of public utilities, earning value can be given little or no weight since earnings are what are to be regulated, but service-worth value is the value which would be based upon the reasonable worth of the services that must never be exceeded I think the same Smyth v Ames rule applies and should apply to highways There are lots of chances to use your own judgment There are some roads in Iowa, also some road structures, that are not worth what they would cost to reproduce The culverts and grades about to be deserted in making alignments are not worth anything

MAKING AND USING THE TRAFFIC CENSUS

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SYNOPSIS

Owing to the present day variety of uses for traffic data the making of a traffic census is a much more complicated operation than the simple count every thirteen days that was started by France in 1844 They are used as bases for construction and maintenance programs, for selection of type and design of pavements, for segregation of routes, for apportionment of revenues, for common carrier rate making, for determining relations between motor vehicle taxes and general property taxes and for many other purposes The cost of a survey planned to yield information on all of the problems is ordinarily prohibitive, so careful advance study is necessary in order that a survey will be certain to yield the particular data wanted Suitable comprehensive forms must be arranged and "details of the master schedule and field organization must be devised with the rigidity necessary to produce regularity of observation, adequacy of supervision and speed in filing field reports, checking for possible errors, and general supervision " However, it must be possible to make quick changes to care for unforeseen contingencies

Since the daily traffic at a station is computed from observations made upon comparatively few actual days during a year and for only a part of those days, it is important that these samples be sufficiently representative to make possible an adequate estimate of the mean daily traffic volumes If the annual traffic is homogeneous and distributed according to the normal probability curve, the standard error in the mean daily traffic can be determined by statistical methods Whether or not traffic is so stable and homogeneous as to afford correct results by statistical analysis has not been fully demonstrated, and therefore studies of such complete statistical universes as those provided by the yearly records of toll bridges or tunnels are advocated

As the French were the leaders both in the art of modern road building and in the science of highway engineering, it is not strange that they should have been the first to develop a traffic census Sometime prior to 1844 the first census was taken, for by that year the French had devised the simple and effective schedule that has characterized

practically every census since made, and from that time at least until the World War of 1914 there has been a regular periodical census on the national routes of France

The French schedule required an observation at intervals of thirteen days, which advanced the record one week day in each fortnight, gave a four weeks' record each year, and distributed this record uniformly over each of the four seasons The natural ratio of observations was retained for each day of the week, although it is probable that week-end traffic was not so different from the rest of the week day traffic as we find it to be Probably market days rather than Saturdays and Sundays were, under conditions existing in France in the middle and late decades of the Nineteenth Century, the days showing the widest variations from the daily average

The three elements in the French system that are noteworthy are the regularity of the observations, the distribution to include all days, and the care taken to maintain the natural ratio among the several observations

The French appear to have used their data for a single purpose—to determine the probable wear and consequently the amount of stone required for maintenance purposes On this determination depended the estimates for annual maintenance costs

The first use of the traffic census in the United States appears to have been made about 1885 The first systematic census was probably not taken until 1906 when Dean A N Johnson made a study of horse-drawn vehicles in the State of Illinois Since that time the traffic census has had more frequent use

The first systematic study in the United States made according to the methods developed by the French engineers was undoubedly that undertaken by the Bureau of Public Roads in 1911 in connection with its studies of the cost of maintaining different types of surfaces used in the Chevy Chase experimental roads and other experiments in the vicinity of Washington, D C In these observations the French system was used practically without change and some attempts were made to evaluate the data in terms of weights The presence in the traffic of a large fraction of motor vehicles made such attempt more or less futile

Since that time the traffic census has come into more or less general use in the United States, and it is interesting to note the variety of purposes to which it has been put

Studies of the density of traffic serve as a basis for programs of construction and maintenance, the classification of roads or routes, the determination of economy of types, for forecasts of future traffic, and for establishing necessary widths

Classification of traffic by types of vehicles furnishes data for the selection of types of pavements, the determination of widths, the segre-

gation of routes for commercial or pleasure purposes, general cross section design, apportioning motor vehicle revenues, and adjusting reciprocity conditions among the several states

