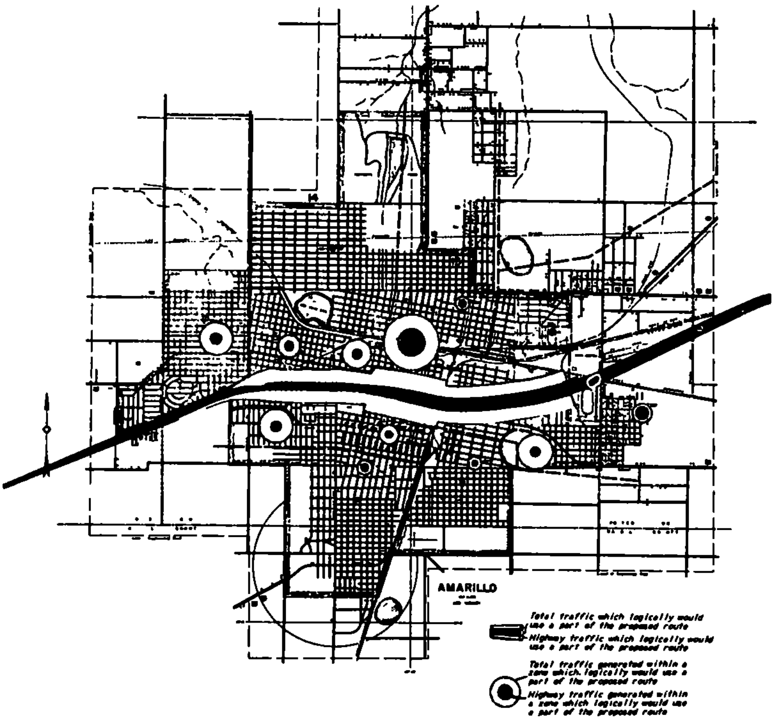


Figure 12

analysis, or both, to an engineering firm which makes a specialty of this type of work. However, taking this easy way out does not tend to enhance the usefulness of the planning survey. As long as we are content to permit others to undertake these more difficult or complicated projects, just so long will our commissioners and chief engineers or directors judge us to be incapable of their execution and will look for outside help.

It is my opinion that the planning surveys can carry through these more complicated projects from start to finish. It will take careful and detailed planning and very close supervision of both field operations traffic reporting agencies. This could be handled through the medium of the Public Roads Administration.

The planning surveys should all be alert to the increasing interest that is being taken by outside agencies and other governmental departments. We recently received a request from one of our State colleges to explain to the senior and graduate students majoring in highway design, the technique of traffic surveys, analyses, and reports. This is definitely a progressive step. When our young engineers become aware of the important part that traffic plays in the location and design of the highways, many mistakes will be avoided.

(Note: In the interest of economy and ease of reproduction the illustrations accompanying this report have been reduced in size and reproduced in one color only. The original illustrations prepared by the Texas Highway Planning Survey were much larger and consequently easier to read. Liberal use of color also enhanced their appearance and legibility. Ed.)

NUMERICAL RATINGS FOR HIGHWAY SECTIONS AS A BASIS FOR CONSTRUCTION PROGRAMS

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SYNOPSIS

A method of assigning numerical ratings to highway sections, taking cognizance of structural adequacy, safeness, and service, as a basis for reconstruction priorities, is offered. The ratings provide a means for arraying in one sequence all the sections of a given system, when the sections vary in traffic importance and in adequacy compared to present design standards. The method is based on deductive reasoning to the extent permitted by existing knowledge, but assumptions based on judgment and trial have been made to bridge the gaps in the deductive process.

The elements comprising the basic qualities are analyzed and weights are assigned to each. Formulas are given for computing values in some elements. A method is proposed for accounting for traffic volume priority.

The method has been applied to 3800 miles of the Arizona State Highway System and 1000 miles of the Arizona Forest Highway System, and has been accepted as a practical and valuable aid in the preparation and substantiating of construction programs.

There is never enough money to correct all the deficiencies in a highway system, such as a state highway system, in one budget period. Even if there were, it would not be physically or economically feasible to do so. It is therefore necessary to program improvements on sections of the system, and the first improvement should be programmed where the need is greatest.

When the deficiencies consisted of unimproved roads, the programming of improvements was relatively simple and could be done on a geographic pattern. Later, some of the original surfacing wore out, and renewal of worn-out surfaces provided an automatic program. During the last 15 years it has become apparent that renewal and replacement are desirable for reasons other than structural deterioration; roads have become obsolete in service rendered, and in safeness of operation. The various sections of any system differ from each other in all of these, and they also differ in importance as measured by traffic volume.

If the need for improvement or renewal, which is a combination of all of the above factors, can be reduced to a single number, the comparison of sections one against the other will be greatly simplified. In a sense, everyone charged with the preparation of a construction program does rate the existing facilities, and up to about a dozen sections can be arranged qualitatively in order of priority. Numerical ratings on a fixed datum provide a convenient form of memorandum for setting these down, and going on to consider the relative position in the list of each of other hundreds of sections in the system. In an extensive system, it is often necessary to combine the observations and requests of several engineers into one program. Numerical ratings provide a common denominator for effecting this combination. Finally, and very important, a quantitative listing of all the sections of a system is a powerful means of substantiating a program against sectional or otherwise biased pressure for fund dispersal.

This report suggests a method for assigning such numerical ratings to all the sections of a given system. It is empiric in that it is better than arbitrary and less than mathematically rational. In the autumn of 1946 it was used to assign ratings to all sections of the Arizona State Highway System. The lists proved to be practical and useful for the purposes enumerated in the preceding paragraph.

Planning the growth and continuance of a system of highways involves four steps, which are:

1. Determination of the extent and location of the system, on the bases of traffic demands and geographic, political and economic factors of the area to be served,
   (a) and of the sources and amounts of funds necessary for this purpose.
2. Allocation of available funds to
   (a) operation,
   (b) maintenance-of-way,
   (c) replacement of worn and obsolete highways,
   (d) extension of the system.
3. Establishment of design standards for the various sections of the system.
4. Periodic (e.g. annual) programming of construction within the amounts set up in step 2, (c) and (d).

This discussion, and the numerical rating system proposed, are concerned with programming the amount allocated in step 2 (c). It is presumed that depreciation and obsolescence are to be offset by renewal of units, or sections, of road at a rate equivalent to the depreciation of the whole system.

The numerical rating for each section multiplied by the length of the section is a convenient although by no means exact quantitative measurement of value remaining in service, which can be arrived at quickly and periodically in the light of present standards without being negated by changing conditions such as prices, construction methods and administrative policy. The total of this value divided by the mileage in the system produces an average rating for the whole system. The comparison from year to year of the system rating will provide a check on whether depreciation is in fact being provided for.

It is realized that the numerical rating as developed below has no absolute significance. As stated by Alfred M. Freudenthal, in "Reflections on Standard Specifications for Structural Design," PROCEEDINGS, ASCE, February 1947:

> "There is no particular virtue in mathematical functions or in numbers as such. If they are not really representative, they can be even more misleading than verbal statements, because, psychologically, the number or formula is bound to give the impression of accuracy. Much engineering knowledge is still description, although its presentation is mathematical.... The significance attributed to information expressed by numbers or mathematical functions is an indication of the level of scientific organization of experience. At the level of descriptive science, experience is purely qualitative, and, therefore, not measurable. Most knowledge has not advanced beyond this stage. A higher level is reached when methods of measuring assumedly relevant, recurrent phenomena have been developed and when the resulting figures and relations are used to devise a quantitative, although empiric, classification of experience. Numerical data still have no absolute significance; they are useful only as far as they are suitable to delimit certain classes of phenomena."

The relative weights assigned the various components of sufficiency could not be determined by wholly deductive reasoning. Assuming that it was desirable to arrange sections of highway in sequence of need for improvement or renewal, the gaps in mathematically rational treatment of the problem were bridged by empirical methods based on judgment and on trial and error. This report describes in detail the method finally used, after trying and discarding several sets of relative weights, in assigning priority sequence to all the sections of the Arizona State Highway System. The results were very satisfactory in that State, but it is realized and readers should understand that in systems having different idiosyncrasies, different weights will probably be necessary for the various elements, and in fact other elements not included in this description may well be introduced. The method is offered as a background for developing methods for use in other States and not as a fixed procedure.

METHOD

The objective of the ratings is to arrange sections of the highway system in sequence of relative need for improvement. This could be done by assigning the highest numbers to the sections of greatest need, and this logic was attempted. However, it was found that this resulted in negative numbers, equivalent to expressing temperature as "how cold" instead of "how hot." The method adopted was to assign sufficiency ratings, with the most sufficient roads having the highest ratings.

The first step was defining the elements of sufficiency which were to be evaluated, and assigning each element its proper importance, or weight. The next step was to develop a method of computing or assigning a value to each element for the section of road being rated. The third step was adjusting the rating according to the importance of the road. The steps are discussed separately below.

ELEMENTS OF SUFFICIENCY

The elements used, and the weight finally assigned to each, are shown in Figure 1.

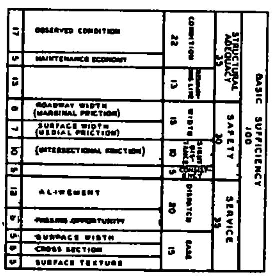

Figure 1

Whole Sufficiency

For convenience, the number 100 was used for the whole sufficiency. Three main qualities to be provided by a road are Structural Adequacy, Safety, and Service. These classifications are general enough to cover all aspects of sufficiency of a highway and each is as important as the other. The 100 points allowed for the whole sufficiency were therefore divided into approximate thirds (35, 30, 35).

Each main classification was then divided into sub-classifications and weights were assigned to the latter. The further this subdividing is carried out, the more uniform will be the treatment of the several road sections, and the simpler is the task of the engineer in assigning values to each element. However, if the subdivisions are too small, the leeway within each is insufficient for recording contrast between sections. That is, if only 5 points are allowed for one element, road sections which are 10% different in value of that element will both receive the same rating.

Structural Adequacy

Structural Adequacy was divided into Condition and Remaining Life. Since it is known that every road depreciates and will eventually have to be replaced, some element of the rating must decrease as the road becomes older. On the other hand, it is conceivable and even probable that for many years the maintenance cost as well as the apparent or measurable condition, and the safety and service, of a given section will remain level. To provide for these facts, an element of "anticipated remaining life," the value of which is computed solely on present age and actuarial data for the surface type and traffic volume group of the section being considered, was introduced as a subdivision of Structural Adequacy. This item was assigned 13 of the 35 points, on the reasoning that significantly more than half (18) of the structural points should be used to evaluate each section on its own merits, as opposed to its average or actuarial merits.

"Condition" of a road structure is a difficult thing to measure. Relative maintenance costs reflect relative structural condition of various sections, other things being equal. However, they probably do not vary as greatly as the condition of the road, simply because it is not possible to perform sufficient maintenance to rectify the condition of many sections; starting with roads of excellent condition and minimum maintenance costs, maintenance will increase as condition becomes worse, up to a point where no more maintenance can be physically applied, but beyond that point there is plenty of room for road sections to be progressively poorer. In Arizona it is not possible to determine the maintenance costs of specific road sections, because of inadequate cost accounting, and it is likely that this is true also in other states.

For these reasons, although the importance of maintenance costs is recognized, and it is realized that annual maintenance can equal the annual cost of a new capital investment, the item of maintenance costs was assigned but 5 of the 22 condition points, and the balance is reserved for variations in observed condition. The term "observed" is used in its broad sense. It does not mean merely looking at the surface, but implies the continuing knowledge of the behavior of surface and subgrade, which materials and maintenance engineers possess.

Safety

The objective and rational way of assigning safety ratings would be simply on the basis of the accident rate of each section, expressed say in terms of accidents per million vehicle miles. The trouble with this method is, first of all, the experience on all but the very heaviest traveled roads is too slight, with the result that the rate is dependent on pure chance. That is, one section may have one accident in its history, and another section, two. This is not enough experience to justify any conclusions as to the relative safety of the roads. Second of all, accident reporting and tabulating is not accurate enough to know what has taken place on short road sections.

There is little conclusive literature on the relation between roadway standards and accident rates. When there is, the method here proposed for rating safety can probably be improved.