The classification of traffic with respect to the kind of operation will serve as a basis for fixing common carrier rates, for determining tourist requirements, for adjusting connecting routes, for establishing conditions of reciprocity, and for determining the relations of gas and motor vehicle taxes

Further studies classifying traffic as to the situs of its origin may be used in the determination of the relations between motor and general property taxes for roads, for classifying roads as of general and of local use, for allotting funds for road construction, and for the general determination of highway financial policies

Obviously, no one survey of traffic has ever been applied to all these purposes, and it is equally obvious that the simple French enumeration and classification by collars will not serve for so varied an analysis as this list of uses indicates The variety of uses listed at once discloses that in any census the details of the record taken must include such data as may be necessary and sufficient to answer the queries raised Expansion of the field data to this necessary and sufficient scope may increase the cost of the traffic census to unwarrantably large figures For this reason, it is essential in the interest of economy to determine very definitely what is wanted from a proposed survey and to organize the field work and devise the record to produce the data as inexpensively as possible This appears at first glance as a simple thing to do But it may be found at the time analysis is undertaken that some leak or loophole in the data exists and it is generally not possible to supply the omission The only certain way to determine exactly what form the record shall take in any case is practically to go through a moot analysis in advance and cover every detail required

In a recent study made by the Bureau of Public Roads of what appeared to be a simple problem, every point raised by the preliminary study of the case was successfully and adequately covered This analysis was sufficiently long to require 56 separate steps in the form of columnar calculations, and each step had to be anticipated and provided for But, in the course of the analysis, the data revealed certain facts that led to new and different queries Attempt to answer these queries with the data assembled and entirely adequate for the original purpose as outlined developed a single omission in the material necessary to answer the question This omission cannot easily be filled, and the circumstance indicates how essential it is that the full case be stated and studied in advance of any traffic survey and the field work organized accordingly.

The case referred to above is the delay study made of the viaduct across the New Jersey meadows The data seems to point to an inter-

esting condition with respect to heavy truck traffic which was not thought of at the time the study was planned Heavy truck traffic appears in a lower ration to all truck traffic on the viaduct than it did on the surface roads Is this or is this not an indication that the reduction of congestion and the level grades on the surface roads have operated to attract and retain heavy truck traffic, which thus avoids the five per cent ramps and the three per cent grades a thousand feet or more long that exist on the viaduct The factual material to answer this very interesting query was not at hand—in fact, only a single detail was lacking—although the original data supplied everything else for the analysis as planned The unexpected query went just beyond the scope of the data

With the required data defined it next becomes necessary to prepare suitable forms for the record These sheets, which used to be a small card or at most a letter size page, are now sometimes of cumbersome dimensions Surveys recently conducted by the Bureau have used sheets as large as fourteen by twenty-six inches

To handle such field records requires usually a lapboard to which the sheets may be attached with rubber bands or metal clips, and frequently such boards are equipped also with the necessary clickers or registering tallies to carry the heavier counts being made

To discuss the various forms of information needed to supply answers to the queries implied in the list of possible uses of the traffic census already cited would go far beyond the scope of this brief paper It will be interesting rather to note certain devices used to simplify securing a good record in a survey that is so large or so far flung in the area covered as to be difficult or so involved with respect to required data as to make it desirable to subdivide the record

It is first to be noted that regularity is one of the essential features of the record Because of this a master schedule of observations is feasible and useful This master form can then be applied to any number of stations To plan the master schedule it is necessary to know the length of the proposed cycle of observations This cycle should be one more or one less than a multiple of seven, so that each succeeding cycle will start on a different day of the week In the total cycle must be included the customary idle days of the observers These idle days can usually be made to average one day off in seven, but they cannot come at regular intervals of seven days The difference between the total length of cycle and the idle days, represents, of course, the number of stations that an observer or an observing party can cover

A simple form for this master schedule is possible and once made it can be applied to as many separate observing groups as may be necessary in the survey It further serves as a fully adequate basis for correlating any miscellaneous observations that the proposed analysis requires, and its principal advantage is that new field schedules for a group of

observers however numerous can be prepared based on the master schedule in a few minutes, whereas the older method of making up a schedule for each observing party independently took considerable time, and sometimes led to confusion

The master schedule is related directly to the field organization and indicates its form A concrete example will serve to indicate what this relation is In a traffic survey in New Jersey recently completed, the state was divided into three sections In each section there were sufficient stations to require three observing parties for day time counts, one for night counts, one special truck party taking special data, and one special bridge party which covered the bridges along the Hudson and Delaware Rivers The size of these divisions was determined by the number of stations in the master schedule, and over each division was placed a supervisor who had charge of the six observing parties operating in the division In all, some 400 men were used on the New Jersey survey because of frequent changes of personnel to spread employment To maintain a carefully observed schedule under such conditions demanded close supervision

The field arrangements were further simplified by an orderly designation of stations All stations in the same cycle were numbered beginning with 101, 201, 301, et cetera, just as houses are numbered 100 to the block The truck stations were numbered from one to 79, and the bridge stations from 80 to 100 In the record the kind of station and its general location, the party operating it, and the supervisor in charge are all disclosed at a glance

These details of master schedule and field organization, while simple and plain, must be devised with the rigidity necessary to produce regularity of observation, adequacy of supervision, and speed in filing the field reports, checking for possible errors and general supervision At the same time, it must be possible to make quick changes if some eventuality indicates such to be needed, and the complete control furnished by the master schedule has appeared, since its use was begun, to offer such possibility whenever tested

Another new device which has been introduced, as traffic surveys have become more varied and detailed, is the station summary sheet. It was the old practice to file observers' reports as they came in, grouping them by stations and comparing them with each other to detect internal evidences of inaccuracy or carelessness. This was done in the head office at Washington Now there is used a summary sheet in the field office, on which the complete record for each station is entered as the report is received from the field There are rarely in any survey more than 12 to 15 parties and this means not more than that many reports to check and enter daily Usually it takes less than the time of one clerk to do this

Spreading the record on a ledger or summary sheet in this way at

once enables the manager of the survey to check the proper date and hour of the observation with respect to the predetermined schedule Setting up the successive counts for each station in parallel permits an instant comparison and the detection of any unusual condition of the record In this way it is possible to check derelictions on the part of the observers quickly and often to secure correction of records that otherwise would be lost

It is further possible on these summary sheets to make all daily summations, and to use the sheets at the conclusion of field work for the general summations and averages for each station This represents a considerable initial step in the analysis

In the use of the summary sheets it is to be noted that the work is entirely mechanical—one of accurately transcribing a record Accuracy is absolutely essential in this process For, if a false entry is made it cannot be detected except by a general repetition of the work Such a check would void the whole purpose of this device

Turning attention now to the use of the census studies, we are confronted with details of statistical analysis that are interesting If we take fourteen 8-hour observations on a station, which is the number permitted by a 27 day cycle, the total sample for the station is approximately 1 3 per cent of the annual total This small sample can only be justified if we are dealing with conditions that have fixed characteristics, with a subject or universe that is homogeneous For instance, if every tenth man passing a point on Pennsylvania Avenue, Washington, D C , in a single day were carefully measured for height, the average of the measurements would be a very close approximation of the average height of all male citizens in the United States, although the sample would not be greater than eight one hundredths of one per cent This is so because the subject is homogeneous In the worst cases the extremes are not remote, and large groups fall within very narrow limits The actual sport cases are so few, they go into museums Similarly with most biological data It is homogeneous and we can arrive soundly at the average size of a mature oak leaf, the average number of kernels on an ear of a certain variety of corn, the protein content of wheat; et cetera, with some very substantial assurance that the averages represent something worth while—an approximate truth so close to the real truth as to be usable for solving related problems

The percentage of the statistical universe that is included in the sample is not important as a factor in the accuracy of the estimate. It is important, however, that the sample be sufficiently representative to make possible an adequate estimate of the mean daily traffic volume and samples can be representative only of homogeneous totals If the samples be taken at random, or better than at random, throughout the universe, which is usually taken as a year, and if this universe is distributed in the form of a normal curve or a distribution more con-

centrated than the normal curve, then the standard error of the means is equal to or less than the standard deviation of the items in the sample, divided by the square root of the number of the items less one