Congestion and friction between opposing or intersecting traffic streams, and between stationary and moving traffic, are doubtless among the most important contributing factors. In Arizona the great majority of roads carry 2500 or less vehicles per day, and these items do not govern. For rating the safeness of this type of rural road, the subjective outlook was applied, by answering the rhetorical question, "What makes me feel safe"? The answer is (1) If a road is wide enough, an alert driver can nearly always avert accidents notwithstanding the behavior of other vehicles, failure of his own, or other faults of the road; (2) Other conditions being equal, the farther he can see, the greater his safety, and (3) the road must not offer abrupt changes, such as sharp curves between long tangents, narrow bridges in wide roads, and vertical dips. These are in descending order of importance and they were assigned values of 15, 10, and 5, out of the 30 points available. The 15 points for width were further divided into equal weights (8 and 7) for roadway width and surface width, on the basis that although the whole road may be roomy enough to avoid collision, a narrow surface on such a road confines opposing traffic streams and creates a hazard.

To use trite phraseology, the three causes of accidents are Marginal friction, Medial friction and Intersectional friction. On low volume rural roads these correspond exactly to roadway width (shoulders), surface width, and sight distance. On high volume roads, and where there is considerable roadside development, the terms "width" and "sight distance" are superseded by the more general terms, and values computed accordingly.

It may be noticed that alinement is not considered in the evaluation of safeness except as implicit in controlling sight distance.

Service

Service to the road user comprises the dispatch and ease with which a given trip can be made. The 35 points were divided 20 for dispatch and 15 for ease. It may well be argued that economy of operation is an equal factor in the service a road should provide. However, dispatch and economy are interdependent, and part of "ease" as defined below also contributes to economy.

The difference in operating costs over various roads is not significant unless the time or distance is excessive on one of them. The principle of the numerical ratings is to provide and evaluate variation between sections. It would be contrary to this principle to introduce a factor whose value would be nearly equal for all sections. Variation in economy is taken care of by variations in dispatch and surface texture.

Dispatch on most rural roads is simply a function of alinement and passing opportunity, and on lower volume roads, more of alinement. The 20 points is therefore divided into unequal portions of 12 and 8, respectively.

On heavy volume roads, dispatch is a function of freedom from congestion, which is dependent upon many other features of design besides alinement. On this type of road, alinement was ignored and evaluation of the 12 points allotted was based on the normal operating speed on the existing road.

"Ease" was considered to be dependent upon traveled lane width, regularity of cross-section (absence of sway), and surface texture, which three items cover most of the reasons for tension or absence thereof in operating a motor vehicle, other than the reasons allied with safety and dispatch.

It may appear, particularly to those whose principal concern is the priority of widening from 2 lanes to 4 lanes, that freedom from congestion is not given enough weight. It was found in Arizona that congested roads which could be remedied by increasing the number of lanes automatically are lacking in all of the items comprising the 30 points for safety, and in surface width which is 5 points of the service component, as well as in the 20 points allotted to dispatch. In other words, conditions leading to congestion are reflected in elements amounting to 55 of the possible 100 points. Furthermore, in step 3, described below, the basic rating is adjusted on the basis of traffic volume and this operates to enhance the priority of such sections. The preponderance of all mileage needing reconstruction is two-lane standard, and one of the problems this rating method attempts to solve is the sequence of priority between medium or low-volume roads which are wholly inadequate in structure and alinement on the one hand, and high volume roads which are inadequate in dispatch on the other hand. The funds are in each case, rural state highway funds, and as long as the road is in the system, the highway department has the obligation of making it standard.

One important factor which is not included in this rating method is directness of line; routes which are completely out of direction are not satisfactorily rated. For example, in Arizona the existing road from Phoenix to Prescott is 114 miles long and portions have very high ratings, while other portions are tortuous, obsolete, and worn out. This route was rated section by section and about 18 miles came out with very low ratings, enough to be in the first priority of improvement, and the balance had fairly high ratings. A new route is proposed between the same points which saves 24 miles of distance, but the ratings do not lend themselves to demonstrating when this work should be undertaken, or even that it should be undertaken at all. (This is discussed further under the heading "Application to Programming.")

It will be noted in Figure 1 that there is interlocking or overlapping of the minor elements; e.g., a high value for sight distance would automatically result in a high value for alinement, and surface width appears in two places. The viewpoint taken is (1) that if good alinement is necessary to produce good sight distance, the analysis results in a proportionate weight for alinement which more correctly reflects its total influence on the overall rating, and (2) that although good sight distance insures good alinement, good alinement is possible without good sight distance, and so forth. From this viewpoint it would be incorrect to combine the related factors, especially when attempting to derive their correct relative weights. This was found to be no inconvenience in rating the 3800 miles in Arizona.

EVALUATING THE ELEMENTS FOR EACH ROAD SECTION

After deciding what elements were to be rated and the relative importance of each, the next step was to devise uniform methods, or formulas, for evaluating each element, for each road section being rated.

These formulas depend on the principle of comparing each road section with the present standard for that section. The comparison is made for each element of sufficiency set forth above.

It is necessary to provide a table of standards, and to know the traffic volume classification of each section of the system. In Arizona there are 15 sets of standards, five different traffic volume groups and 3 kinds of topography in each group. (Certain standards are equal in several of the 15 sets.)

Observed Condition, weight 17 points, was rated on a plain qualitative basis, as follows:

Excellent	16-17 points
Good	12-15 points
Fair	8-11 points
Poor	0-7 points

Maintenance Economy, weight 5 points.

Each section was assigned a value from 0 to 5 from judgment and conference with the maintenance engineers. In general, this rating was more or less an extension of "observed condition." In some cases, however, there was a difference. Gravel roads were rated very low in maintenance