This law indicates that the larger the number of items in a sample, the smaller will be the standard error If the number of items in a sample be as few as 14 (as is true of present practice) the standard error of the mean would be equal to the standard deviation divided by 3 7; but, if the number of samples be as many as 70, the standard error would be equal to the standard deviation divided by 8 3. Such a larger number of long counts would make the expense prohibitive, and it is, therefore, necessary to reduce the length of the watch The possibility is suggested that the watch might be reduced from 8 hours to 30 minutes, or less, in order that the number of watches may be increased while the total time required for the survey may be reduced. The Bureau is now investigating the effect of this and its practicability in field operations

Now, the very interesting question confronts us in all traffic analysis as to whether traffic is certainly so stable and so homogeneous in its character as to permit of statistical analysis with any assurance that our figures are valid Few of us have ever stopped to consider this in the past We have assumed that our traffic census results are probably within some 10 per cent correct, which is a satisfactory working approximation of the truth Actually, nothing specific has occurred to indicate definite error in past results, and traffic census studies have been so scattered and simple in most cases that no indication has been given to make us doubt the soundness of traffic statistics honestly taken and analyzed according to current methods

In fact, such tests as we have been able to make have supported our position in the rough The check survey conducted by the Bureau and the State Highway Department in New Hampshire, after an interval of exactly five years, showed results close enough to satisfy practical requirements Some studies made by the Port of New York Authority satisfactorily stood the test of extrapolation backward to apply to old records Studies of monthly daily average traffic on many surveys indicate a decidedly characteristic annual curve—a flattened sine curve with the line of the mean producing intersections almost always within a spread of two weeks in April–May and October–November

In spite of these apparently assuring circumstances we are faced with the fact that traffic surveys are becoming more and more detailed, the national economy as affected by highway construction and highway transport is demanding more and more data, and more exact data, analysis is becoming complicated and lengthy in keeping with the increased and more elaborate field data, and, of course, with it all goes a serious increase of cost The net result is a growing advocacy of

abbreviated surveys, which will first of all reduce costs and error, and as a supplementary advantage reduce the time required to make the survey and the analysis of the data

We cannot refuse to accept the soundness of the advocates of skeleton surveys from the point of view they have taken The natural question is, however, as to how such abbreviation will affect the accuracy of our studies All we have now with which to compare the analysis of a skeletonized survey is the analysis of another more elaborate survey in the same area One result will perhaps differ from the other But we cannot tell whether that difference represents an increase or decrease in accuracy, nor do we know what the error is in our present method, because we are making the fundamental assumption of a homogeneous subject of investigation, where in fact we may not have that condition in large degree

If, therefore, we are to continue using elaborate and more elaborate traffic data, as is certainly indicated by existing requirements, and if we are to reduce the time spent on the surveys below present practice, we should institute some investigations that will be helpful in determining the general approximation under which we are now working and the effects of skeletonizing our present methods

To do this we must have a complete statistical universe to work with We could get this by taking a record for 24 hours a day throughout a year Such an experiment is out of the question, besides, we wish to have an answer to this question sooner than such a method will permit

The necessary steps toward a study of the soundness of our present methods and an actual determination of their accuracy are clear The determination of the relative accuracy of derived or abbreviated methods must be the analysis of full records that are now in existence, such as those for toll bridges or tunnels, which constitute the necessary complete universe in a statistical sense Against these observed totals others computed from any variety of sampling may be set in comparison, and by these means we will be able to determine just how far we may advisedly go in changing our present methods The mathematical theory of sampling points toward more but shorter watches with a gain in precision and a saving in expense, together with more prompt results Will complete traffic records lend themselves to the analysis of mathematical method? Will the means estimated from a considerable sample of short counts prove to be nearer the true mean than those estimated from the smaller samples of longer counts now in use? Theory answers "Yes" But, we must test our theory by its practical application