TABLE 1

TABLE USED FOR DETERMINING "ESTIMATED REMAINING LIFE" RATING

Yr Built	Age	Mixed Bituminous R_4 Type Survivor Curve 15 Yr Average Life			PC Concrete R_4 Type Survivor Curve 25 Yr Average Life			Bit Surf Tr Medium Traffic Vol L_1 Type Survivor Curve 5 Yr Average Life		Bit Surf Tr Low Traffic Vol L_1 Type Survivor Curve 8 Yr Average Life		
		Total Life	Yrs to Go	Points	Total Life	Yrs to Go	Points	Yrs to Go	Points	Total Life	Yrs to Go	Points
1946	0	15	15	13	25	25	13	5	5	8	8	8
1945	1	15	14	13	25	24	13		4	8 2	7 2	7
1944	2	15	13	13	25	23	13	3 4	3	8 4	6 4	6
1943	3	15 1	12 1	12	25	22	13		3	8 8	5 8	6
1942	4	15 1	11 1	11	25	21	13	2 55	3	9 2	5 2	5
1941	5	15 2	10 2	10	25	20	13		2	9 8	4 8	5
1940	6	15 3	9 3	9	25	19	13	2 0	2	10 4	4 4	4
1939	7	15 4	8 4	8	25	18	13		2	11 1	4 1	4
1938	8	15 5	7 5	7	25	17	13	1 5	1	11 7	3 7	4
1937	9	15 5	6 5	6	25	16	13		1			3
1936	10	15 7	5 7	6	25	15	13	1 0	1	13 2	3 2	3
1935	11	15 9	4 9	5	25	14	13		1			3
1934	12	16 2	4 2	4	25	13	13	0	0	14 8	2 8	3
1933	13	16 4	3 4	3	25 2	12 2	12					2
1932	14	16 7	2 7	3	25 4	11 4	11			16 2	2 2	2
1931	15	17 2	2 2	2	25 6	10 6	11					2
1930	16	17 7	1 7	2	25 7	9 7	10			18 0	2 0	2
1929	17	18 3	1 3	1	26 0	9 0	9					2
1928	18	19 0	1 0	1	26 3	8 3	8				1 0	1
1927	19	19 7	0 7	1	26 6	7 6	8					0
1926	20	20 5	0 5	0	26 8	6 8	7					0
1925	21	21 2	0 2	0	27 1	6 1	6					
1924	22	22	0 0	0	27 4	5 4	5					
1923	23				27 8	4 8	5					
1922	24				28 2	4 2	4					
1921	25				28 7	3 7	4					
1920	26				29 2	3 2	3					
1919	27				29 8	2 8	3					
1918	28				30 4	2 4	2					
1917	29				31 1	2 1	2					
1916	30				31 8	1 8	2					
1915	31				32 5	1 5	2					

economy although their condition might be very good. Surface treated roads may have an observed condition of excellent, but because of high maintenance costs, may have a very low maintenance rating.

If precise cost accounting were in effect, the unit cost of each section could be used directly for the maintenance rating. The application could be by subtraction of one rating point for each increment of unit cost above a determined minimum. If this method were used, it would seem proper to assign the maintenance item much more than 5 points of the 22 for structural adequacy. For reasons stated under the heading "Elements of Sufficiency," the item of observed condition cannot be eliminated or supplanted entirely by "maintenance economy," but it could be reduced to perhaps 8 points, which would leave some latitude for expressing differences between sections and at the same time would increase the weight of the non-controvertible cost-of-maintenance to 14 points.

Estimated Remaining Life, weight 13 points.

One point was allowed for each year of life remaining; the years remaining were determined from survivor curves of the patterns suggested in Bulletin 125 of the Iowa Engineering Experiment Station. For convenience, these were reduced to tabular form for the types and traffic volumes encountered in Arizona. The table used is reproduced here as Table 1.

When the years remaining attained 13, the maximum value for this element, all younger surfaces were rated at 13 points. The reasoning is that if less than one point per year is used, the spread between the various sections will be reduced and the purpose of introducing this rating element is counteracted; furthermore, the ratings are to be executed periodically and there is not much point in trying to peer into the future more than 13 years; the object of the "life" element in the whole rating is accomplished if retirement is begun to be anticipated that far in advance.

Roadway Width, 8 points.

The deviation from standard was measured in the field, and the proportion which the actual was of the standard, was multiplied by 8 to obtain this value. Since surface width is accounted for separately, roadway width is really shoulder width. In Arizona on many roads there is no physical distinction between the surface and the shoulders. Shoulder width of the actual road is therefore computed by subtracting the standard width of surface from the actual roadway width. The fraction that this is of the standard shoulder width is multiplied by 8 to give the rating. In the form of an equation,

$$R = 8 \times \frac{W_{RA} - W_{SS}}{W_{RS} - W_{SS}} \qquad (1)$$

Where R is the rating in roadway width,
W_{RA} is the actual roadway width,
W_{SS} is the standard surface width (can be less than actual), and
W_{RS} is the standard roadway width.

Surface Width, 7 points.

It was assumed that a width 7 feet less than standard is wholly inadequate, and rates zero. The rating is 7 minus the deficiency in width expressed in feet. If the standard is 22 feet and the actual is 20 feet, the deficiency is 2 and the rating 7 - 2, or 5. This may be expressed as follows:

$$R = 7 + W_{SA} - W_{SS} \qquad (2)$$

Where R is the rating in surface width, and
W_{SA} is the actual surface width in feet,

In this or any other rating computation, if the dimension or quality of the actual road exceeds the standard, the rating is of course the total weight assigned the element, and never greater.

The remaining elements, namely stopping sight distance (or intersectional friction), consistency, alinement, passing opportunity, cross section, and surface texture, were rated by inspection in the Arizona survey. Surface width as an item of service was rated by subtracting the deficiency in feet from 5. In the case of roads where dispatch was governed more by roadside interference, or heavy traffic volume, than by curvature, this element was rated in proportion to the average attained speed in the section, compared with the standard design speed.

It is feasible to apply judgment, or "inspection" ratings to all the elements, particularly where one engineer conducts the entire survey. Doing it in this fashion, i.e., using tables or formulas for remaining life and width elements but using judgment for all the other items, two engineers driving together were able to assign ratings to about 200 miles of road per day of driving. It is necessary to drive as fast as the road can be driven in order to make true observations of the effect of restricted sight distance, alinement, and the other factors other than structural adequacy. Driving slowly as when inspecting the surface, these items are likely to cause an entirely different reaction on the observer. Stops were made to measure widths which due to various reasons, often differ from plan widths. Sight distances were not measured.

It would be preferable to apply formulas wherever possible, for the sake of uniformity and to preclude bias, as well as to insure that several engineers will arrive at the same results for equal conditions. Formulas for sight distance, alinement, and passing opportunity have been worked out and are appended at the end of this report. These have been tested in the office, taking data from plans, and appear to be satisfactory but they are somewhat tedious and consequently expensive, particularly if the sight distances are measured in the field as they should be.

ADJUSTMENT FOR TRAFFIC VOLUME

The basic sufficiency, derived above, is simply a numerical expression of a comparison of each road section with the standards for that section. Since these standards depend to a large extent upon the traffic volume, the basic sufficiency does recognize to a degree, the traffic on each section.

However, important roads which deviate from one standard should be given priority over less important roads which deviate from another standard by the same amount. Or, put another way, to attain an equal position on the priority list, important roads need not deviate from standard as far as minor roads. A system of adjusting the basic rating to accomplish this effect was devised, which reduces the ratings of high volume roads, and increases the ratings of low volume roads.

Dividing the basic rating by the traffic volume, or subtracting the basic sufficiency from 100 to obtain the deficiency, and then multiplying by the traffic volume, would give higher priority to heavy volume roads; in fact, it would give such a large advantage to the latter, that none but the heaviest traveled roads would ever appear on the list. The State highway system is in the nature of things bound to embrace a wide range in volume, and a considerable portion of the mileage must therefore be low volume roads, with any normal frequency distribution. Suppose that one road has a sufficiency of 90, or a "deficiency" of 10 points, and carries 10,000 vehicles per day; this would make a volume-deficiency factor of 100,000. Now suppose another road on the same system has a sufficiency of 50, or a deficiency of 50 points and carries 500 vehicles per day; the factor would be 25,000. It would be absurd to improve the first road up to a sufficiency of 97.5 before improving the second.

The method devised eliminates this objection. No adjustment is made when the traffic volume on the section is equal to the average traffic volume of the system being tabulated. When the volume on the section exceeds the system average, the sufficiency is lowered; the amount of lowering is proportional to the logarithm of the traffic volume. Using the logarithmic function has the effect of keeping the adjustments within practical values, i.e. all adjusted ratings still come out between 0 and 100. It also has some logical significance, as the adjustment between sections carrying 100 and 500 per day (the 500 being 5 times as important as the 100) is the same as the adjustment between 200 and 1000, 1000 and 5000, or any other pair where one section has 5 times the volume of the other.

Furthermore, no adjustment is necessary nor desirable if the basic rating is either 0 or 100. Any section, if on the system at all and no matter how low in importance, which has a basic sufficiency of 0 should be at the top of the priority list, and any section which meets standards in all respects (basic sufficiency 100) does not need any adjustment regardless of traffic volume.

A three-variable equation which accomplishes the results stated in the preceding two paragraphs, and is plotted as a family of curves for any given system, was derived as follows:

If B is the basic rating,
R is the adjusted rating,
R_S is the adjusted rating where traffic volume is the average traffic volume on the system,
y is the adjustment,
T is the traffic volume on the section, and
T_S is the average traffic volume of the system;

then when $T = T_S$, no adjustment is made, and

$$R_S = B \text{ (Fig. 2)} \qquad (3)$$

For basic sufficiency, B, of 0 or 100, the adjusted sufficiency would still be 0 or 100. For any value of T, therefore, y is made equal to 0 for B = 0 and for B = 100, and is made greatest at B = 50 (Fig. 3). A

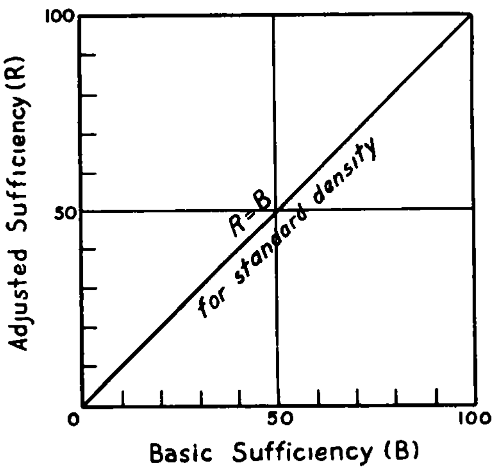

Figure 2

parabola accomplishes this and gives satisfactory results. By trial it was established that for T of 1 vehicle per day, a maximum y of 50 is reasonable (this means that when the basic sufficiency, or the final rating of a road section carrying T_S vehicles

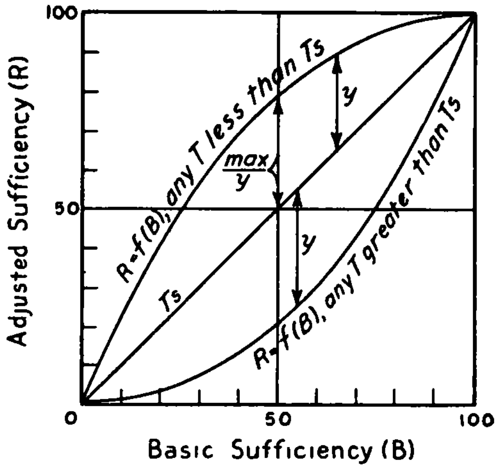

Figure 3

per day is 50, the adjusted sufficiency of the same road carrying 1 vehicle per per day would be 100). The equation of this parabola when T = 1 is

$$y = \frac{100\ B - B^2}{50} \quad \text{(Fig. 4)} \tag{4}$$

For a given value of B, y varies as the logarithm of T, or

$$y = K \log \frac{T}{T_S} = K (\log T - \log T_S) \tag{5}$$

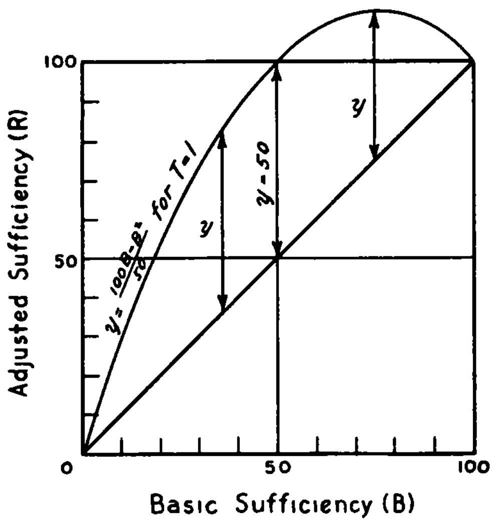

Figure 4

Equating (4) and (5),

$$K = \frac{B^2 - 100B}{50 \log T_S} \tag{6}$$

The adjusted rating, R, is the rating for standard volume plus y, and from (3), R_S = B and R = B + y. Substituting from (5) and (6),

$$R = B + K (\log T - \log T_S) \tag{7}$$

$$= B + \frac{B^2 - 100B}{50 \log T_S} (\log T - \log T_S).$$

Figure 5 shows several intercepts of this equation for various values of T, where T_S = 1000 vehicles per day. This chart was used for determining the adjusted ratings for the Arizona Federal-aid System.

It will be noted that for all practical values of T, R falls within the range 0 to 100; also that values of y are reasonable for all values of B. The difference in R between volumes of 5,000 and 10,000 is small, which is as it should be since both are of first importance; or at least the difference in importance is no greater than that between volumes of 500 and 1000.

EXECUTION

In Arizona a form for recording data in the field was designed and mimeographed on card stock, 5 by 8 in. The form used is shown in Figure 6.

Each route was divided into consecutive sections which were identified by route and route mile, the limits of which were determined by convenience (existing project termini), and homogeneity. Since existing designated projects control existing records and, frequently, changes in type or construction standards, they would be natural units to use for each rating section. However, it was found that one or more of the basic elements often changed in value within a project, and obviously a new rating had to be made when this occurred. Because of this, the route mile was the only practical means of identification of sections. Breaks were also necessary where the standards changed.

The sections varied from a fraction of

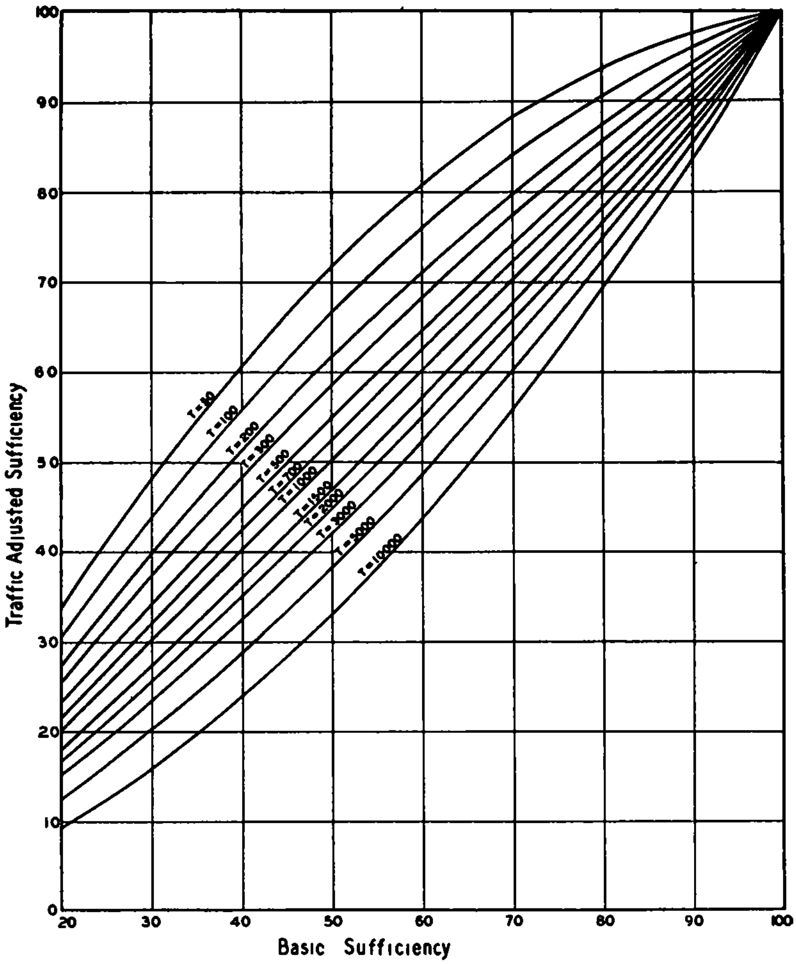

Figure 5

a mile to about 15 miles, and averaged about 5 miles in length; they cannot be too short or the values for items like alinement become meaningless, and on the other hand if they are too long, local deficiencies are diluted, and conversely "good" mileage might be contaminated by a short stretch of deficient road.

The information on the cards was transferred to business machine accounting cards (punched cards), and various lists were then made up. The first list of course was a list in ascending order of adjusted sufficiency ratings. Within each rating, the sections were arranged in ascending order of safety rating. Another list was made in the form of a route log giving the sufficiency of each section of a route in geographic sequence. A frequency curve showing the number of miles having various ratings was prepared, and the average rating (weighted by mileage) of the system was computed.

A limited number of copies of the lists are available to interested readers, at the Arizona Highway Department, Phoenix, Arizona.

APPLICATION TO PROGRAMMING

It is possible to use the top part of the list of ascending ratings as a construction program, going down in the list just as far as the available money will go, with the following modifications:

First, as stated in the introduction, the money for construction must be divided

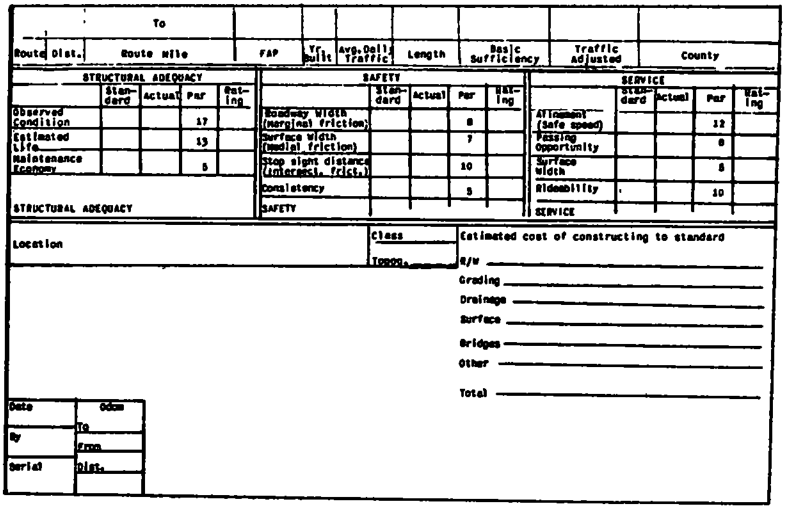

Figure 6

into "renewal" and "new routes." The new routes will not appear on the rating list.

Second, section termini for construction will necessarily be determined in the route survey or design stage. For example, a stretch of 15 miles is rated as follows:

Mile	0.00 to 5.60	65
	5.60 to 6.00	45
	6.00 to 15.00	55

The 0.40 mile of 45 points will be in the top priority, the 9.0 miles of 55 will be about 5 years from the top, and the rest will be more than 5 years away. For a practical construction program mile 5.60 to 15.00 should all be improved at one time.

Third, sections of high priority, but which will be eliminated from the system by major relocation, naturally will not be programmed. Major relocations are in some ways the same thing as new routes. In any event, the numerical ratings of existing highways will not help much in programming their construction. The necessity for, and the timing of, such construction should be based on individual, comprehensive studies for each case, coupled with continuous accounting methods which will show the current financial condition of the whole system.

Although it is recommended that the ratings be made annually, the program based on the ratings should be a five-year program. Each year, a new five-year program can be set up; thus the annual program becomes merely a segment of the running continuous program, and the modifications of the rating list to the construction program are smoothed out, particularly in the determining of practical termini for projects.

ACKNOWLEDGMENT

The cooperation of the Arizona Highway Department, Mr. W. C. Lefebvre, State Highway Engineer, Mr. Earl V. Miller, Assistant Deputy State Highway Engineer, and Mr. William E. Willey, Engineer of Economics and Statistics, in applying the method and testing its value, is sincerely appreciated. The author carried out the work under the Public Roads Administration, Mr. Charles C. Morris, Division Engineer, and Mr. G. L. McLane, District Engineer.

APPENDIX

Evaluation formulas for sight distance and alinement.

Stopping Sight Distance (weight 10 points)

The relative sufficiency of a section containing restricted sight distance would seem to be proportional to the length restricted, and how restricted. That is, suppose the standard minimum sight distance is 1000 ft. Then a half mile wherein the sight distance is 800 feet would be more sufficient than a half mile wherein the sight distance is, continuously, 500 feet. But perhaps a half mile at 800 feet would be as great a deficit as 1/10 mi. wherein the sight distance is 400 feet. Some experimenting with the many variables involved was done, and the following formula seemed practical:

$$R_S = \frac{L - 2.5\,N\,S_m}{L} \times 10 = 10 - \frac{25\,N\,S_m}{L} \qquad (8)$$

where S_m is the standard minimum sight distance
L is the length of section
N is the number of restricted places
R_s is the rating

This may be interpreted physically as meaning that a sharp vertical curve would necessitate grade adjustment for a distance of 2.5 times the minimum required sight distance, in order to attain that minimum. A typical case would be a section 2 miles long, where the standard calls for 800 feet, and there are three places where 500 feet is the maximum distance that can be seen. In this case,

$$R_s = 10 - \frac{25 \times 3 \times 800}{2 \times 5280} = 4$$

It is very possible that the formula can result in a value of less than zero. In this case zero should be used.

Alinement (weight 12 points)

A method of combining the intensity and frequency of deficiencies from standard is offered. The travelable speed of a curve varies roughly as the square root of the radius, or inversely as the square root of the degree of curve. For a single excessive curve, then, the relative sufficiency (r_c) for the length involved would be $r_c = \sqrt{D_s/D_a}$, where D_s is the standard maximum degree of curvature and D_a is the actual degree of curvature. To find the rating for a section of road with this curve included, it would appear proper to multiply the rating r_c by the length which is deficient, multiply the remainder of the section by 1, and divide the sum by the total length of the section to obtain a weighted rating. Actually, this results in too high a rating for a section with numerous short excessive curves. To provide for reduction of the rating due to number of deficiencies and to simplify calculation, it is proposed to assign a constant length for each excessive curve, equal to one mile divided by the standard degree. This also provides for the fact that an excessive curve spoils more than its own length, and penalizes those sections with faulty alinement design. Thus where the standard maximum curvature is 3 deg., one excessive curve is considered to affect 0.33 mile; where it is 10 deg., one excessive curve is considered to affect 0.10 mile, etc.

Let L = length of section in miles
D_s = standard maximum degree of curvature
D_a = actual degree of curvature for each substandard curve
N = number of substandard curves
$r_c = \sqrt{D_s/D_a}$, proportion of standard (intensity) for each curve

Then the length substandard by the above definition is $1/D_s$ for each excessive curve, or N/D_s for the sum of all excessive curves.

The length standard would be $L - N/D_s$.

The weighted average A for the section is the length standard multiplied by 100 percent plus the sum of the lengths substandard multiplied by r_c, all divided by the length of the section.

$$A = \frac{1.00\,(L - \frac{N}{D_s}) + \sum r_c \times \frac{1}{D_s}}{L} = 1 - \frac{N - \sum r_c}{L D_s} \qquad (9)$$

For example, the following section built in rolling country in 1931 where 3 deg. is the present standard is cited:

Length of section 3.54 miles.

Excessive Curves No.	D_a (deg.)	$r_c = \sqrt{\frac{3}{D_a}}$
1	6	.71
1	4	.87
1	6	.71
1	6	.71
1	6	.71
1	6	.71
1	5	.77
1	6	.71
1	4	.87
1	6	.71
1	6	.71
11		$\sum r_c$ = 8.19

$$A = 1 - \frac{(11 - 8.19)}{3.54 \times 3} = 0.74$$

The alinement rating (out of 12) is 12A, or in this case, 9.

Several sections of substandard alinement have been rated by this formula and the results are consistent with the facts. It seems almost impossible to arrive at a rating less than 0, although if this happened, 0 would be used.

Passing Opportunity (weight 8 points)

A knowledge of the traffic density during the peak hours of the year, of the section being rated, is necessary to assign a fair value to this element. If this is low enough so that passings are rarely necessary to avoid delay, then passing sight distance is not required frequently. If, however, the traffic density lies between this limit and the upper limit, where unlimited sight distance is of no avail, then the rating can be computed as the proportion of 8 that the unrestricted mileage is of the total mileage. If passing opportunity is restricted during 30 or more hours a year by the traffic density, instead of by restricted sight distance, the rating should be zero.

HIGHWAY PLANNING IN A RURAL STATE

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The Highway Planning Surveys as originally constituted consisted of three principal activities: Road Inventory, Traffic Survey, and Financial Survey.

Road Inventory

To this activity was assigned the responsibility for mapping all roads open to public travel in the State and tabulation of such additional information as would determine the adequacy of the facilities for present and probable future traffic. This information included width and type of surface; locations and dimensions of bridges; and location of all rural dwellings, schools, churches and other improvements or developments that might be the origin or destination of traffic. Drainage areas, corporate limits of cities and villages and boundaries of parks and other reservations are also shown on the maps.

Traffic Survey

The purpose of the traffic survey was to determine the amount of traffic on all roads and to classify the traffic by vehicle types and sizes. Origin and destination studies were made and traffic trends and behaviors that would be significant with respect to future traffic were noted.

Financial Survey

The purpose of the financial survey was to ascertain tax levies, tax collections and expenditures by purposes over a considerable period. Special studies were made of highway costs, highway life and such other related information as would provide for determination of the probable future costs of adequate highway facilities.

The original studies in all States were made in a comparable manner which was necessary if comparisons between States were to be possible. During the war, these data provided an inexhaustible source of information for many of the pressing problems that arose.

The uses made of Highway Planning Survey data fall into three groups: (1) Use of the original data by the Highway Department; (2) Use of special studies, made either as a specific request or as a part of the regular work by the Highway Department; and (3) Use of all these data by other governmental agencies and private enterprise. The latter has assumed a much greater degree of importance than was anticipated.

Since the war, shortages, chiefly in personnel, have seriously hampered the Highway Planning Surveys in that they have been unable to bring the work up-to-date and to make the analyses that are necessary if the large highway construction program now in effect is to be properly facilitated.

Transportation difficulties that arose during the war brought to the front many serious problems and demonstrated the fact that the Planning Surveys, in the future, must cease emphasizing statistics in general and study particular situations and conditions.

In a rural State like North Dakota the problems that confront the Planning Survey are not ordinarily very involved, but they vary greatly in extent, and factual information is necessary for proper solution. Also in a predominantly rural State, the Planning Survey may acquire additional duties. For instance: North Dakota finances do not allow an adequate amount of physical research to supplement properly the statistical research of the Planning Surveys. Under those conditions, it is apparently necessary for the Planning Surveys to assume responsibility for a limited amount of physical research if the desired results are to be achieved.

In a predominantly rural state, the interest of the individual toward roads is great and the responsibility of the highway administrator in furnishing adequate highway facilities is very pressing. In order that the maximum transportation facilities be furnished under such a condition, detailed knowledge of conditions is necessary and intuition will not suffice.

The fact that in North Dakota not over 10 miles of rural road will, within the foreseeable future, even approach the point of traffic congestion for a two-lane highway must be faced. Under those conditions any rural road built in North Dakota to the minimum standards acceptable to the motorists will have a volume capacity far in excess of any traffic that will ever use the road.

Similarly, a road must be built to carry a specified weight unless weight barriers are to be raised on all truck traffic. This necessitates the construction of all principal highways to carry these recognized weights even though the motor vehicle registration figures indicate that there are less than 300 vehicles in the State which may be expected to even approach the weight for which the roads are designed.

Full use of the data gathered by the Planning Surveys will make it possible to build roads to standards adequate for the duty to be imposed on them. Constructing roads to either higher or lower standards than necessary simply means reduced benefits to the highway users as a group.

In North Dakota or any other predominantly rural State having a large mileage and small population, the ability of the State to own and perpetuate a highway system poses a problem of the greatest importance because in those States the per capita tax cost is going to be among the highest. Solution of the problem of solvency requires data which have the confidence of all road building agencies.

Problems such as these apply not only to the state highway systems but to the Federal-aid secondary and county highway systems.

Successful cooperation between the State Highway Department and the local political subdivisions is necessary. The Federal-aid highway act of 1944 was very specific in its requirement that there be cooperation between the State and these political subdivisions.

In many instances, the local road problems of the political subdivisions are even more pressing and acute to those involved than are the over-all problems of the State. The Planning Survey is the only organization in a position to assist, with factual data, in the solving of these problems. As these problems are solved together, all highway administrators obtain a broader perspective of the purpose of highways in general and systems in particular.

In urban areas and for interurban traffic, one of the most reliable means of obtaining highway use data is through origin-destination studies. For farm-to market type traffic, such studies are generally not feasible. However, careful study of the road inventory maps showing existing highway facilities, cultural, and other related information, coupled with traffic data will usually be more satisfactory in the solution of most rural problems than is the more comprehensive origin-destination study which, in itself, must be limited to a relatively small area.

Experience has shown that local officials will more readily grasp and attempt to solve their problems when these data are made available in a form whereby the over-all problem may be easily seen and understood. The collection and tabulation of a mass of data and its analysis by lengthy mathematical computation and extended discourse serves no purpose for the highway administrator.

The fact must be recognized, however, that local administrators, long experienced in matters concerning their state or locality, have a more keen intuitive knowledge of the economics of the problem involved than they are often given credit for. They are interested only in a maximum benefit at a minimum cost with due regard for the future. Extended treatment of a problem beyond the realm of realism serves only to cause loss of confidence in pertinent data. Residents of rural areas have a very active interest in all highway matters and their attitude is not in the least passive.

In some of the rural States industrial development is very limited. In North Dakota it has been practically non-existent. In recent years, however, a tendency toward the decentralization of industry has developed and many of smaller manufacturing or assembling plants are being located close by the larger cities.

Such a development is very fortunate

in its nature because of the fact that fixed facilities, such as highways, can be planned and located before the industrial section is built. This condition makes for an ideal use of Planning Survey data, for, under such conditions, many of the causes of highway inadequacy can be eliminated before they occur.

Many highway problems must, because of their nature, be handled through legislation. In a predominantly rural State like North Dakota, these problems are not likely to be as numerous nor, in certain instances, as involved as would be the case in an industrialized State.

Certain problems, however, such as motor vehicle imposts, may become much more involved because of the high per capita cost. If this highway cost is to be equitably distributed on the basis of highway use, considerable detailed data must be available; otherwise the imposts will be inadequate or beyond the ability and willingness of certain of the highway users to pay, which will result in diminishing returns.

The Planning Survey is the only organization that has these necessary data and is in a position to keep them continuously current. The same condition applies to most of the other highway problems which require legislative determination.

The Planning Surveys, in their analysis of governmental data, often come upon examples of operations that could be readily improved. Although the Planning Surveys were set up and operate as fact-finding bodies which should not assume the role of administrators, their experience, varied personnel and necessary knowledge of legal requirements place them in a position to recognize departmental deficiencies or irregularities as well as to determine analytically means and methods of correction. Experience has shown that proper presentation to the highway administrator will bring results. Such a procedure cannot react unfavorably toward the Planning Survey as long as it is careful not to assume any permanent administrative functions outside of its own type of operation.

The data collected and being kept current by the Planning Surveys form an almost inexhaustible reservoir of information necessary for the sound solution of basic highway problems. Statistical data which are compiled and not kept current with changing conditions soon cease to have any practical value. The gathering of statistical data without a proper analysis thereof is simply a complete waste of time and effort.

In the analysis of the accumulated data, the Planning Surveys are often deficient and lack definiteness of direction. Such a condition leads to reduced confidence on the part of highway administrators in the work as a whole, and this phase of the work must be vigorously pressed if the Planning Surveys are to accomplish their true purpose.

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